Facultative river dolphins: conservation and social ecology of freshwater and coastal Irrawaddy dolphins in Indonesia
Kreb, D.

Citation for published version (APA):

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: http://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.
CHAPTER 10

Impacts of habitat on the acoustic behaviour of coastal and freshwater Irrawaddy dolphins, *Orcaella brevirostris* in East Kalimantan, Indonesia

Daniëlle Kreb and Junio Fabrizio Borsani

One group of six dolphins was trapped since 1999 until present in between two rapids in a habitat of only 2 km of length. The dolphins acoustic behaviour showed a low diversification and no whistles were heard.
ABSTRACT

Vocal repertoires of one coastal and one river population of Irrawaddy dolphins, *Orcaella brevirostris*, in Balikpapan Bay and Mahakam River, respectively, were studied in 2002 in order to reveal the impact of habitat on acoustic behaviour and in particular of social communication. Vocalizations were most varied and frequent in one core area of dolphins in the river, in which a well-identified sub-population with a high site-fidelity occurred and with the highest degree of social exchange among groups in comparison to two other areas in the river and the coastal bay population. These vocalizations included single- (“jaw-claps”) and multiple- broadband (“click trains”) clicks; broadband- (“squeaks” and “creaks”) and narrow-band- tonal pulsed sounds (“grunts”, “moans” and “quacks”); narrow-band frequency-modulated sounds, i.e., 2 types of calls and whistles of up to 5 frequency modulations. Pod-specific whistle-dialects exist among coastal and riverine populations, but also within sub-pods within the river, which differ in the number of modulations, duration, minimum and maximum frequencies. Call sharing occurred among neighbouring areas but not among remote areas. There is also evidence for individual “signature” whistles and “contact” whistles. Vocal repertoire (sound types) was more similar between the likely more genetically related, coastal and freshwater populations in East Kalimantan than between coastal populations of Australia and East Kalimantan. Vocal repertoire was less varied for coastal Irrawaddy dolphin populations in East Kalimantan and Australia compared with the Mahakam River and may be determined by ecological conditions. The whistles and vocalizations rates (numbers per time unit) seem to be determined by social structures. Larger groups with (more) calves whistled less often than smaller groups, which may be caused by the fact that there is less need for contact whistles. Whistle frequencies were significant higher upon approach of (speed) boats of > 40 hp and lasted longer than in their absence.

RINGKASAN

Tipe suara dari satu populasi lumba-lumba Irrawaddy (*Orcaella brevirostris*) laut dan sungai, telah dipelajari pada 2002 untuk mengungkapkan pengaruh habitat pada tipe suara dan khususnya komunikasi sosial. Suara lebih banyak berubah-ubah dan lebih sering dalam satu tempat utama lumba-lumba di sungai, dalam suatu sub populasi yang telah diketahui dengan tingkat kesetiaan pada tempat yang tinggi dan dengan tingkat pertukaran antar kelompok tertinggi dalam perbandingan dengan populasi di dua daerah lain di sungai dan laut dalam teluk. Suara ini termasuk “jaw-clap” tunggal dan banyak “click” dengan frekuensi yang luas dan dalam waktu lama; frekuensi “squeak dan creak” luas dan suara dengan frekuensi rendah (menggumam, melenguh dan berkotek), dua (2) tipe dari panggilan dan bunyi siulan dari 5 atau lebih modulasi frekuensi. Juga terdapat siulan dengan dialek khusus untuk kelompok di antara populasi laut dan sungai, namun juga antara sub-kelompok di sungai, dimana berbeda
Acoustic behaviour of coastal and freshwater Irrawaddy dolphins


INTRODUCTION

General background

River dolphins and porpoises are among the world’s most threatened mammal species. The habitat of these animals has been highly modified and degraded by human activities, often resulting in dramatic declines in their abundance and range (Reeves et al., 2000). In Indonesia, one representative freshwater dolphin population is known to inhabit the Mahakam River and associated lakes system in East Kalimantan, i.e., the facultative river dolphin species *Orcaella brevirostris*, commonly and locally referred to as the Irrawaddy Dolphin or pesut, respectively. The species is found in shallow, coastal waters of the tropical and subtropical Indo-Pacific and in the following major river systems: Mahakam, Ayeyarwady, Mekong (Stacey & Arnold, 1999). The species is protected in Indonesia and adopted as symbol of East Kalimantan. Based on monitoring surveys conducted from 1999 until 2002 in the Mahakam, which indicated a population abundance of less than 50 individuals (Kreb, 2002), the IUCN has raised the status of the Mahakam Irrawaddy dolphin population from ‘Data Deficient’ to ‘Critically Endangered’ in 2000 (Hilton-Taylor, 2000).

The only information on the acoustic behaviour of the Irrawaddy dolphins in the Mahakam pertains to a study of these dolphins in a captive environment (Kamminga et al., 1983). The dolphin was described to be a lively, fervently vocalizing animal similar to the Amazonian freshwater Boto, *Inia geoffrensis*, but no audible whistles or pure tones were observed. More recent studies include an unpublished study on freshwater Irrawaddy dolphins in the Mekong River (Borsani, 1999), during which whistles, jaw-claps, pulse-trains, and single clicks could be heard. Another study was conducted on coastal Irrawaddy dolphins in Australia, which revealed that the dolphins exhibited a varied repertoire consisting of broadband clicks, pulsed sounds...
that resemble the freshwater tucuxi, *Sotalia fluviatilis* and nonwhistling delphinids (e.g., *Cephalorhynchus* spp.). Whistles were found simple in form and low in frequency (1 to 8 kHz) (Van Parijs et al., 2000).

In the present study, we have observed the acoustic behaviour of two populations of free-ranging freshwater and coastal Irrawaddy dolphins in the Mahakam River and Balikpapan Bay in East Kalimantan, respectively. Our objectives are 1) to identify and compare the vocal repertoire and amount of vocalizing of both populations but also within different identified sub-pods in the Mahakam River, 2) to relate vocalizations to behaviours displayed, 3) compare the vocalizations with those from Irrawaddy dolphins in Australian coastal waters and in the Mekong River to investigate whether the acoustic behaviour of the Irrawaddy dolphin follow an ecological (freshwater/coastal) and/or geographical separation (Asia/Indonesia/Australia), 4) to investigate whether whistle shapes and frequencies are more determined by ecological, genetic or social factors by identifying whether whistles within different species of river dolphins and within sub-pods of one population of Irrawaddy dolphins in the Mahakam are more or less similar to each other, than those whistles of ecologically different, but more geographically, nearby living populations of the same species that are most likely more genetically related.

The comparison of the acoustic behaviour of the freshwater and coastal Irrawaddy dolphin populations may be valuable in terms of determining whether the Mahakam population is an isolated, single breeding population that needs careful management to maintain a viable population.

**METHODS**

**Study areas**

Acoustic recordings of freshwater Irrawaddy dolphins in the Mahakam River were made at three different study sites (Figure 1). Core areas 1 and 2 were areas of high dolphin densities in the Middle Mahakam River, from 180 km to 375 km from the mouth, which included confluence areas of the main river with tributaries and lakes. These areas were chosen because dolphins in each area had a high site fidelity based on a photo-identification study (Kreb, *in press a*). Mean river width in this area measured 200 m (SD = 53 m, *n* = 105), whereas mean water depth at an average water level was 15 m (SD = 6 m, *n* = 65). Mean water clarity in the study area (measured with a Secchi disk) at an average water level was 23 cm (SD = 7 cm, *n* = 27). Bottom substrate is muddy. The middle Mahakam is an area of intensive fishing activity (MacKinnon et al., 1997). Some coal mining and logging activities occur here, especially in the tributaries. Furthermore, this area is subject to intensive boat traffic with boats passing every 3 minutes on average, mostly constituting boats of less than 40 hp (Kreb, *in press b*). The transport infrastructure is poorly developed in East Kalimantan and the Mahakam River is the main transport artery. The Ratah tributary
(core area 3) joins the Mahakam at 500 km from the mouth. The dolphin habitat is an area of only 2 km length with a rocky bottom and shore substrate in between two rapid streams. Only long, motorized canoes (40 hp and higher) pass the area irregularly. Acoustic recordings of coastal Irrawaddy dolphins were made in Balikpapan Bay, which stretches from 116°42’ to 116°50’ E and 1° to 1°22’ S (Figure 1). Water surface area of the bay is ca. 120 km². Maximum width of the bay is ca. 7 km. Shorelines within the bay consisted mainly of mangrove vegetation. Average water depth at dolphin sightings within the bay was 14.5 m (SD = 8.0 m, n = 39).
Mean clarity recorded at sighting locations in the bay is 170 cm (SD = 58 m, n = 24). Boat traffic was most frequent in the downstream part of the bay, where mostly ferries and speedboats crossed the bay in one lane. In one of the mangrove tributaries where most recordings were made, we encountered mainly speedboats that frequented a logging company upstream. Small fishing boats could be found in all areas of the bay and shrimp fishing was the most common activity. Bottom substrate was mainly muddy/ sandy. Dolphin densities were more or less equally distributed throughout the bay.

**Data acquisition**

The acoustic study was conducted during the months April, May 2002 at medium water levels and repeated in August 2002 during low water levels. The high water level season was excluded because it was assumed that the higher flow rates would cause more background noise and would cause difficulties in making recordings from the small research canoe. Total effective recording effort consisted of 16 h during 21 days, excluding searching and travel days. In the Mahakam, 12 h recordings were made over 14 days and in Balikpapan Bay 4 h over 7 days. Recordings were made of group in between 2 and 8 individuals in the Mahakam and between 2 and 10 individuals in Balikpapan Bay.

Recordings were made from different groups of dolphins (different group sizes and/ or composition) in several different areas of the river and bay. Recording time per group was more or less equally spread over the entire length of the day by strategically visiting those areas where a high chance existed to encounter a group of dolphins soon after searching commenced. These areas were already identified during several abundance monitoring surveys in 1997 and from 1999 until 2002 (Kreb, 1999; Kreb, 2002).

When a group of dolphins was encountered we attempted to follow it for the entire day until 1800 h at maximum and continually made recordings (average group follow time = 7 h; SD = 3 h; range = 1.5 -13 h). For each recording session, starting and ending time of the session (in h/min/s), group size and composition (presence of neonates, calves or juveniles), general group behaviour (feeding, milling, socializing, travelling or a combination between these categories), and spatial group distribution were recorded. A recording session lasted as long as good recordings could be made and no change in group size/ composition or in general group behaviour occurred. The survey team existed of four persons: one sound recorder; one data recorder, who wrote down individual behaviours displayed for each minute; a second data recorder and observer, who drew the spatial distribution of the group and recorded distances between individuals and towards the hydrophone each minute; one observer, who would inform the “behaviour” data recorder about the individual behaviours displayed by the dolphins.
A High Tech Inc.- 94-SSQ hydrophone was used for recording (frequency range: 2Hz - 30 kHz at –168 dB re 1V/μPa) that hung 1.5 m deep into the water. The hydrophone was connected to a Sony TCD-100 DAT walkman-recorder set at a sampling rate of 48 kHz (providing an effective frequency range of 20 Hz to 24 kHz). SONY DAT tapes (60-90 min) were used.

Dolphin observations were conducted from two types of vessels. The first was a wooden boat with inboard engine of 26 hp and 16 m length with observer eye-height 3.5 m above the water. This boat was used if the dolphins were milling in one area so that the boat could stand-by with engine off, which provided better observation positions than the second boat we employed that was a wooden canoe of 10 m length with an outboard motor of 5 hp and with observer eye-height 1 m above the water. This small boat was used if the dolphins spent a great deal of the time traveling and did not remain for a long time in one area.

Analysis

Sound recordings were down-loaded at a 48 kHz sampling rate in a PC using a Windows spectral analysis program Syrinx 2.2.1 (Burt, 2003). The sounds were stored to wave sound files that could be linked to a database with time and date of the recording, location, group size and composition, and spatial distribution. All files were grouped per general behavior category. Recording sessions (with continuous sound recording) that were longer than 4 minutes (~ 22 MB) were split into two or three files for better handling in analysis as otherwise a lot of memory was needed to open and display the files. This resulted in a total of 149 sound files with a total duration of 4.5 hours recording (mean duration = 1.8 min; SD = 1.4 min) for the Mahakam and 26 files with a total duration of 0.7 hours (mean duration = 1.7 min; SD = 1.6 min) for the Balikpapan Bay study areas. Only those sections from sessions were down-loaded that were analyzable, leaving bad recording sections out with too much background noise. For the Balikpapan Bay area silent passages, where dolphins did not vocalize in spite of their close presence, were included in analyses to quantify number of vocalizations per behavior and duration category. The numbers of sounds within a sound type were counted for all files combined per behavior category, except for broad-band clicks (pulse trains). These were so numerous that pulse trains in the river were counted until a number of 304 samples were obtained and 26 samples in Balikpapan Bay
Table 1. Vocalizations identified for Irrawaddy dolphins in the Mahakam River and described according to their duration, repetition rates, minimum and maximum frequencies and the differences between these frequencies.

<table>
<thead>
<tr>
<th>Categories sound types</th>
<th>&quot;common name&quot; sound type</th>
<th>n</th>
<th>mean duration (sec)</th>
<th>mean rep. rate</th>
<th>range rep. rate</th>
<th>mean min freq</th>
<th>mean max freq</th>
<th>freq range</th>
<th>mean D freq</th>
<th>range D freq</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 loud single broadband click</td>
<td>jaw-clap</td>
<td>134</td>
<td>0.044</td>
<td>&gt; 22000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 multiple broadband clicks</td>
<td>pulse click trains</td>
<td>&gt;304</td>
<td>2.472</td>
<td>35</td>
<td>2.97</td>
<td>&gt;22000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 broadband tonal pulsed sounds</td>
<td>squeak</td>
<td>50</td>
<td>0.047</td>
<td>899</td>
<td>349-1511</td>
<td>&gt;22000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 narrowband tonal pulsed sounds</td>
<td>creak</td>
<td>118</td>
<td>0.912</td>
<td>463</td>
<td>226-1244</td>
<td>&gt;22000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 narrowband frequency modulated sounds</td>
<td>grunt</td>
<td>18</td>
<td>0.69</td>
<td>905</td>
<td>447-1783</td>
<td>1825</td>
<td>3819</td>
<td>459-8544</td>
<td>1994</td>
<td>574-4822</td>
</tr>
<tr>
<td>6 narrowband frequency modulated sounds</td>
<td>moan</td>
<td>97</td>
<td>0.75</td>
<td>404</td>
<td>132-1199</td>
<td>1643</td>
<td>4453</td>
<td>257-13569</td>
<td>2810</td>
<td>157-12313</td>
</tr>
<tr>
<td>7 narrowband frequency modulated sounds</td>
<td>quack</td>
<td>65</td>
<td>0.05</td>
<td>396</td>
<td>213-736</td>
<td>532</td>
<td>1775</td>
<td>532-6318</td>
<td>1243</td>
<td>91-5582</td>
</tr>
<tr>
<td>8 narrowband frequency modulated sounds</td>
<td>call 1</td>
<td>19</td>
<td>0.371</td>
<td>3472</td>
<td>3884</td>
<td>3472-9320</td>
<td>415</td>
<td>0-1434</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 narrowband frequency modulated sounds</td>
<td>call 2</td>
<td>16</td>
<td>0.174</td>
<td>1538</td>
<td>1859</td>
<td>1538-4320</td>
<td>388</td>
<td>0-1847</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 narrowband frequency modulated sounds</td>
<td>whistle (CF)</td>
<td>64</td>
<td>0.295</td>
<td>5068</td>
<td>5187</td>
<td>5068-11783</td>
<td>127</td>
<td>0-557</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 narrowband frequency modulated sounds</td>
<td>whistle 0 mod up</td>
<td>45</td>
<td>0.235</td>
<td>6193</td>
<td>8234</td>
<td>6193-15848</td>
<td>2317</td>
<td>332-6836</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 narrowband frequency modulated sounds</td>
<td>whistle 0 mod down</td>
<td>16</td>
<td>0.264</td>
<td>3101</td>
<td>4035</td>
<td>3101-6484</td>
<td>1332</td>
<td>404-2740</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 narrowband frequency modulated sounds</td>
<td>whistle 1 mod up</td>
<td>86</td>
<td>0.262</td>
<td>6132</td>
<td>8001</td>
<td>6132-18442</td>
<td>1868</td>
<td>0-9845</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 narrowband frequency modulated sounds</td>
<td>whistle 1 mod down</td>
<td>16</td>
<td>0.262</td>
<td>5998</td>
<td>6866</td>
<td>5998-13902</td>
<td>1097</td>
<td>398-2341</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 narrowband frequency modulated sounds</td>
<td>whistle 2 mod up</td>
<td>25</td>
<td>0.308</td>
<td>6075</td>
<td>8793</td>
<td>6075-16704</td>
<td>2638</td>
<td>0-9932</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 narrowband frequency modulated sounds</td>
<td>whistle 2 mod down</td>
<td>5</td>
<td>0.174</td>
<td>5863</td>
<td>5714</td>
<td>1907-9252</td>
<td>1585</td>
<td>251-5024</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 narrowband frequency modulated sounds</td>
<td>whistle 3, 4, 5 mod</td>
<td>25</td>
<td>0.487</td>
<td>6856</td>
<td>10482</td>
<td>3469-17704</td>
<td>3874</td>
<td>579-11708</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 = rep rate > 500 < 1500; mean max freq > 22000 Hz; 2 = rep rate < 500 Hz; mean max freq > 22000 Hz; 3 = rep rate > 500 < 1500; mean max freq < 5000 Hz; 4 = rep rate < 500 Hz; mean max freq < 5000 Hz; 5 = wavering calls; 6 = continuous frequency & modulated calls; 7 = continuous frequency & modulated whistles
Figure 2. Spectrographic representation (fast Fourier transforms, sample rate 48 kHz, FFT size = 512) of three types of broadband tonal, pulsed sounds (top figure) and two types of narrowband tonal, pulsed sounds, i.e., Creak and Squeaks (figure below). In the center of the lower figure is a pulse train of broad-band clicks with increasing, decreasing and increasing click rates (65, 11 & 58 clicks per sec). The spectrogram is limited by the recording equipment, which was only able to record up to 24 kHz.
Balikpapan Bay. These were considered enough to calculate average duration and click rates. In the Mahakam, good quality recording time was distributed over different behaviour categories as follows: feeding (43% of total recording time), slow swimming (34%), socializing (14%), milling activity (8%), and fast swimming (1%). In Balikpapan Bay, activities during which most recording sessions were made included feeding (57%), slowly swimming (39%), milling (3%), and fast swimming (1%).

The term social communication is explained in this article in terms of vocalizations, which are directed to other individuals to transfer different kinds of information (individual identification, *i.e.*, so called “signature” calls first described by Caldwell & Caldwell (1965), or to establish or maintain contact (Tyack, 1987; Sayigh et al., 1990; Smolker et al., 1993). To compare social communication for different habitats we looked at whistles, which have been described to fit the mentioned earlier meaning. We used similar group sizes and behaviours, and excluded whistles made during approaching boats to compare 1) the numbers of whistles in coastal and freshwater habitat and within different core areas in the river, 2) minimum and maximum frequencies, and 3) whistle duration. The measurements of whistles were compared using the non-parametric Mann-Whitney U-test (Fowler & Cohen, 1990). To compare the numbers of whistles in different areas, the numbers of whistles per behaviour in each area were divided by the recording time for that behaviour, and were then added and divided by the number of behaviour categories. The resulting average number of whistles per time unit was multiplied with the mean recording effort of all areas to obtain the total number of whistles per area with equal recording effort. The numbers of whistles were compared between the areas using a Chi-square test and applying Yates' correction when there was only 1 degree of freedom. We also tested whether there was a correlation between the number of whistles per min recording effort and group size, as well as the number of calves in a group, using the Product Moment Correlation Coefficient (*r*). To test the impact of approaching (speed)boats of > 40hp on whistle duration and frequencies, we compared whistles with the same modulations, same behaviour categories, same group sizes and in one area, in the absence and presence of these boats using the Mann-Whitney U-test.

**RESULTS**

**Repertoire**

Sounds produced by dolphins in the Mahakam River could be distinguished broadly in five categories: 1) loud single broadband clicks, 2) multiple broadband clicks, 3) broadband tonal pulsed sounds, 4) narrow-band tonal pulsed sounds, 5) narrow-band frequency modulated sounds (Table 1). Each different type of vocalization is graphically represented in a spectrogram (Figures 2 & 3). After pulse trains (> 304), whistles are the most common sounds produced by the dolphins (*n* = 282), then jaw claps (*n* = 134), creaks (*n* = 118), moans (*n* = 97), “metallic” quacks (*n* = 65), what we
Figure 3. Spectrographic representation of narrowband frequency-modulated sounds. Calls of type 1 had a wavering contour, whereas calls of type 2 were of continuous frequencies or modulated as shown here. Whistles with up to 5 modulations were produced in the Mahakam River. In this graph, the whistle of 1 modulation was followed by a loud, single broadband click (“jaw-clap”). The whistle with 0 modulation and large frequency increase (from 892 Hz to 6243 Hz) in this graph preceded a boat approach.

Vocalizations produced by coastal Irrawaddy dolphins in Balikpapan Bay could be distinguished in the same five categories as those in the Mahakam River (Table 3).
Table 2. Vocalizations identified for Irrawaddy dolphins in Balikpapan Bay and described according to their duration, repetition rates, minimum and maximum frequencies and the differences between these frequencies.

<table>
<thead>
<tr>
<th>Categories sound type</th>
<th>&quot;common name&quot; sound type</th>
<th>n</th>
<th>mean duration (sec)</th>
<th>mean rep. rate</th>
<th>range rep. rate</th>
<th>mean min freq</th>
<th>mean max freq</th>
<th>range freq</th>
<th>mean D freq</th>
<th>range D freq</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 loud single broadband click</td>
<td>jaw-clap</td>
<td>8</td>
<td>0.039</td>
<td></td>
<td></td>
<td>&gt;22000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 multiple broadband clicks</td>
<td>pulse click trains</td>
<td>&gt;26</td>
<td>5.92</td>
<td>53</td>
<td>20-90</td>
<td>&gt;22000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 broadband tonal pulsed sounds(^1)</td>
<td>creak</td>
<td>9</td>
<td>0.101</td>
<td>309</td>
<td>249-359</td>
<td>&gt;22000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 narrowband tonal pulsed sounds(^2)</td>
<td>moan</td>
<td>2</td>
<td>0.302</td>
<td>503</td>
<td>426-580</td>
<td>1914</td>
<td>4999</td>
<td>903-8192</td>
<td>3085</td>
<td>904-5266</td>
</tr>
<tr>
<td></td>
<td>quack</td>
<td>25</td>
<td>0.059</td>
<td>445</td>
<td>148-2019</td>
<td>1431</td>
<td>2898</td>
<td>484-5344</td>
<td>1466</td>
<td>0-3906</td>
</tr>
<tr>
<td>5 narrowband frequency modulated sounds(^3)</td>
<td>call 1</td>
<td>4</td>
<td>0.342</td>
<td></td>
<td></td>
<td>1890</td>
<td>2258</td>
<td>1043-3862</td>
<td>368</td>
<td>234-594</td>
</tr>
<tr>
<td>narrowband frequency modulated sounds(^4)</td>
<td>whistle (CF)</td>
<td>2</td>
<td>0.243</td>
<td></td>
<td></td>
<td>6972</td>
<td>7065</td>
<td>2438-11692</td>
<td>92</td>
<td>0-185</td>
</tr>
<tr>
<td></td>
<td>Whistle 0 mod down</td>
<td>4</td>
<td>0.144</td>
<td></td>
<td></td>
<td>6916</td>
<td>7128</td>
<td>1639-11616</td>
<td>358</td>
<td>117-673</td>
</tr>
<tr>
<td></td>
<td>Whistle 0 mod up</td>
<td>4</td>
<td>0.147</td>
<td></td>
<td></td>
<td>9297</td>
<td>10407</td>
<td>8612-10695</td>
<td>1110</td>
<td>411-2083</td>
</tr>
<tr>
<td></td>
<td>Whistle 1 mod up</td>
<td>9</td>
<td>0.183</td>
<td></td>
<td></td>
<td>9884</td>
<td>10804</td>
<td>2699-16081</td>
<td>919</td>
<td>280-2083</td>
</tr>
<tr>
<td></td>
<td>Whistle 2 mod up</td>
<td>3</td>
<td>0.179</td>
<td></td>
<td></td>
<td>6983</td>
<td>7805</td>
<td>1589-10880</td>
<td>822</td>
<td>513-1317</td>
</tr>
<tr>
<td></td>
<td>Whistles 2 down</td>
<td>1</td>
<td>0.054</td>
<td></td>
<td></td>
<td>1589</td>
<td>2102</td>
<td></td>
<td></td>
<td>513</td>
</tr>
</tbody>
</table>

\(^1\) rep rate < 500Hz; mean max freq >22000 Hz; \(^2\) rep rate < 500Hz; mean max freq < 5000 Hz; \(^3\) wavering calls; \(^4\) continuous frequency & modulated whistles
Table 3. Whistle types and their abundance per study area

<table>
<thead>
<tr>
<th>AREAS</th>
<th>Recording effort (min)</th>
<th>Total number whistles</th>
<th>CF</th>
<th>Mod = 0</th>
<th>Mod = 1</th>
<th>Mod = 2</th>
<th>Mod = 3,4,5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mahakam</td>
<td>271</td>
<td>281</td>
<td>23%</td>
<td>22%</td>
<td>36%</td>
<td>10%</td>
<td>9%</td>
</tr>
<tr>
<td>Balikpapan</td>
<td>166</td>
<td>24</td>
<td>8%</td>
<td>33%</td>
<td>38%</td>
<td>17%</td>
<td>4%</td>
</tr>
<tr>
<td>Area 1(^1)</td>
<td>76</td>
<td>21</td>
<td>24%</td>
<td>14%</td>
<td>62%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Area 2(^1)</td>
<td>183</td>
<td>260</td>
<td>23%</td>
<td>22%</td>
<td>34%</td>
<td>11%</td>
<td>10%</td>
</tr>
</tbody>
</table>

\(^1\) = Both areas are in the Mahakam River

The repertoire of individual sound types was less varied though, and the most common sounds produced in decreasing order are pulse trains \((n > 26)\), quacks \((n = 25)\), whistles \((n = 24)\), creaks \((n = 9)\), jaw-claps \((n = 8)\), type 1 calls (wavering calls; \(n = 4)\), moans \((n = 2)\). Whistles were produced with up to four frequency modulations, and the most common whistle had one modulation (Table 3). Most whistles (71%) commenced with an initial raising frequency, whereas 21% commenced with a decreasing frequency and 8% of whistles had a continuous frequency. Eighteen whistles were distinguished based on their spectral contours, of which some were repeated during the same or different sightings.

Differences between repertoires were found among three core areas in the Mahakam River. “Upstream” area 2 had the most varied repertoire with all sounds produced as in table 1 and whistles of up to 5 modulations. “Downstream” area 1 lacked the calls of type 2 and whistles consisted only of zero to one modulation. In the rapid stream area 3, no moans, calls of type 1 and whistles were heard at all. Also, calls of type 2 in area 3 were of continuous frequency, whereas in area 2 these calls had up to 3 modulations. In both areas 1 and 2, whistles with one modulation of frequency were most common (Table 3). In area 1, we also found “whistle trains”, individual whistles produced in fast sequence consisting mostly of 4 whistles with mean interval of 0.15 sec \((SD = 0.036; n = 8)\).

Vocalizing time per (sub)population

All sound types

Dolphins in the Mahakam River were significantly more vocal than their coastal relatives, where 4 sounds other than pulse trains (and including whistles) per minute recording were produced on average in contrast to 2.5 sounds per minute in Balikpapan Bay \((X^2 = 78; df = 1; P < 0.01)\) (Table 4). Most sounds per minute recording effort were produced by river dolphins during fast swimming, which were
Table 4. Sound types per behavioral category in the Mahakam River and Balikpapan Bay.

<table>
<thead>
<tr>
<th>Behavioral Category</th>
<th>Mahakam</th>
<th>Balikpapan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recording effort (min)</td>
<td>Quack %</td>
</tr>
<tr>
<td>Swim slow</td>
<td>92</td>
<td>11%</td>
</tr>
<tr>
<td>Feeding</td>
<td>117</td>
<td>9%</td>
</tr>
<tr>
<td>Milling</td>
<td>21</td>
<td>7%</td>
</tr>
<tr>
<td>Swim fast</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Play</td>
<td>37</td>
<td>3%</td>
</tr>
<tr>
<td>Total n</td>
<td>269 min</td>
<td>65</td>
</tr>
</tbody>
</table>

^1= percentage of occurrence of each sound type within one behavior category; ^2= average number of sounds per minute of different behaviour categories
Acoustic behaviour of coastal and freshwater Irrawaddy dolphins

all whistles. Next, most frequent sounds were heard during play and included in decreasing order mostly whistles, moans, and jaw-claps. During slow swimming, dolphins produced different sound types more or less equally often. During feeding and milling, whistles and jaw-claps were most frequent. In Balikpapan, sounds were just as frequently heard as in the river during the behaviour activities, fast swimming, and milling. During fast swimming, dolphins exclusively produced whistles, whereas during milling quacks and creaks were most common. A low number of vocalizations per minute were heard during slow swimming and feeding. During feeding, quacks, whistles, jaw-claps, and calls were emitted most frequent in decreasing order, whereas during slow swimming, first whistles, then jaw-claps, and finally barks prevailed.

Vocalizing time per (sub)population

All sound types

Dolphins in the Mahakam River were significantly more vocal than their coastal relatives, where 4 sounds other than pulse trains (and including whistles) per minute recording were produced on average in contrast to 2.5 sounds per minute in Balikpapan Bay ($X^2 = 78; \text{df} = 1; P < 0.01$) (Table 4). Most sounds per minute recording effort were produced by river dolphins during fast swimming, which were all whistles. Next, most frequent sounds were heard during play and included in decreasing order mostly whistles, moans, and jaw-claps. During slow swimming, dolphins produced different sound types more or less equally often. During feeding and milling, whistles and jaw-claps were most frequent. In Balikpapan, sounds were just as frequently heard as in the river during the behaviour activities, fast swimming, and milling. During fast swimming, dolphins exclusively produced whistles, whereas during milling quacks and creaks were most common. A low number of vocalizations per minute were heard during slow swimming and feeding. During feeding, quacks, whistles, jaw-claps, and calls were emitted most frequent in decreasing order, whereas during slow swimming, first whistles, then jaw-claps, and finally barks prevailed.

Within the different core areas in the Mahakam River, differences in the amount of vocalizing were also found. Most sounds per minute were produced by dolphins in area 2, namely 4.4 sounds per minute, which was significantly different and higher than in the “rapid stream” area 3 and “downstream” area 1, where on average 1.7 sound per min and 1.1 sounds per min were heard ($X^2 = 232; \text{df} = 2; P < 0.01$).

Whistles

Most whistles in the Mahakam were produced during fast swimming (65%), then slow swimming (12%), playing (10%), milling (8%) and feeding (5%). Likewise, in Balikpapan Bay, most whistles were heard during fast swimming (90%).

In comparison to Balikpapan Bay, significantly more whistles than expected were produced in the Mahakam River ($X^2 = 62; \text{df} = 1; P < 0.01$). In the Mahakam River
and Balikpapan bay, 2.4 whistles per minute and 1.4 whistles per minute were produced.

When comparing the two core areas within the Mahakam River, we found that in areas 1 and 3 significantly less whistles were produced within the same recording time than in area 2 ($X^2 = 392; \text{df} = 2; P < 0.01$). In areas 1 and 2, 0.2 whistles and 2.5 whistles are produced per minute, respectively. In area 3, no whistles were heard at all.

There was a negative correlation (although not significant) between the number of whistles per minute recording effort and group size and number of calves per group ($r = 0.48; \text{df} = 14; P = 0.06 \& r = 0.46; \text{df} = 14; P = 0.07$). Larger groups with (more) calves whistled less often than smaller groups.

**Whistle and call characteristics per (sub) population**

After combining all types of whistles irrespective of number of modulations, we found that whistles in the Mahakam had a mean duration of 0.23 sec (SD = 0.27; range = 0.02 – 3.09 sec), mean minimum frequencies of 5.8 kHz (SD = 2.9 kHz; range = 0.8 – 14.5 kHz) and mean maximum frequencies of 7.4 kHz (SD = 3.8 kHz; range = 1.4 – 18.4 kHz). All whistles combined in Balikpapan Bay had a mean duration of 0.18 sec (SD = 0.08 sec; range = 0.05 – 0.35 sec), mean minimum frequency of 8.7 kHz (SD = 4.1 kHz; range = 1.6 – 15.2 Hz) and mean maximum frequency of 9.4 kHz (SD = 4.3 kHz; range = 1.6 – 16.1 kHz).

We found that whistles of one modulation commencing with raising frequencies in coastal and freshwater habitat were significantly different in minimum and maximum frequency, as well as in the differences between minimum and maximum frequency ($U = 209, 280 \& 54; n_1 = 24 \& n_2 = 9; P < 0.01$). Namely, whistles of this type in the bay had higher minimum and maximum frequencies (mean = 9.9 kHz & 10.8 kHz) but lower delta frequencies between minimum and maximum frequencies (0.9 kHz) than those produced in the river (mean minimum = 6.1 kHz; maximum = 8.0 kHz, Delta Frequency = 1.9 kHz). No significant differences in the duration of this type of whistle were found. Whistles types with zero modulations and initial raising or decreasing frequencies were not different between both habitats.

Continuous frequency whistles of “downstream” area 1 in the Mahakam River were significantly lower in minimum and maximum frequencies (2.1 kHz & 2.3 kHz) than those in “upstream area” 2 (5.9 kHz & 6.1 kHz) ($U = 50$ for both min and max frequencies; $n_1 = 10 \& n_2 = 5; P < 0.01$). Whistles of one modulation with initial raising frequencies were significantly different between both areas. Whistle duration in area 2 was significantly longer than in area 1 (mean = 0.15 sec & 0.26 sec, respectively) ($U = 27.5; n_1 = 16 \& n_2 = 10; P < 0.01$). Minimum and maximum frequencies were significantly higher in area 2 (8.2 kHz & 10.3 kHz) than in area 1 (2.4 kHz & 3.1 kHz) ($U = 45.5 \& U = 136.5; n_1 = 16 \& n_2 = 10; P < 0.05 \& P < 0.01$). Also, the differences
between the minimum and maximum frequencies of whistles were significantly different (Delta frequency = 0.7 kHz in area 1 & 2.1 kHz in area 2) (U = 18; n₁ = 16 & n₂ = 10; P < 0.01).

Duration, minimum and maximum frequencies, and number of modulations of calls of type 1 were compared for core areas 1 and 2, and river and bay, whereas calls of type 2 were compared for areas 2 and 3. We found no significant differences for calls of type 1 between areas 1 and 2, and between the river and bay, although the mean minimum and maximum frequencies were much lower in the bay (mean minimum = 1.9 kHz; SD = 1.0 kHz; mean maximum = 2.2 kHz; SD = 1.2 kHz) than in the Mahakam (mean minimum = 3.5 kHz; SD = 2.4; mean maximum = 3.9 kHz; SD = 2.5 kHz). Since N for area 3 was only 3 calls no test could be applied, but the mean minimum and maximum frequencies were distinctively lower in area 3 (mean = 0.5 kHz; SD = 0.56 kHz) than those in area 2 (means = 1.7 – 2.1 kHz; SD = 0.9 & 1.2 kHz).

Impact of speed boats

Frequencies of continuous-frequency whistles were significantly higher in the presence of (speed) boats of > 40hp (mean = 5568 Hz) than in their absence (mean = 5247 Hz) (U = 72; n₁ = 10 & n₂ = 10; P = 0.05). Whistles with zero and one modulations with both initial raising frequencies all had higher minimum (means = 7508 Hz & 6355 Hz) and maximum frequencies (means = 10016 Hz & 83221 Hz) in presence of (speed)boats > 40hp than in their absence (means minimum frequencies = 6351 Hz & 6000 Hz; means maximum frequencies = 8123 Hz & 8326 Hz) (zero-modulation whistles: U = 66 & 109; n₁ = 6 & n₂ = 15; P = 0.05 & P < 0.01; one-modulation whistles: U = 205 & 296; n₁ = 13 & n₂ = 20; both P < 0.01). Duration of whistles of one modulation was also significantly longer in presence of these boats (mean = 0.365 sec) than in their absence (mean = 0.285 sec) (U = 174; n₁ = 13 & n₂ = 20, P = 0.05).

DISCUSSION

The acoustic behaviour of Irrawaddy dolphins in the Mahakam River and Balikpapan Bay differed in a number of aspects: vocal repertoire, amount of time spent vocalizing (all sound types and whistles) and shape, duration and frequencies of whistles. The freshwater dolphins had a more varied repertoire, spent more time vocalizing, and produced more complex whistles, which seems to fit with their turbid environment in which they have to rely on acoustics instead of vision and also reflects a dynamic, social system. Their whistle frequencies were lower, but they had higher delta frequencies of minimum and maximum frequencies than their coastal relatives.
The riverine Irrawaddy dolphins’ whistle frequency ranges (0.8 – 18.4 kHz) resemble most those whistles of the riverine Indus dolphin, *Platanista g. gangetica* and Yangtze dolphin or baji, *Lipotes vexillifer*, which had frequency ranges of 0.8 to 16 kHz (Andersen & Pilleri, 1970; Pilleri *et al*., 1971) and 3 to 18.4 kHz (Jing Xianying *et al*., 1981; Xiao Youfu & Jing Rongcai, 1989), respectively. Also, the dominant frequencies of the baji of 6 kHz corresponded with those of the pesut, which were between 5.8 and 7.3 kHz. In the Mekong River in Laos, whistles of one pod of Irrawaddy dolphins were described (Borsani, 1999), which all corresponded to one type of whistles of two modulations with initial raising frequency and with mean minimum and maximum frequencies of 3 kHz and 8 kHz. On the other hand, in the Mahakam whistles of this type had higher mean, minimum frequencies, *i.e.* 6.0 kHz, and similar mean, maximum frequencies, *i.e.* 8.8 kHz. Dominant whistle frequencies were highest for tucuxi, *Sotalia fluviatilis* (10-15 kHz) of all other (facultative) river dolphin species and whistles also had a higher, maximum frequency range, *i.e.* 23.9 kHz (Da Silva & Best, 1994; Wang Ding *et al*., 1995). However, their whistles were simpler as they only produced simple, zero-modulated, rising whistles and whistles of one modulation that lasted shorter (less than 0.5 sec) in contrast to the whistles of pesut that lasted up to 3.1 sec and had up to 5 modulations. Frequency ranges (0.2 – 5.2 kHz) and dominant frequencies of the bouto, *Inia geoffrensis* (1.8 – 3.8 kHz) had much lower, maximum frequencies than those of the pesut (Wang Ding *et al*., 1995). It has been suggested that the low frequency whistles of the bouto have better refractive capabilities, important to species whose habitats are rivers, which have higher noise levels than pelagic environment and carry more suspended material (Evans & Awbrey, 1988). This may explain the lower frequencies of Irrawaddy dolphins in the Mahakam in comparison to Balikpapan Bay, but still does not explain why frequencies of Irrawaddy dolphins in the Mahakam and Mekong, the tucuxi, Indus dolphin and baji are still much higher than those of Inia since they share similar environments.

Dolphins in downstream area 1 vocalized less often, produced less and simpler whistles with significant different measurements than in upstream area 2 and had only one type of call. This may suggest that these sub-populations have their own group dialect reflecting their own social structure. In core area 2 daily 2 to 6 different groups were encountered in one and the same confluence area and interactions of mean duration of one hour may occur with two other groups during day time (Kreb, 2004). In area 1, each group only encountered one other group on average during day time and has a smaller sub-population. Dolphins of area 1 in that respect more resemble those killer whales, which live in stable, social groups and mostly produce simple, group-specific whistles (Ford, 1991; Strager, 1995). The dynamic social situation in area 2 then more reflects a “fission-fusion” system although to a lesser extent than those of coastal bottlenose dolphins (e.g. Wells, 1991). In contrast, the group of 6 dolphins trapped in the rapid stream area of 2 km in length, where they have been since 3 years at the time of study have a less varied vocal repertoire, vocalize less frequently, and did not whistle, which may imply that they do not need to establish contact and identify themselves. Similar low vocalization rates and low variety of
repertoire were found for a group of freshwater Irrawaddy dolphins in an isolated area in the Mekong River that during the 8 days of study had no exchange with other groups and which also spent a lot of their time listening. However, they still produced whistles that resembled one another, which might appear to indicate relatedness (Borsani, 1999).

So, a low number of whistles produced per unit time seem to suggest a low, social diversification, which is also found in studies of other cetacean species (Tyack, 1991). This also seems to correspond with the lower mean number of whistles per unit time in Balikpapan Bay, where interactions with other groups occurred less frequently and were mostly functional in terms of feeding together and less frequently socializing. However, in the Mahakam, interactions were of different kinds of nature, i.e., intensive socializing, agonistic or avoidance interaction, low level interactions, feeding and travelling together (Kreb, 2004). However, dolphins in Balikpapan Bay may also spent less time vocalizing because they spent most of their more time listening, presumably to the sounds of grouper fishes and shrimps, which could be heard for a great deal of the time. This is similar to a pod of Irrawaddy dolphins in the Mekong River, who spent a great deal of the time passively listening to prey fishes as suggested by Borsani (1999). Also, the fact that clarity was much higher in the bay (mean = 170 cm; SD = 58 cm; n = 24 cm) than in the river (mean = 23 cm; SD = 7 cm; n = 27 cm), may explain the differences, if coastal dolphins make more use of their sighting- than vocal capabilities.

Calls produced in the Mahakam were different for each of the 3 areas: Core areas 1 and 2 share calls of type 1, whereas areas 2 and 3 share calls of type 2. Calls of each type in different areas have their own characteristics in terms of number of modulations. This seems to correspond with the dialects of repetitious calls, which have been demonstrated to be pod-specific for killer whales (Ford, 1991). When comparing whistle types of coastal Irrawaddy dolphins in Balikpapan Bay with whistle types described for Irrawaddy dolphins in coastal waters of Queensland, Australia, the first appeared to have more whistle types, i.e., continuous frequency whistles and whistles with 1, 2 or 4 modulations with raising or decreasing initial frequencies. Only two whistle types were described of the Australian Irrawaddy dolphins, of which whistle type 1 had one modulation and initial raising frequency and whistle type 2 had zero modulations and initial decreasing frequency (Van Parijs et al., 2000). Also, the minimum and maximum frequencies of Australian whistles of types 1 and 2 were all lower than similar types of whistles of Balikpapan and from the Mahakam (same modulations and initial raising or falling pattern). Mean minimum and maximum frequencies in Australia of whistle type 1 are 3.2 kHz and 4.2 kHz, whereas in Balikpapan these are 9.9 kHz and 10.8 kHz and in the Mahakam 6.1 kHz and 8.0 kHz. The duration of whistles, however, is more or less similar in all areas. Whistles of type 2 in Australia had mean minimum and maximum frequencies of 3.1 kHz and 4.2 kHz, whereas in Balikpapan these were 6.9 kHz and 7.1 kHz. Nevertheless, whistles of this type in the Mahakam had similar mean frequencies, i.e., 3.1 kHz and 4.0 kHz. Also, whistle duration was nearly similar, i.e., 0.26 sec and 0.3
sec in Balikpapan and Australia, respectively and was shorter on average in Balikpapan Bay, i.e., 0.14 sec. In Balikpapan Bay, the mean, minimum frequencies of 7.0 kHz resembled more those in the Mahakam and the mean, maximum frequencies of 7.8 kHz were similar to both Balikpapan and Mekong River. Unfortunately, there are no whistles of this type available from Australia for comparison. Type 2 whistles in the Mahakam have closer resembling frequencies with those in Australia than with those from Balikpapan Bay and in the Mahakam River also significant differences exists in whistle frequencies within different sub-populations. However, the whistle types in terms of numbers of modulations and raising and falling patterns of the Mahakam population are much more varied in contrast to those in Australia and in this aspect more similar to the Balikpapan population.

When comparing the frequency ranges and dominant frequencies of coastal whistles in Balikapan Bay (1.6 – 16.0 kHz & 8.7 – 9.4 kHz) with those of their most closely related relative the killer whale, *Orcinus orca*, as suggested by Le Duc et al. (1999), we find that the latter are very similar (1.5 -18 kHz & 6 – 12 kHz) (Steiner et al. 1979; Ford & Fisher, 1983; Morton et al., 1986).

Whistles in this study may be categorized in several whistle “types” according their modulations, and their initial rising or decreasing frequencies, such as described for bottlenose dolphins in McCowan & Reiss (1995). However, a greater number of distinctively shaped whistles than number of whistle types occur in the Mahakam and Balikpapan Bay, which may be repeated during similar or different sighting occasions and may correspond with the individual signature whistles as first reported by Caldwell & Caldwell (1965; Caldwell et al., 1990; Sayigh et al., 1999) for captive bottlenose dolphins, *Tursiops truncatus*. However, since the number of different shaped whistles during some recording sessions exceeded the group size with more than twice the number, whistles are not only used as signature whistles, but likely also to establish or maintain contact (Tyack, 1987; Sayigh et al., 1990; Smolker et al., 1993; Janik & Slater, 1998).

A cautious, premature conclusion of all comparisons between and within genera may be that whistles types (in terms of their spectral shapes) and whistle frequencies may have a high plasticity. Although whistles are to some extent determined by ecological factors (similar environments), they may even vary within one population (group dialects). Possibly, social structures have a more determining impact on whistle types and frequencies. This coincides with the findings of Ding et al. (1995), who compared whistles of several bottlenose populations and found that although there may be differences between whistles from different or the same individuals within the same population, there are still some characteristics that are unique for each population.

Sounds other than whistles and broadband clicks were more similar between Balikpapan Bay and in the Mahakam in comparison with those recorded in Australia, of which only the squeak corresponded with similar sounds of the Mahakam. This may indicate that the specific vocal repertoire (specific sounds types) is determined more by genetic relatedness than habitat factors. The vocal repertoires in terms of
numbers of different sound types in Balikpapan Bay and in Australia are both less varied in comparison to the freshwater dolphins in the Mahakam and may indicate that vocal variety may be shaped by ecological conditions.

Finally, we may conclude that although acoustic behaviour does not answer the question of whether or not the freshwater Irrawaddy dolphin populations represent different (sub)species or merely geographical forms, acoustic behaviour may help to define stocks as separate management units.

An explanation for the fact that whistles were significantly higher and lasted longer in approach of boats may be that dolphins try to overcome the vessel noise to give a clear, sign to other dolphins of each other’s position. Pacific humpback dolphins, *Sousa chinensis*, in Australia significantly increased their whistle rate in response to passage of a boats suggesting that the noise from transiting vessels affects dolphins’ group cohesion (Van Parijs & Corkeron, 2001). These humpback dolphins also whistled more when there were more calves present, and these whistles were suggested to function as contact calls in contrast to the Mahakam population where no significant positive relation existed. Moreover, a tendency existed that dolphins whistled less frequently when calves were present in the group. A most likely explanation is that mother and calves already maintain close contact as they were always found to swim close together and do not need to whistle often.

**ACKNOWLEDGEMENTS**

We would like to thank the Indonesian Institute of Sciences (LIPI), Mulawarman University of Samarinda (UNMUL), East Kalimantan nature conservation authorities (BKSDA), Zoological Museum Amsterdam (ZMA), Plantage Library, for providing permits, for their cooperation and support. We would like to thank field assistants Arman, Budiono, Syahrani, Ahank, and Munadianto (UNMUL) and our boatsmen. We would like to thank Van Tienhoven Foundation for their financial support for this acoustic behaviour study.

In addition, we would like to thank the following persons in particular: A. Ariffien Bratawinata, F. R. Schram, P. J. H. van Bree, H. P. Nooteboom, V. Nijman, M. Lammertink, T. A. Jefferson, G. Parra.

**REFERENCES**


