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Living Under an Aquatic Freeway: Effects of Boats on Irrawaddy Dolphins (*Orcaella brevirostris*) in a Coastal and Riverine Environment in Indonesia

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Abstract

Interactions between boats, and coastal and freshwater Irrawaddy dolphins (*Orcaella brevirostris*), were studied in East Kalimantan, Indonesia, during 2001. The goal was to determine the conditions under which dolphins reacted to boats and to recommend conservation actions. Both coastal and freshwater Irrawaddy dolphins surfaced less in the presence of boats, but the avoidance reaction lasted longer for the river dolphins. River dolphins surfaced significantly less often in the presence of motorized canoes (< 40 hp), speedboats (40-200 hp), and container tugboats (> 1,000 hp). Coastal dolphins only reacted to speedboats, and only when they approached at a 50-m distance. River dolphins reacted within a maximum distance of 250 m before and 300 m after a speedboat passed. Besides surfacing changes, river dolphins actively avoided container tugboats. The strength of reactions did not depend on the dolphins' behavior, group size, or age. Hypersensitivity by river dolphins to intensive boat traffic could explain the different responses between coastal and river dolphins. To prevent dolphin displacement from their core areas, an action plan currently is being developed by a nongovernmental organization in cooperation with Indonesian governmental institutions and residents. Speedboat owners will be urged to reduce boat speed in areas indicated on sign boards.

Key Words: boat disturbance, conservation, Indonesia, surfacing patterns, Irrawaddy dolphin, *Orcaella brevirostris*

Introduction

The Irrawaddy dolphin (*Orcaella brevirostris*) is a facultative freshwater dolphin, occurring both in shallow coastal waters and large riverine systems in tropical Southeast Asia and subtropical India (Stacey & Arnold, 1999). In Indonesia, Irrawaddy dolphins occur along the coasts and in one river in East Kalimantan, the Mahakam (Kreb, 1999). The International Union for the Conservation of Nature (IUCN) status of this freshwater population recently was clarified and defined as "Critically Endangered" (Hilton-Taylor, 2000). The mean Mahakam population size was estimated at 43 individuals (95% CI = 31 to 76, CV = 8% - 15%) based on direct counts, strip-transect analysis, and Petersen and Jolly-Seber mark-recapture analyses of photo-identified dolphins (Kreb, 2002, in press). The dolphins occur primarily in deep pools located near confluences and meanders, and occasionally in connecting lakes and tributaries. These areas also are primary fishing grounds and subject to intensive motorized vessel traffic (Kreb, unpublished data). Between 1995 and 2001 at least 37 dolphins were killed by entanglement in gillnets (81%), illegal hunting (8%), and vessel collisions (5%). The impacts of boat traffic on the dolphins were investigated because the dolphins prefer specific confluence areas where boat traffic is intense (Kreb, unpublished data).

A number of studies have focused on the short-term and long-term reactions of whales and dolphins to boats: Richardson et al. (1995), Lesage et al. (1999), and Gordon & Moscrop (1996) reviewed several studies on the behavioral effects of small cetaceans, in particular bottlenose dolphins (*Tursiops truncatus*) and belugas (*Delphinapterus leucas*), and their reactions to boat traffic. Short-term behavioral changes involved longer dive times, shorter surface intervals with increased blow rates, changes of direction, "freeze" responses with tight pod formation, increased swimming speed, and changed acoustic behavior (from a reduction in calls to a shift to higher frequency bands). An increase in whistle repetition at the onset of a vessel approach was proposed to be an effective way to reduce signal masking and enhance communication in a noisy environment (Buckstaff, 2003). Additionally, long-term changes involved shifting to higher frequencies and greater intensity echolocation signals as an adaptation to a noisier environment, as well as departure from frequently disturbed areas. Approach (bow-riding dolphins) or neutral (with no apparent change in directional movement) responses to boats were found in two studies on bottlenose dolphins in areas with typical tourist boat densities (Allen & Read, 2000; Gregory & Rowden, 2001). In contrast, Janik & Thompson (1996) found that bottlenose dolphins dived longer and/or moved away when approached by dolphin-watching boats. An initial approach response to dolphin-watching boats was found by Hector's dolphins (*Cephalorhynchus hectori*), which turned into either disinterest or active avoidance after a 70-min encounter (Bejder et al., 1999). Bottlenose dolphins also were reported to decrease their use of primary foraging habitats during periods of high boat density (Allen & Read, 2000). Subsurface responses of bottlenose dolphins to approaching boats, which were recorded on videotape, involved decreased interanimal distance, changed heading, and increased swimming speed (Nowacek et al., 2001). Observations of river dolphins are sparse and only qualitatively investigated. Smith (1993) reported that Ganges dolphins (*Platanista gangetica*) avoided motorized boats, and Zhou & Li (1989) found that the baiji (*Lipotes vexillifer*) in the Yangtze River generally dived for longer times and tended not to surface within 50 m of boat traffic. Irrawaddy dolphins in the Mekong River surfaced less often when large motor boats were within 100 m and surfaced closer to slow moving boats (Stacey, 1996).

This study was conducted to determine if boat traffic affected the freshwater population of Irrawaddy dolphins in the Mahakam River in East Kalimantan, Indonesia. A coastal Irrawaddy dolphin population in a nearby coastal bay in East Kalimantan, where boat traffic was less intense, formed a reference population. Both quantitative and qualitative reactions of dolphins to different types of boats at different distances were measured in both the river and coastal bay habitats. In addition, we examined whether behavioral responses were related to the dolphins' activities prior to the arrival of boats, group size, or the presence of calves. These comparisons identified conditions that affect dolphin responses. The results facilitated recommendations for boat traffic control in certain areas and for certain boat types—a modest step forward towards the conservation of Irrawaddy dolphins in Indonesia.

Materials and Methods

Study Areas

Boat traffic was studied at two sites in East Kalimantan, Indonesia: (1) the middle Mahakam area, 180 km to 375 km from the mouth, and (2) Balikpapan Bay (Figure 1).

The Mahakam River is one of the major river systems of Kalimantan and runs from 118° to 113° E and between 1° N and 1° S. The regional climate is characterized by two seasons: (1) dry (from July-October, southeast monsoon) and (2) wet (November-June, northwest monsoon). Dry and wet periods alternated during the wet season as well. The river measures approximately 800 km from its origin in the Müller Mountains to the river mouth (MacKinnon et al., 1997). The study area was in the middle Mahakam area (from 180 km to 375 km from the mouth) because of the high dolphin densities (Kreb, 2002). Mean river width in this area measured 200 m (SD = 53, range 110-400 m, n = 105), whereas mean water depth at an average water level was 15 m (SD = 6, range 6-37, n = 65). Mean water clarity in the study area (measured with a Secchi disk) at an average water level was 23 cm (SD = 7, n = 27). The middle Mahakam and the connecting lakes system is an area of intense fishing activity with an annual catch since 1970 of 25,000 to 35,000 metric tons (MacKinnon et al., 1997), and the highest dolphin densities are there (Kreb, 2002). Some coal mining and logging activities also occur here, especially in the tributaries. Furthermore, the middle Mahakam area is subject to intense boat traffic, with boats passing our stationary observation vessel every 3 min on average, mostly boats of < 40 hp (Table 1). Infrastructure is poorly developed in Kalimantan, and rivers are the main mode of transportation. Hence, in central East Kalimantan, the Mahakam River is the main transport system. Boats most frequently encountered were small canoes with outboard engines of < 40 hp, boats with inboard engines of < 40 hp and of 40 hp to 800 hp, speedboats with outboard engines ranging from 40 hp to 200 hp, and container-tugboats of > 1,000 hp.

Balikpapan Bay stretches from 116° 42' to 116° 50' E and 1° to 1° 22' S (Figure 1). The water surface area of the bay is approximately 120 km^2. Maximum width of the bay is approximately 7 km. During the study period, the Irrawaddy dolphins in the Balikpapan survey area were observed from the observation vessel at locations varying from 2 m to 30 m deep. Average water depth at dolphin sightings within the bay was 14.5 m (SD = 8.0, n = 39) and outside the bay averaged 5.7 m (SD = 3.6, n = 13). Mean water clarity recorded at dolphin sightings in the bay was 170 cm (SD = 57.7, n = 24). Boat traffic was most frequent in the downstream part of the bay, where ferries and speedboats crossed the bay in one lane. Usually, five tankers were present in the bay, but most of the time these were stationary. In one of the

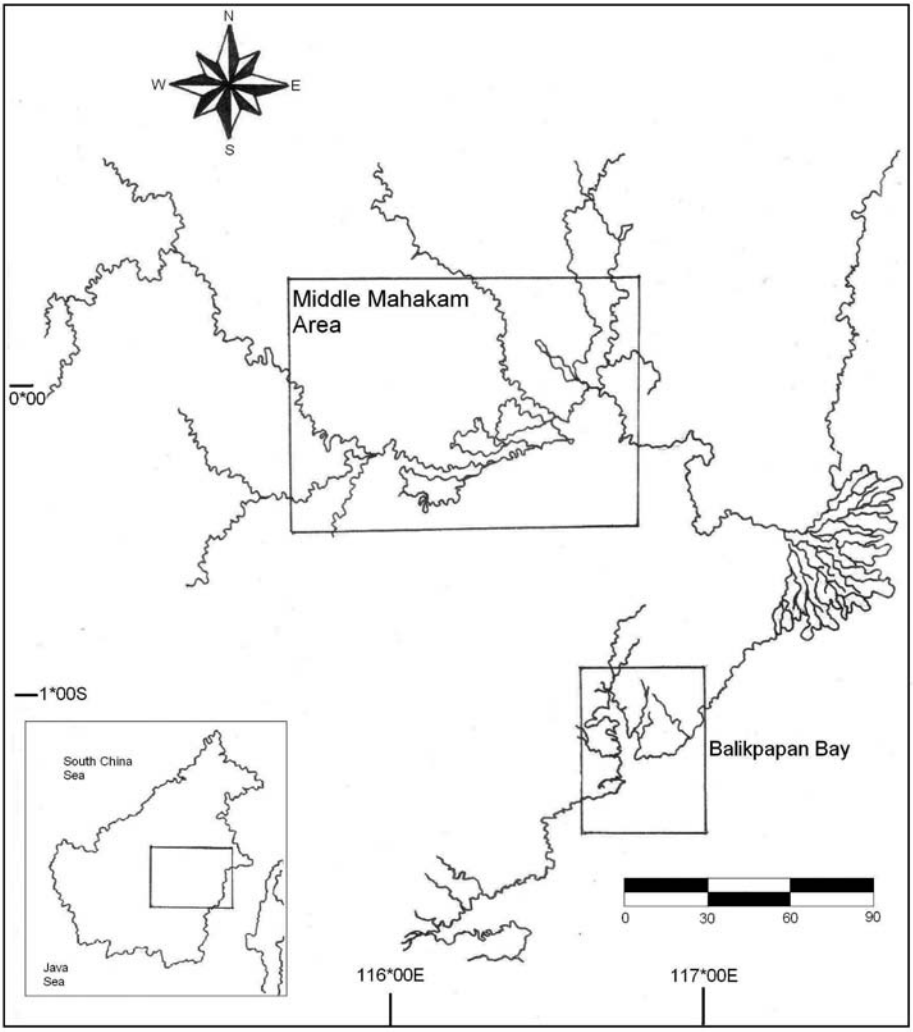

Figure 1. Map of study area at Mahakam River and Balikpapan Bay, Indonesia

Table 1. Average number of boats per hour by vessel type in the middle Mahakam area and Balikpapan Bay during daylight hours

	Boat types				
Study area	Outboard/ inboard < 40 hp	Inboard > 40 hp	Speedboat 40-200 hp	Container tugboat > 1,000 hp	All boat types
Mahakam	13.0	2.4	4.6	0.7	20.7
Balikpapan Bay	1.7	0.2	1.4	0.1	3.2

tributaries where dolphins occurred daily, speedboats, which frequented an upstream logging company, were encountered. Small fishing boats were in all areas of the bay. Dolphin encounters were more or less equally distributed in the bay.

Data Acquisition

Boat/dolphin interactions were studied in the Mahakam River during four periods in 2001: 23 June-5 July; 10-24 August; 2-9 September; and 25 October-7 November. Studies on coastal dolphins were conducted between 30 May-10 June and between 2-15 October 2001. These periods were chosen because these included low and medium water levels. The dolphin/boat interactions were hypothesized to be more detrimental in the dry season due to reduced water depth and the narrowing of the river thereby restricting dolphins' movements. Therefore, we focused on dolphin/boat interactions during low water levels. The surveys were conducted in high dolphin density areas to maximize the number of group sightings and in three habitat types: (1) main river, (2) tributaries, and (3) confluence areas.

Dolphin observations were conducted from two types of vessels. The first was a wooden boat with a 26-hp inboard engine and 16 m in length with the observer's eye-height at 3.5 m above the water. The second was a wooden canoe 10 m in length, with a 5-hp outboard motor with observer eye-height at 1 m above the water. When using the large vessel, we kept a distance of 100 m away from dolphins when the engine was on; however, for the small vessel, a distance of 50 m away was maintained based on preliminary work with shore observations that indicated dolphins did not respond at the closer distances for similar types of boats. The boat driver maintained a constant speed, heading direction, and distances to the dolphins. Observations also were made from an elevated land-based platform, 7 to 10 m above the water surface (depending on water levels), which provided an unobstructed view of one important dolphin confluence area and the connecting areas: 2 km upstream the main river, 500 m downstream the main river, and upstream in the tributary.

The observation team consisted of four people: observer 1 recorded dolphin surfacing behavior and boat traffic, and observer 2 drew a spatial distribution of the group and recorded distances among individuals. New drawings were made when the spatial distribution changed and the time at which the change occurred was recorded. Two other observers indicated behavioral displays and noted when dolphins surfaced and boats arrived. After each observation session, water depth was measured at the dolphins' main location using a sonar fish-finder (Fish-Finder 260, Apelco).

Dolphin reactions to boats were indicated by changes in surfacing patterns. Two methods were used. First, we compared the average number of individuals surfacing (based on the number of group surfacings divided by group size) per min during the absence and presence of boats. The following data were recorded continuously for at least 15 min: group size, group composition (i.e., presence of neonates, calves, or juveniles), individual and group behaviors of dolphins, total number of surfacing per min, type and time of boats entering and leaving an area, and distance to the dolphins. Speedboats, container tugboats, and boats with inboard engines > 40 hp were recorded as "present" if they were < 300 m from the core of the dolphin group. Small boats were recorded as "present" when < 100-m distance to the core of the dolphin group. Dolphins, "far away" from the core group (> 50 m to the nearest individual) were not included in the observation session. Since surfacing reactions were measured per boat type, we assigned multiple boat approaches in one min (27 of 397 encounters) to the boat type category with the largest horsepower. This was done since we found that dolphins reacted more strongly (i.e., surfaced less in close presence to boats with larger hp engines).

Some observation sessions were extended beyond 15 min when there were many boats passing and continued until 5 boat-absent min were obtained. A new session started when a new group was encountered, if during the 15-min session another group joined, if the group split, if group behavior changed, or if another daytime period started (three session blocks: from 0800-1100 h, 1101-1500 h, and 1501-1800 h). Data collected for less than 15 min were analyzed if the number of boat-absent min was at least five min (see "Data Analysis").

Distance from boats to the dolphins was estimated visually by the observer. Distance estimation training was conducted by the observers by estimating distance from one object along the river bank to another. These estimations were cross-checked by a simple calculation based on the boat speed and time traveled between both objects using a GPS and a stopwatch. In the same way, observers now and then referred to floating objects in the river and estimated river width every 15 min to standardize their estimation and error.

The second method compared the number of dolphin surfacings per boat by distance classes. For all boat encounters, the distance between each surfacing dolphin and the approaching/leaving boat was recorded. Thereafter, a dolphin's surfacing or not surfacing was marked for each distance class (see below). Distance between boat and surfacing dolphins was estimated visually. For example, if during a speedboat encounter only two dolphins surfaced and the distance to each individual was measured as 170 m and 190 m, then a response was noted in the 151 to 250-m distance class. All other distance classes were recorded as no surfacings. Two boat categories were distinguished: (1) small, motorized canoes and low-engine boats < 40 hp (for these boats, dolphin behaviors were recorded of each dolphin at 0-25 m, 26-75 m, and 76-100 m from the boat), and (2) speedboats with outboard engines from 40 hp to 200 hp (hp was on the outboard engine and read using binoculars), boats with inboard engines > 40 hp, and container barges > 1,000 hp. Dolphin surfacing was recorded for the following large boat distance ranges: 300-251 m, 250-151 m, 150-51 m, and 50-0 m.

The data set from both methods was based on a group-follow protocol with dolphin groups observed for > 30 min. The first method used a focal-group sampling method for continuous assessment of group behavioral displays, predominant group activity (> 50% of observations), and number of surfacings within 1-min time blocks (Mann, 1999). The second method used a one-zero sampling method to determine whether a dolphin surfaced within a certain boat distance class. For both methods, observations were analyzed if the boat traveled at a steady speed. The second method was applied only for single boat approaches within the distance classes at 300 m for speedboats or 100 m for small canoes < 40 hp.

Occasional underwater recordings were made when boats approached dolphins to define the maximum distance classes for recording surfacing rates for each type of boat. The distance of the boat to the dolphin at which the noise could be heard clearly by the observers was used as the distance range, although dolphins detect sounds over larger distance ranges. For underwater listening, a High Tech Inc. 94-SSQ hydrophone (frequency response: 2Hz to 30 kHz, sensitivity -168 dB re 1V/µPa) was hung over the observation vessel to a depth of 1.5 m.

Data Analysis

Average surfacing rates per individual in the absence/presence of boats were calculated per session. These were calculated as the total number of surfacings per min of the group under observation. The number of surfacings per min were summed for all boat-absent min in the session. Likewise, total surfacings were summed for all boat-present min in the 15-min session. These total surfacings per session for boat-absent vs boat-present categories were divided by the number of boat-absent or boat-present min to obtain the average group surfacings per min. The average group surfacing rate was divided by group size to obtain the average surfacing rate per individual, hereafter abbreviated in the text as "surfacing rates." Surfacing rates in the presence vs the absence of boats were compared within each session in which at least one boat passed, which were 37 and 16 sessions in the river and bay, respectively.

Surfacing rates were only calculated for the 15-min sessions during which at least 5 min (not necessarily continuous) were free of boat traffic (on average 3.6 boats in the river and 2.0 boats in the bay were recorded in the 15-min sessions with boats present). These surfacing rates without boats were then compared with surfacing rates of those in which one or more boats passed by during the same session. A minimum of 5 boat-absent min per session was chosen to overcome potential biases associated with fluctuations in surfacing rates per min inherent in the natural pattern of surfacing. This was tested by drawing replicated random selections of different sample sizes from an entirely boat-absent session. All ten replicates of the surfacing rates of this sample size (i.e., 5 boat-absent min) fell within the standard deviation of the average surfacing rate, which was based on 15 min. Smaller sample sizes showed significant deviations from the standard deviation.

All tests involved non-parametric statistics (Fowler & Cohen, 1990; Siegel & Castellan, 1988). Wilcoxon's matched pair tests was used to determine the effects of presence and absence of several types of boats within a sampling period (in the "Results" section, n is the number of pairs less the number of pairs for which no differences were found, i.e., $d = 0$). The Mann-Whitney U-test was used for differences in surfacing rates among different boat types. Effects of group size on the surfacing rates in absence and presence of boats were tested using Pearson's Product Moment Correlation test. To test for the correlation between group size and strength of reactions to boats, boat reactions were expressed as negative differences between surfacing rates in the absence and presence of boats and tested with the Spearman Rank Correlation Test. Because the surfacing rates in the presence of boats already proved significantly lower (see "Results"), only those data when dolphins showed negative reactions to boats (i.e., had lower surfacing rates in presence than in absence of boats) were used. Then, we tested if group composition was an influencing factor on surfacing rates in the presence and absence of boats. In this case, surfacing rates of groups with calves, which were found only within group sizes of four to eight individuals, were compared with groups without calves of similar group sizes, using the Mann-Whitney U-test. These comparisons were made in the absence and presence of boats. Reactions of dolphins as expressed in differences in surfacing rates in the absence and presence of boats were compared with the Kruskal-Wallis and Mann-Whitney U-tests for three habitat types in the river, which were the main river, confluence areas, and tributaries. We used Pearson's Product Moment Correlation test to test if any correlation existed between surfacing rates and depth both in the absence and in the presence of boats. Seasonal differences in surfacing rates were tested for low and medium water levels in order to test if surfacing rates, which were collected during different surveys, could be combined and did not bias the overall results using the Mann-Whitney U-test. A

Mann-Whitney U-test determined if the predominant (core) group activity (> 50% of time per min) during the sampling session affected surfacing rates, both in the absence and in the presence of boats.

To test for other reactions to boats than surfacing changes, the number of times general group behavior changed after a boat passed during the next min of dolphins surfacing were recorded for each boat type. These numbers were then compared with the number of times behaviors did not change using Chi-square tests and applying Yates' correction.

Reactions of dolphins per distance class using one-zero sampling and data set 2 (see "Materials and Methods") were all tested using Chi-square tests and applying Yates' correction for one degree of freedom. The number of encounters during which at least one dolphin of the group surfaced for each distance and for each boat type was compared with the number of times that no dolphin surfaced at all for similar distances. Combined distance class comparisons between surfacing and nonsurfacing occasions also were made. Moreover, frequencies of dolphin surfacing among distance classes were compared. All test results were analyzed for two-tailed values and significance was assumed when $p \leq 0.05$.

Results

Changes in Surfacing Rates

Observation effort data are presented in Table 2. Boat traffic in the Mahakam River was greater than recorded for Balikpapan Bay. During 75% of the 15-min sessions in the bay (total $n = 66$), no boats entered within the defined dolphin-boat distances for different boat types (i.e., 300 m for speedboats, container tugboats, and boats with inboard engines > 40 hp, and 100 m for small vessels of < 40 hp), whereas in the river only 15% of the sessions (total $n = 58$) were completely boat-absent. Boat traffic in the Mahakam River (mean = 20.7 boats/h) is 6.5 times more intensive than in the Balikpapan Bay (mean = 3.2 boats/h). In the river, canoes with outboard engines of < 40 hp were most frequent and speedboats were second. In the bay, vessels with inboard engines of < 40 hp and speedboats were equally common or rare (Table 2). Most encounters between dolphins and boats involved boats with inboard engines < 40 hp or speedboats of 40 hp (Table 2).

In the river, the mean surfacing rate per individual was significantly greater in the absence of boats (0.97 surfacing/min) than in their presence (0.74 surfacing/min) (Wilcoxon matched pairs: $t = 98$, $n = 33$, $p < 0.002$). In contrast, in the coastal bay, there were no significant differences in surfacing rate with 0.89 surfacing/min for both conditions (Wilcoxon matched pairs: $t = 62$, $n = 16$, $p > 0.1$). Dolphins in the river significantly surfaced less in the presence of boats of < 40 hp (0.67 surfacing/min, $t = 61$, $n = 25$, $p = 0.02$), speedboats of 40-200 hp (0.55 surfacing/min, $t = 9$, $n = 13$, $p < 0.02$), and boats tugging large containers of > 1,000 hp (0.47 surfacing/min, $t = 1$, $n = 7$, $p = 0.05$), when testing per boat type (all Wilcoxon matched pairs). In decreasing order, river dolphins surfaced least often in the presence of container tugboats, speedboats, and motorized canoes, but the group differences were not significant (Kruskal-Wallis: $H = 4.75$, df = 2, $p > 0.05$). On the other hand, differences in the medians (all sessions) of surfacing rates (per session) between the first and last boat types were found to be significant (Mann-Whitney U-test: $U = 30$, z = 2.15, $n_1 = 6$, $n_2 = 24$, $p = 0.015$); however, river dolphins did not surface less in the presence of vessels traveling at medium speed with inboard engines of > 40 hp (1.16 surfacing/min, $t = 26$, $n = 10$, $p > 0.05$). Our observation vessel (with outboard motor of 5 hp) approached within the defined distances on one session, and dolphins were found to surface at the same rate as in the absence of boats (0.93 surfacing/min).

Dolphins within the bay did not surface more or less frequently in the presence of speed boats of 40-200 hp (0.92 surfacing/min, $t = 22$, $n = 11$, $p > 0.1$) or boats with inboard engines of < 40 hp (0.74 surfacing/min, $t = 16.5$, $n = 9$, $p > 0.1$). These were the only boats that were commonly encountered besides ferries, of which no encounter with dolphins was observed. Surfacing rates in the presence of boats were compared among three boat types; there was a significant difference in the presence and absence of boats in the river environment.

Dolphins surfaced least often in the presence of container tugboats, and then speedboats and motorized canoes of < 40 hp. Group

Table 2. Observation effort and number of Irrawaddy dolphin/boat encounters in the Mahakam area and Balikpapan Bay

Study area	Session time (h)	*n* sessions	*n* sessions with boats	*n* sessions without boats	*n* boat/dolphin encounters
River	14	58	49	9	343
Bay	13	66	16	50	54
Total	27	124	65	59	397

differences were not significant (Kruskal-Wallis: $H = 4.75$, df = 2, $p > 0.05$), but differences in the medians (all sessions) of mean individual surfacing rates (per session) between the first and last boat types were significant (Mann-Whitney U-test: $U = 30$, $z = 2.15$, $n_1 = 6$, $n_2 = 24$, $p = 0.015$).

Surfacing rates per min in the absence of boats for river and coast were similar—0.97 and 0.98 times (CV = 18%, range 0.32-2.0, $n = 36$; CV = 21%, range 0.2-2.5, $n = 70$) during milling and slowly swimming behavior.

Surfacing Reactions in Relation to Distance Between Dolphins and Boats

Table 3 presents the number of dolphin/boat encounters by boat type and dolphin reactions by distance class (also visualized in Figures 2 & 3). Reactions for speedboats with different hp engines are combined as dolphins showed significant reactions to all types of speedboats. Dolphins significantly did not surface at all when approached at < 300 m by speedboats of 40 hp ($X^2 = 31.2$, df = 1, $p < 0.0001$); 85 hp ($X^2 = 26.4$, df = 1, $p < 0.0001$), 115 hp ($X^2 = 53.2$, df = 1, $p < 0.0001$), and 200 hp ($X^2 = 25.1$, df = 1, $p < 0.0001$). Speedboats of 40 hp were most frequently encountered (34 times), then 115 hp (20 times), 200 hp (11 times), and 85 hp (10 times). In the coastal bay, only speedboats of 40 hp were encountered (26 times).

Coastal dolphins significantly did not surface when speedboats passed within a ≤ 300-m radius to the group (in relation to the group's last observed position) ($X^2 = 22.3$, df = 1, $p < 0.0001$). River dolphins did not surface at all in the presence of small motorized canoes, speed boats, and other boats (> 40 hp) ($X^2 = 32.3$, df = 1, $p < 0.01$; $X^2 = 136.4$, df = 1, $p < 0.01$; $X^2 = 1.8$, df = 1, $p < 0.01$). Exceptions were dolphin reactions to tugboats and the observation vessel for which no significant differences were found between the number of times that even one dolphin surfaced in the presence of these boats.

Surfacing reactions for river dolphins are presented in Figure 2 for each distance class for small canoes of < 40 hp. The impact from boats of < 40 hp in the river and bay for both situations increased with shorter distances and was largest within 0 to 25-m distance of the dolphins when a boat was near and within 0 to 75 m after a boat passed. River dolphins surfaced more often before than after boats passed ($X^2 = 12.86$, df = 1, $p < 0.01$).

Figure 3 shows surfacing reactions of river dolphins to speedboats by distance class. The number of occasions when at least one dolphin surfaced increased stepwise for each increasing distance class. No significant differences were found in dolphin surfacings prior to or after boats passed. River dolphins react significantly when speedboats enter an area within 250 m until they leave the area within 300-m distance of the dolphins; whereas coastal dolphins only react significantly when the boat approached with a 50-m distance and until it left the area at 300-m distance.

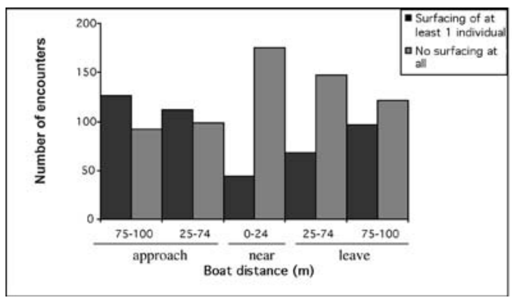

Figure 2. Irrawaddy river dolphins surfacing reactions to boats of <40 hp; distance classes from left to right correspond to the sequence of the approach of a boat.

Table 3. Irrawaddy dolphin reactions to different types of boats of > 40 hp by distance class

		Speedboat 40-200 hp		Inboard >40 hp	>1,000 hp
Boat position	Boat to dolphin distance (m)	River $n = 75$	Coast $n = 26$	River $n = 38$	River $n = 10$
A	300-250	n.s.	n.s.	n.s.	n.s.
A	250-150	s	n.s.	n.s.	n.s.
A	150-50	s	n.s.	n.s.	n.s.
A/L	50-0; 0-50	s	s	s	n.s.
L	50-150	s	s	s	n.s.
L	150-250	s	s	n.s.	n.s.
L	250-300	s	s	n.s.	n.s.
Total	all distances	s	s	s	n.s.

A = approaching boat; L = leaving boat; n.s. = nonsignificant reaction (i.e., for most encounters at that distance class at least one dolphin of the group surfaced during the encounter); s = significant reaction to boats ($p < 0.05$) (i.e., for most encounters at that distance class no dolphin surfaced during the encounter)

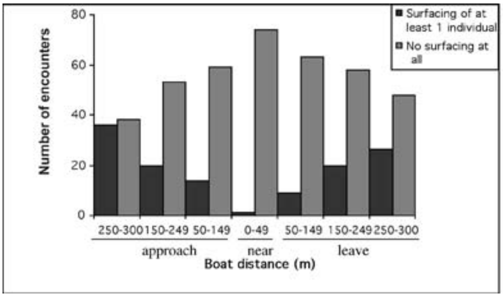

Figure 3. Irrawaddy river dolphin surfacing reaction to speedboats; distance classes from left to right correspond to the sequence of the approach of a boat.

For other boats of > 40 hp, no significant differences were found in dolphin surfacing among the distance classes. These boats caused the strongest reactions in dolphin surfacing behavior by them not surfacing at all when approached at a 50-m distance until the boats left an area of 150-m distance to the dolphins.

Other Factors than Boat Presence Influencing Surfacing Rates

Surfacing rates when boats were absent in the river (Figure 4) were significantly higher with greater group size (Product Moment Correlation: $r = 0.36$, df = 39, $p = 0.05$). Surfacing rates in the presence of boats, on the other hand, did not correlate with group size, and these were similar for small or large groups (Product Moment Correlation: $r = 0.13$, df = 35, $p > 0.05$). No significant relation was found between group size and strength of reactions to boats (expressed as differences between individual surfacing rates in the absence and presence of boats) (Spearman Rank Correlation: $r_s = 0.149$, $n = 28$, $p > 0.05$). Mean dolphin group size over all sessions was 4.6 ($n = 48$, SD = 2.0, range 1-10).

We also checked if group composition was an influencing factor by comparing surfacing rates of groups with calves (0.95 surfacing/min), which were found only within group sizes of four to eight individuals, to groups without calves of similar group sizes (1.22 surfacing/min). In the absence of boats, no significant differences were found between the means of the two samples (Mann-Whitney U-test: $U = 88$, $z = -0.93$, $n_1 = 13$, $n_2 = 11$, $p > 0.05$). Also, in the presence of boats, groups with vs without calves did not have significantly different average individual surfacing patterns—that is, with 0.70 surfacing/min and 0.79 surfacing/min, respectively (Mann-Whitney U-test: $U = 79$, $z = -0.41$, $n_1 = 13$, $n_2 = 11$, $p > 0.05$).

Dolphin reactions (differences between surfacing rates in the presence and absence of boats) also were compared between three types of habitat within the river—(1) main river, (2) confluence area, and (3) tributary—of which the mean width for the first and last were 200 m (SD = 54 m) and 43 m (SD = 13 m), respectively. No significant differences in reactions were found between each habitat type (Kruskal-Wallis: $H = 0.67$, df = 2, $p > 0.05$). No correlation was found between depth and the surfacing rates of dolphins in the river and in the bay, both in the absence (Product Moment Correlation: $r = 0.54$, df = 3, $p > 0.05$; $r = 0.155$, df = 38, $p > 0.05$) or presence of boats (Product Moment Correlation: $r = 0.121$, df = 47, $p > 0.05$; $r = 0.466$, df = 8, $p > 0.05$). Median surfacing rates were similar during low and medium water levels both in the absence and presence of boats (Mann-Whitney U-test: $U = 128$, $z = -5.68$, $n_1 = 10$, $n_2 = 10$, $p > 0.05$; $U = 118$, $z = -5.1$, $n_1 = 10$, $n_2 = 10$, $p > 0.05$).

When testing the influence of behavior on surfacing rates, dolphins engaged in slowly swimming or milling activities appeared to surface similarly in the absence of boats (Mann-Whitney U-test: $U = 117$, $n_1 = 20$, $n_2 = 16$, $p > 0.05$). Likewise, behavior did not influence surfacing rates when

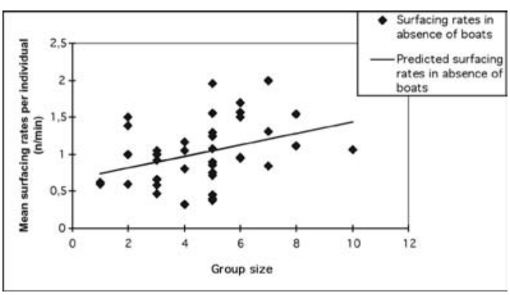

Figure 4. Irrawaddy river dolphin group size and mean surfacing rates per min per individual

Table 4. Irrawaddy dolphin reactions to boats of < 40 hp by distance class for river vs coastal habitats

<40 hp	Boat to dolphin distance (m)	River $n = 216$	Coast $n = 28$
A	100-75	s*	n.s.
A	75-25	n.s.	n.s.
A/L	25-0; 0-25	s	s
L	25-75	s	s
L	75-100	n.s.	n.s.
Total	all distances	s	n.s.

A = approaching boat; L = leaving boat; n.s. = nonsignificant reaction (i.e., for most encounters at that distance class at least one dolphin of the group surfaced during the encounter); s = significant reaction to boats ($p < 0.05$) (i.e., for most encounters at that distance class no dolphin surfaced during the encounter); * = significantly surfacing in presence of boats

Figure 5. A container barge passing through a narrow and shallow tributary of the Kedang Pahu River, which also represents primary dolphin habitat; during the dry season, these types of boats occupy three-quarters of the total river width causing a great deal of disturbance to the dolphins.

boats passed by (Mann-Whitney U-test: $U = 13$, $n_1 = 20$, $n_2 = 16$, $p > 0.05$).

Finally, we tested if dolphins showed other reactions in response to boat traffic than changes in surfacing rates. For all boat types and cases, when the predominant group behavior changed after a boat passed within the next min were compared with the number of times behaviors did not change. Apparently, dolphins did not change their predominant group behavior when boats approached within our pre-defined distances (see "Materials and Methods"). Only in four out of 130 boat encounters recorded did group behavior change after a boat passed.

Potential Impacts of the Observation Vessels

The presence of the large observation vessel (at > 100-m distance) and the small observation vessel (at > 50-m distance to the dolphins) did not influence dolphin surfacing rates—that is, there were no significant differences in median surfacing rates when recorded from the observation vessel or when recorded from the shore (Mann-Whitney U-test: $U = 143$, $n_1 = 25$, $n_2 = 11$, $p > 0.05$).

Qualitative Responses to Boat Traffic

Unfortunately, data on dolphin surfacing in the presence of large container tugboats were only collected during seven sessions. This had to do with the fact that the boats were mostly encountered in one narrow tributary (and adjacent confluence area) where sessions at most times had to stop for safety reasons. Therefore, most encounters between dolphins and container ships were documented according to protocol from an observation bridge in the confluence area of Muara Pahu in primary dolphin habitat. Nevertheless, a number of observations were made other than recording the number of surfacings that are worthwhile to mention. During medium water levels, on average, four empty container boats and four heavily loaded, large container boats moved up and down the narrow tributary each day, which represents primary dolphin habitat. During low water levels, about ten smaller container tugboats moved up and downstream each day. When a container boat passed the confluence area to move up or downstream of the tributary, dolphins usually anticipated by swimming a short distance away from the boat's heading direction. Because the distance was too short to define this behavior as slowly swimming, the general behavior on the data sheet was still regarded as milling.

Reactions to container boats in the narrow tributary of Kedang Pahu (mean width of river = 45 m at medium water levels; mean depth = 5 m at the locations where, and in the period when the boat encounters were recorded) are even more conspicuous than in the deeper confluence area (average depth of 15 m). Dolphins changed their swimming direction or waited to allow a container boat, which was moving in the same direction as the dolphins, to pass by and then resumed their swimming direction; however, there also were cases when dolphins increased their swimming speed if they were moving downstream with a container tugboat following from behind, in this way arriving ahead of the boat in the confluence area of main river and tributary. When the dolphins moved upstream and encountered more than one container tugboat in sequence that moved downstream, they also moved downstream ahead of the first container boat. During one occasion, one group of five dolphins moving downstream encountered a container tugboat moving upstream and they reacted by swimming fast, surfacing almost continuously, producing loud blows, displacing much water, and diving until the boat approached at a 10-m distance away.

In the narrow tributary with many river bends, the noise of an empty container tugboat was heard under water using a hydrophone at 150-m distance, and dolphins were still heard vocalizing. At a 100-m distance, however, no dolphins were heard, and at a 80-m distance, the sound was becoming uncomfortably loud for humans. According to Gordon & Moscrop (1996), belugas are supposed to suffer discomfort at received levels of about 140-160 dB. When the container boat passed, the noise level immediately dropped, and dolphins were heard vocalizing again at 70-m distance from the boat. Increasingly uncomfortable noise levels for the human ear were caused by speedboats in the same tributary at 300-m distance. At the same time, no dolphin was heard vocalizing until the boat passed at a 150-m distance when noise levels also dropped. Whether they could still echolocate was undetermined. On a few occasions, speedboats appeared after a river bend, and this caused startled responses and immediate dives by the dolphins.

Discussion

Methodological Constraints

One of the shortcomings of the analyses occurred in cases when there were two boats passing by during the same min (7% of all recorded encounters) and the average individual surfacing rates per min were entered in only one boat type category. The largest hp boat type category was chosen because dolphins surfaced least often in the presence of container tugboats, then speedboats of > 40 hp, and motorized canoes of < 40 hp (see "Results," "Changes in Surfacing Rates"). Another shortcoming was that surfacing rates during the 15-min sessions were counted for each min using real time. So, if a boat was present within the defined distance in the first or last thirty sec of a min, this was recorded as a boat-min, which may cause differences between surfacing rates in the absence and presence of boats to be diluted.

Interpreting Results

Surfacing rates decreased most significantly during encounters with container boats, secondly with speedboats, and then with small, motorized canoes of < 40 hp. Although the impacts of the first two boat types are more intense, boats of the last category also caused significant reactions in surfacing rates. Motorized canoes are by far the most frequent and are in this respect an important factor of disturbance. A reason why these small boats of < 40 hp evoked significant reactions, while larger boats > 40 hp other than speedboats and container boats did not, is probably that the small boats use outboard engines that produce high-frequency sounds (e.g., 5 kHz), and hearing sensitivity of small cetaceans improves with increasing frequency (Richardson et al., 1995). Coastal Irrawaddy dolphins in Australia produced whistles between 1 and 8 kHz and were mostly heard during both foraging and socializing behaviors (Van Parijs et al., 2000). The frequency of the noise produced by outboard vessels is within this same range and, therefore, most likely is a disturbing factor in the dolphins foraging and socializing activities. Another likely factor for outboard vessels of < 40 hp is that these boats often move fast and make sudden changes in speed and direction.

Differences in dolphin reactions to boats (expressed in differences in average individual surfacing rates in the absence vs presence of boats) between coastal and river habitats could be a result of habituation to noise for the last group since boat traffic was almost seven times more intensive in the river. Gordon & Moscrop (1996) suggested that dolphins either become habituated to the sound and show less response, or they show an increasing level of disturbance with exposure.

Implications for Conservation

This is the first detailed quantitative study on boat disturbances of freshwater dolphins. Boat traffic in the Mahakam River was intense with 20.7 boats per hour passing on average, and 6.5 times more frequent than in the Balikpapan Bay, with only 3.2 boats passing on average per hour. The greatest disturbers were speedboats and container tugboats. These boats were particularly dangerous as they moved in a narrow tributary representing major dolphin habitat, an area in which dolphins may experience great difficulty in evading both their physical presence and the noise produced by these vessels. When speedboats pass in confluence areas and river bends dolphin/vessel collisions can occur. Boats and their sounds may appear too suddenly and at a short distance after these bends for dolphins to avoid a collision. During this study, one juvenile dolphin was found dead with wounds thought to be inflicted by a boat's propeller. Other disturbers are the canoes with outboard engines of < 40 hp because of their high rate of trespassing and sudden changes in courses and speed.

In the river dolphins most important core area—the confluence area of Muara Pahu (Kreb, unpublished data)—boat traffic of all types discussed here was particularly intense. Besides the time that was spent to record dolphin/boat encounters (Table 1), an additional 30 observation days (from 0800 to 1800 h) was spent in this confluence area to study habitat use, where the highest density of dolphins was recorded during six periods from January 2000 to November 2001 and at different water levels. On average, three different groups (range between two and six groups) of dolphins frequented the confluence area daily for an average of 42% of observation daytime (Kreb, in press). Dolphins' continuous presence in this intensive boat traffic area does not mean that they are not disturbed, but, rather, it underlines the importance of that area to the dolphins (Brodie, 1989). Frequent interruption of dolphin feeding, resting, or socializing through active boat avoidance, disrupted echolocation signals for safe navigation and active hunting, and masking of acoustic cues to hunt passively and to locate group members for maintaining social cohesion and coordination may induce stress of which the long-term physiological effects are still unknown (Richardson et al., 1995). Prolonged exposure to sound-induced stress for terrestrial mammals reportedly has led to harmful effects in digestive and reproductive organs and similar effects are suggested to be likely for cetaceans (Gordon & Moscrop, 1996).

Another threatened area is a narrow and shallow tributary of the Kedang Pahu River, that also represents primary dolphin habitat (Kreb, in press). When container barges pass through this tributary during the dry season, they occupy three-quarters of the total river width. When dolphins encounter these boats in this limited area, they are possibly exposed to noise levels that may cause a temporary hearing threshold shift, and perhaps even permanent hearing loss. Gordon & Moscrop (1996) reported that for belugas, noise levels of 140 dB re 1μ Pa at their most sensitive frequencies are assumed sufficient to cause threshold shifts. Most dominant echolocation clicks for Irrawaddy dolphins are between 50-75 kHz (Kamminga et al., 1983), but these boats are not likely to produce noise in that frequency range. Although small cetaceans are more likely to be affected by high-speed vessels that produce high-frequency noise, the noise produced by tugboats is clearly annoying for the human ear and at least interferes with vocalizations (medium frequencies) for social communication. Similar interference likely applies to speedboats. Noise levels of ca. 142 dB re 1μ Pa by an outboard engine of 70 hp at 50-m distance were estimated in the frequency range of 400 Hz-4 kHz (Gordon & Moscrop, 1996).

From 1998 until 2001, at least two juvenile dolphins died in the Mahakam as a result of injuries due to a vessel collision, most likely with speedboats (Kreb, in press). Also, in other species, vessel collisions have been described: Damage from ship propellers reportedly accounted for 6.5% of baiji deaths (Chen Peixun, 1989). Wells & Scott (1997) documented vessel collisions between small boats and bottlenose dolphins. Young belugas were found to be less likely than adults to react to boats approaching at high speed (Richardson et al., 1995). Although our results show that dolphins generally are aware and anticipate approaching, high-speed vessels by long dives, very occasionally (1 out of 75 cases) one dolphin surfaced within 0-25-m distance of the speedboat. Startle responses also were observed if a speedboat appeared around a river bend at close range of the dolphins; they made immediate dives. Another dangerous situation occurs when dolphins were engaged in activities with many surface behaviors such as mating; on such occasions, the dolphins did not attempt to avoid fast moving vessels. Shane (1990) also stated that dolphins least commonly altered their behavior in response to boats when they were actively socializing.

Conclusions

In conclusion, Irrawaddy dolphins in the Mahakam showed significant changes in their surfacing pattern in reaction to various approaching boat types. Some likely consequences such as stress, temporary or permanent hearing loss, occasional injuries, or death by vessel collisions are serious threats to this freshwater dolphin population. A possible positive development is that there are plans to improve a previously existing but hardly used road along the river, which leads to most of the coal- and gold-mining companies upstream. Thus, road traffic may become an alternative to river traffic. An ongoing conservation program to protect important dolphin habitat was initiated by a local nongovernmental organization in cooperation with local government at the end of 2000. The conservation program also plans to place board signs for boat speed reduction in important dolphin areas in close cooperation with local residents and speedboat owners. Hopefully, in the near future, reduction of noise and physical harassment by boats will prevent displacement of dolphins from these biologically important areas.

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Literature Cited

Allen, M. C., & Read, A. J. (2000). Habitat selection of foraging bottlenose dolphins in relation to boat density near Clearwater, Florida. *Marine Mammal Science*, *16*, 815-824.

Bejder, L., Dawson, S. M., & Harraway, J. A. (1999). Responses by Hector's dolphins to boats and swimmers in Porpoise Bay, New Zealand. *Marine Mammal Science*, *15*, 738-750.

Brodie, P. F. (1989). The white whale, *Delphinapterus leucas* (Pallas, 1776). In S. H. Ridgeway & Sir R. Harrison (Eds.), *Handbook of marine mammals: River dolphins and the larger toothed whale, Volume 4* (pp. 119-144). London: Academic Press.

Buckstaff, K. C. (2003). *Effects of watercraft noise on the acoustic behavior of bottlenose dolphins,* Tursiops truncatus, *in Sarasota Bay, Florida.* Master's thesis, University of California, Santa Cruz. 41 pp.

Chen Peixun. (1989). Baiji, *Lipotes vexilifer* Miller, 1918. In S. H. Ridgeway & Sir R. Harrison (Eds.), *Handbook of marine mammals: River dolphins and the larger toothed whale*, *Volume 4* (pp. 25-43). London: Academic Press.

Fowler, J., & Cohen, L. (1990). *Practical statistics for field biology.* Philadelphia: Open University Press.

Gordon, J., & Moscrop, A. (1996). Underwater noise pollution and its significance for whales and dolphins. In M. P. Simmonds & J. D. Hutchinson (Eds.), *The conservation of whales and dolphins* (pp. 281-319). Greenwich, UK: John Wiley & Sons Ltd.

Gregory, P. R., & Rowden, A. A. (2001). Behaviour patterns of bottlenose dolphins (*Tursiops truncatus*) relative to tidal state, time-of-day, and boat traffic in Cardigan Bay, West Wales. *Aquatic Mammals*, *27*, 105-113.

Hilton-Taylor, C. (2000). 2000 *IUCN red list of threatened species.* Gland, Switzerland and Cambridge, UK: IUCN.

Janik, V. M., & Thompson, P. M. (1996). Changes in surfacing patterns of bottlenose dolphins in response to boat traffic. *Marine Mammal Science*, *12*, 597-602.

Kamminga, C., Wiersma, H., & Dudok van Heel, W. H. (1983). Investigations on cetacean sonar VI. Sonar sounds in *Orcaella brevirostris* of the Mahakam River, East Kalimantan, Indonesia: First descriptions of acoustic behaviour. *Aquatic Mammals*, *10*(1), 83-94.

Kreb, D. (1999). Observations on the occurrence of Irrawaddy dolphin, *Orcaella brevirostris*, in the Mahakam River, East Kalimantan, Indonesia. *Zeitschrift für Säugetierkunde*, *64*, 54-58.

Kreb, D. (2002). Density and abundance of the Irrawaddy dolphin, *Orcaella brevirostris*, in the Mahakam River of East Kalimantan, Indonesia: A comparison of survey techniques. *The Raffles Bulletin of Zoology, Supplement*, *10*, 85-95.

Kreb, D. (in press) *Conservation and social ecology of freshwater and coastal Irrawaddy dolphins,* Orcaella brevirostris *in Indonesia.* Ph.D. dissertation (to be published in October 2004), University of Amsterdam, Amsterdam.

Lesage, V., Barette, C., Kingsley, M. C. S., & Sjare, B. (1999). The effect of noise on the vocal behavior of belugas in the St. Lawrence River Estuary, Canada. *Marine Mammal Science*, *15*, 65-84.

MacKinnon, K., Hatta, G., Halim, H., & Mangalik, A. (1997). *The ecology of Kalimantan* (The Ecology of Indonesia Series 3). Oxford, UK: Oxford University Press.

Mann, J. (1999). Behavioral sampling methods for cetaceans: A review and critique. *Marine Mammal Science*, *15*, 102-122.

Nowacek, S. M., Wells, R. S., & Solow, A. R. (2001). Short-term effects of boat-traffic on bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. *Marine Mammal Science*, *17*, 673-688.

Richardson, W. J., Greene, C. R., Jr., Malme, C. I., & Thomson, D. H. (1995). *Marine mammals and noise*. San Diego: Academic Press.

Shane, S. H. (1990). Behaviour and ecology of the bottlenose dolphin at Sanibel Island, Florida. In S. Leatherwood & R. R. Reeves (Eds.), *The bottlenose dolphin* (pp. 245-265). London: Academic Press.

Siegel, S., & Castellan, N. J., Jr. (1988). *Non-parametric statistics for the behavioral sciences* (2nd ed.). New York: McGraw-Hill Book Company.

Smith, B. D. (1993). 1990 status and conservation of the Ganges river dolphin *Platanista gangetica*, in the Karnali River, Nepal. *Biological Conservation*, *66*, 159-169.

Stacey, P. J. (1996). *Natural history and conservation of Irrawaddy dolphins,* Orcaella brevirostris, *with special reference to the Mekong River, Lao P.D.R.* Master's thesis, University of Victoria, BC, Canada.

Stacey, P. J., & Arnold, P. W. (1999). *Orcaella brevirostris*. *Mammalian Species*, *616*, 1-8.

Van Parijs, S. M., Parra, G. J., & Corkeron, P. J. (2000). Sounds produced by Australian Irrawaddy dolphins, *Orcaella brevirostris. Journal Acoustical Society of America*, *108*(4), 1938-1940.

Wells, R. S., & Scott, M. D. (1997). Seasonal incidence of boat strikes on bottlenose dolphins near Sarasota, Florida. *Marine Mammal Science*, *13*, 475-480.

Zhou, K., & Li, Y. (1989). Status and aspects of the ecology and behaviour of the baiji, *Lipotes vexilifer*, in the Lower Yangtze River. In W. F. Perrin, R. L. Brownell, Jr., K. Zhou, & J. Liu (Eds.), *Biology and conservation of the river dolphins* (Occasional Papers of the IUCN Species Survival Commission, 3) (pp. 86-91). Gland, Switzerland: IUCN.

Living Under an Aquatic Freeway: Effects of Boats on Irrawaddy Dolphins (Orcaella brevirostris) in a Coastal and Riverine Environment in Indonesia. Article. Dec 2004. Danielle Kreb. Karen D. Rahadi.Â Both coastal and freshwater Irrawaddy dolphins surfaced less in the presence of boats, but the avoidance reaction lasted longer for the river dolphins. River dolphins surfaced significantly less often in the presence of motorized canoes (1,000 hp). Coastal dolphins only reacted to speedboats, and only when they approached at a 50-m distance. River dolphins reacted within a maximum distance of 250 m before and 300 m after a speedboat passed. Besides surfacing changes, river dolphins actively avoided container tugboats. Irrawaddy dolphin Orcaella brevirostris in the Cambodian Mekong River: an initial survey. Ian G. Baird and Isabel L. Beasley. Abstract Irrawaddy dolphins Orcaella brevirostiris are found in coastal waters from the Bay of Bengal east to Palawan, Philippines and south to northern Australia. They also occur in three large tropical river systems in South-east Asia: the Mekong, Mahakam and Ayeyarwady.Â Boats moved at moderate and variable speeds while out of potential dolphin habitat (determined from interview data). When in suspected dolphin habitat (such as deep water pool areas), boat engines were stopped. 4. D. Kreb K.D. Rahadi: "Living Under an Aquatic Freeway: Effects of Boats on Irrawaddy Dolphins (Orcaella brevirostris) in a Coastal and Riverine Environment in Indonesia" Aquatic Mammals Vol. 30 No. 3 pp. 363-375 2004. 5. H. Sugimatsu T. Ura J. Kojima S. Hiryu R. Bahl S. Behera A. Pattnaik I. Mandan S. Tomuro D. Kreb: "Development and deployment of the long-term in-situ observation system of the Irrawaddy dolphins (Orcaella brevirostris) in Borneo" Proc. UT13 Tokyo Japan March 2013.