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Habitat use and behaviour of Irrawaddy Dolphins (*Orcaella brevirostris*) in the Mekong River of Laos

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Abstract

This field study addressed a number of natural history parameters of Irrawaddy dolphins (*Orcaella brevirostris*) in the Mekong River of Laos that were not well-documented, including diving behaviour, foraging ecology, habitat use, social behaviour, group size, and diurnal movements. Irrawaddy dolphin sightings were most common in the morning and decreased throughout the day. This could indicate diurnal feeding, given that foraging is suggested by repeated direction changes, lack of through travel, and observed fish consumption. Habitat use was highest off the tributary mouth and adjacent Sandy Island. Mean water depth at the study site was 18.4 m, current speed of the main channel was 0.15 m/s, and water temperature was 31°C. Mean dive duration of dolphins was 115.3 s and similar for all group sizes. When no boats were within 100 m of dolphins, mean dive duration was significantly shorter than when boats were present. The longest dive times occurred in the shallowest and the deepest water. There was no significant relationship between surface direction or group cohesiveness and dive duration. The mean number of respirations per dolphin on each surface run was 1.96, and did not change with boat presence. The average dolphin group size was 3. There was no significant relationship between group cohesiveness and boat type or speed. Discrete surface activities occurred on 14% of surface runs and neither boat speed or the distance dolphins surfaced from boats were associated with the presence of these surface activities. These activities occurred most frequently in shallower water, especially in one area away from the tributary mouth. Dolphins tended to surface closer to paddle boats than to large boats. Of over six hundred photographs taken, only 11 were of sufficient quality to identify individuals. Two animals, and tentatively up to six, could be identified.

The conclusions of this study must be placed into the context of the limited time and space over which the research was conducted. Irrawaddy dolphin behaviours and environmental interactions observed are likely site- and time-specific, especially in this dynamic habitat. This study provided a portrait of Irrawaddy dolphins that is far from complete, but is an example of baseline research that is needed before being able to progress to question-oriented studies. Long-term, in-depth observations over a larger area are needed.

Key words: Irrawaddy dolphin, *Orcaella brevirostris*, Mekong River, Laos, habitat use, behaviour, vessel interactions.

Introduction

Irrawaddy dolphins (*Orcaella brevirostris* Owen in Gray, 1866) occur in the tropical-subtropical Indo-west Pacific (Stacey & Arnold, 1999). The species is found in various habitats, including shallow coastal, freshwater lake, and Ayerawady (Irrawaddy), Mahakam, and Mekong River systems. Little is known about the life history of Irrawaddy dolphins, and they are classified as "data deficient" by the World Conservation Union (Hilton-Taylor, 2000). As a result, the World Conservation Union's Cetacean Specialist Group recommended research on the status and conservation of the Irrawaddy dolphin in southern Asia as a priority for attention and funding (Reeves & Leatherwood, 1994). The International Whaling Commission's Sub-committee on Small Cetaceans recommended studies on Irrawaddy dolphins in Laos, with particular emphasis on distribution, abundance, genetics, and toxicology (International Whaling Commission, 1994).

Irrawaddy dolphins are known to occur in the Mekong River of southern Laos, from Khone (Leepee) Falls to the Cambodian border (Baird *et al.*, 1994). The Khone Falls, found 3 km upstream (west) from the village of Hang Khone, acts as a barrier to further movement up river. Only one record of Irrawaddy dolphins above Khone

Falls has been obtained from interview surveys (Baird & Mounsouphom, 1994). In Laos, Irrawaddy Dolphins also have been reported to occur in the Sekong, Sekhaman, Sesou, Sepian, and Sekampoh Rivers and tributaries, and from the Houay Twai and Houay Khaliang streams (Baird *et al.* 1994).

The study site, the Mekong River along the Lao/Cambodian border, was chosen for its history of reliable sightings during the dry season. Three research questions directed this study: (1) What is the spatial distribution of the dolphins in the study area?, (2) How does this correspond with dominant habitat features?, and (3) How do dolphin behaviours correspond to habitat features and boat presence? Thus, this study presents information about respiration rates, surface behaviours, diurnal behaviour, habitat use, group characteristics, and behaviour around boats.

Cetacean respiration rates can provide information for census surveys (Leatherwood *et al.*, 1982), and indicate feeding (Kopelman & Sadove, 1995) or behavioural states (Chu, 1988). Surface behaviours also can be indicative of behavioural states. Diurnal activities are an important consideration in population assessments (Bräger, 1993). Descriptions of habitat and habitat use are important for conservation purposes (Stacey & Leatherwood, 1997). Group characteristics provide insights into social and ecological relationships. Dolphin responses to boats will assist in evaluating the potential impact from ecotourism, such as dolphin-watching. Laos is targeting ecotourism in development plans (Laird, 1993), and a small dolphin-watching operation already exists at the study site (Baird, 1994).

Materials and Methods

As the Mekong River flows from southern Laos into Cambodia, it delineates the border between the two countries for about 5 km before continuing through Cambodia towards the South China Sea. Along this stretch of river are several fishing villages, including the Lao villages of Hang Khone (1993 human population of 222) and Hang Sadam (human population of 386), situated at either end of a deep-water area on one of the main channels of the Mekong (Fig. 1). About 90% of the families engage in fishing as their primary occupation (I. G. Baird, pers. comm.). The widening of the river channel into a deep-water pool, with a width of 100–600 m, is locally called Boong Pa Gooang (13°56′N, 105°56′E) and comprises the study site. The Lao/Cambodian border runs through the middle of this pool. The water flows from the north and west, through a maze of channels, toward the south. The villages of Hang Khone and Hang Sadam have established a no-fishing reserve between the islands found in quadrats 13, 14, 21, and 22 (Fig. 2). Due to the political situation in this border area, opportunities to travel up- and down-river or to venture across the border at the study site into Cambodia were limited. For this reason, much of the data were collected from the Lao shore.

In this area, dolphins are seen daily during the dry season (December May, with lowest water levels in April) and less frequently during the wet season (June November, with highest water levels in August September; Pantulu, 1973; Baird *et al.*, 1994). Presumably, the deep-water pools are most important to dolphins during the dry season. Nearby, at Kratie, Cambodia, water flow increases from 1764 m^3/s in the dry season to 52 000 m^3/s in the wet season, and average current velocities increase from 0.2 m/s to 1.4 m/s (Pantulu, 1973).

Based on two preliminary visits to the study site in 1993, data were collected from March 25 to April 21, 1994, during the dry season. To identify the location of dolphins and vessels, we made daily observations from shore using a field map of the study site, divided into 46, 100 m^2 quadrats (Fig. 2). Although there are difficulties in estimating locations and distances visually from shore, the estimates were assisted by reference points (e.g., islands, points of land, fishing buoys) and previous calibration exercises with a tape measure on shore. Data collection was undertaken from the balcony of a house along the bank of the Mekong River, on the outskirts of the village of Hang Sadam. The house was approximately 15 m above the water level of the main river channel about 100 m from the bank during this low-water season. The main channel of the Mekong River flows through the study site from west to east.

To understand habitat, during 30–31 March, two depth measurements (to the nearest cm) were taken in each quadrat in the Lao part of the study site. At the same time, we lowered a thermometer to a depth of 1 m to determine water temperature. The water current was measured by the rate of drift of a large tree stump and small sticks. We made notes on the physical and biotic features of the riverbank to provide a further description of habitat.

One or two people scanned the study site every 5 min using binoculars (either Nikon 8 × 35 or Swift 8.5 × 44). Village residents sometimes informally joined in the search. We recorded degree of cloud cover and water surface conditions, regardless of dolphin presence, at the beginning of the observation period, every hour on the hour thereafter, and when we noticed a marked change in conditions.

We defined a group of dolphins as animals not more than 100 m from another dolphin. At times, there was more than one group in the study area. If

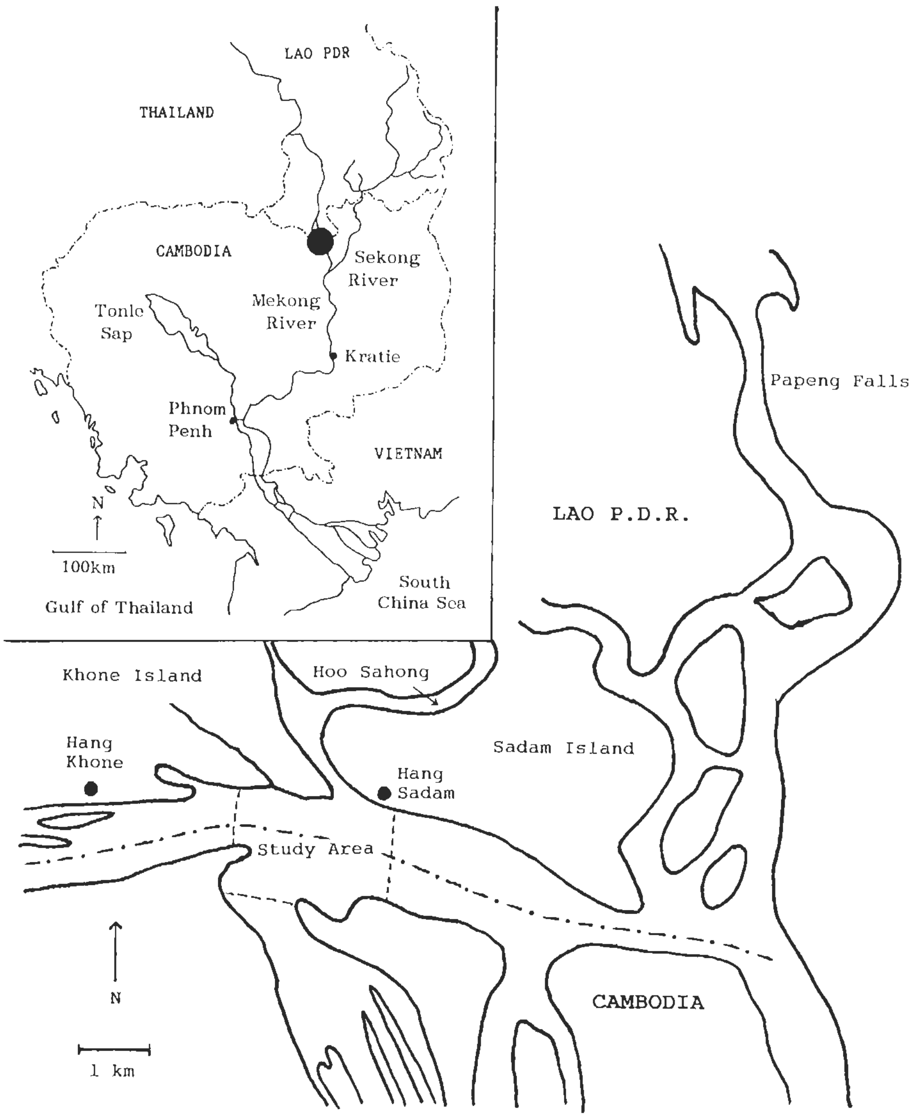

Figure 1. Map of study area in southern Laos.

groups were too far apart to observe simultaneously, we collected detailed data on the closest group, and general information about the other(s). A 'new group' was designated when the number of animals in the group changed, or when a group of animals reappeared after being out-of-sight for more than 10 min. Dolphins typically surfaced 2 or more times in quick succession as a group and then dove for a longer duration. The period between dives was defined as a surface run. The unit of analysis was a surface run followed by a dive. Since we could not distinguish dolphins, and thus could not measure individual dive duration, instead we measured group dive duration, the time from the disappearance of the last dolphin to the emergence of the first after a dive.

When dolphins were detected, one person observed with binoculars while the second recorded information. The location was defined as the quadrat where the majority of the dolphins in the group surfaced. Using a digital watch, the time to the nearest second of each dolphin's surfacing was recorded. A typical surfacing involved the appearance of the top of the head and blowhole followed in a rolling motion by the back and dorsal fin. Activities other than typical surfacings were noted.

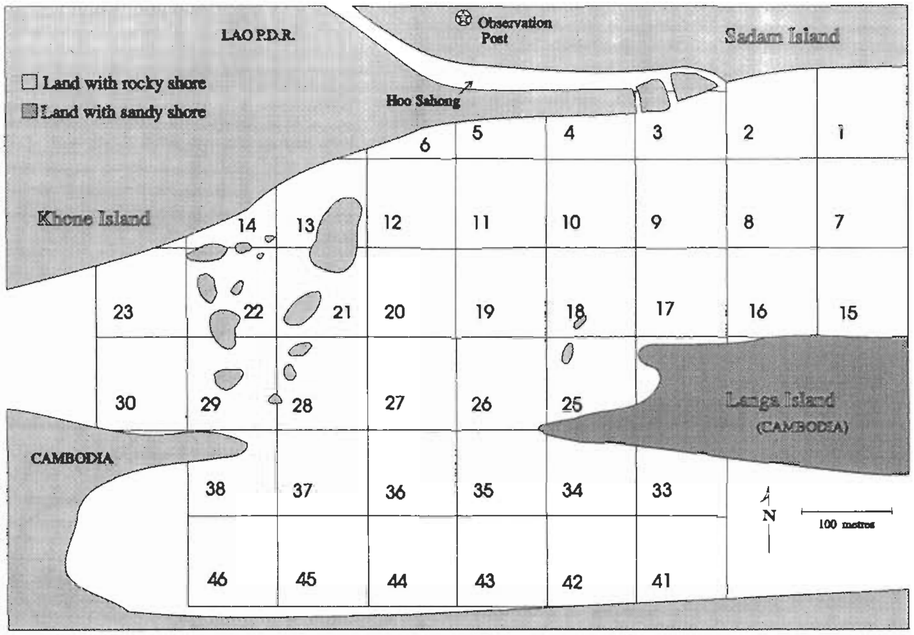

Figure 2. Study area in southern Laos showing numbered quadrats and habitat description.

We also recorded direction of travel, group size, cohesiveness, and whether all respirations were accounted for within each surface run. If a vessel came within 100 m of any dolphin, we recorded the time when the two were 100 m apart, the boat type, estimated speed, and the time when the vessel was 100 m away again. Attempts were made to photo-identify individual dolphins (Appendix I).

Using SPSS, the data set included the following variables: record identification number; date, cloud cover, wind speed, group identification number, group size, time first animal in group surfaced after dive, quadrat, direction, cohesiveness, time last animal in group submerged for dive, number of surfacings during surface run, calculated dive length, boat type (if present), boat speed, whether or not dolphins surfaced within 100 m of boat, and list of surface activities. Correlations between group characteristics, habitat parameters, vessel traffic, surface activities and diving were statistically analysed. Most analyses employed chi-square test or One-way Analysis of Variance. Results were considered significant at $P<0.05$.

Although most of the ANOVA assumptions (i.e., a random sample from a normal population and the variances of the groups are equal- -Norusis, 1993) are met, all samples (i.e., the surface runs and groups of dolphins) are not independent. However, the potential for temporal autocorrelation, the probability that the occurrence of a behavior at one point in time will affect its likelihood of being observed at the next point of time, can be reduced by increasing the time interval between data counts (Crockett, 1996). The interval at which independence can be assumed varies with species and behavior, and ranges from 1 min for gelada baboons (Slatkin, 1975), 4.5 min for yellow baboons (Slatkin, 1975), 10 min for ungulates (Stanley & Aspey, 1984), to 15 min for brown capuchin monkeys (Janson, 1984). By comparison, the time interval between observations of dolphin groups, the first unit of analysis, was usually more than 30 min, but the time interval between surface runs, the second unit of analysis, averaged about 2 min. Thus, the statistics reported here involving surface runs should be used as indicative measures, not as conclusive evidence of correlations. We could not use repeated measures ANOVA because we could not match individual dolphins or groups of dolphins from one sighting to the next.

Results

Habitat description

Fifty-six measurements (of 28 quadrats on the Lao side) of water depth ranged from 5.0 to 35.4 m with a mean depth of 18.4 m. Water temperature was consistently 31°C. The current speed in the main channel in the study area was 0.15 m/s and 0.75 m/s for the Hoo Sahong Channel. About 70% of the shoreline (excluding the small islands) was solid rock with sparse vegetative cover in small pockets

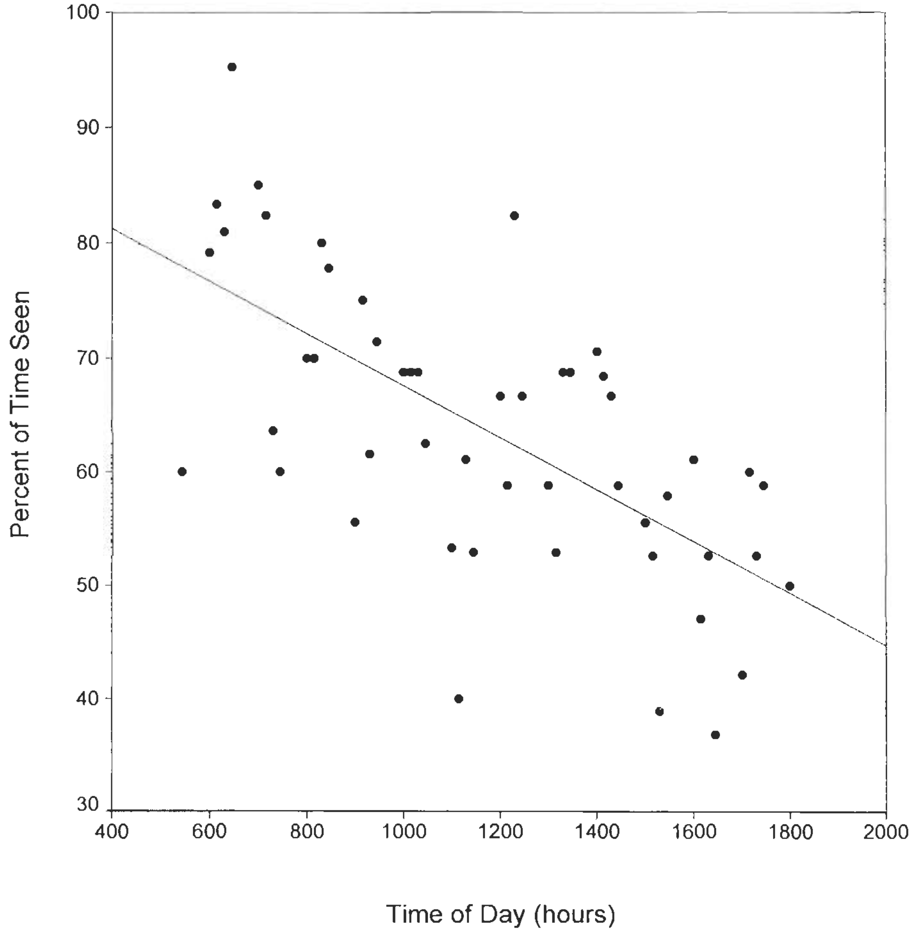

Figure 3. Sighting frequency of Irrawaddy dolphins by time of day in the Mekong River of southern Laos (including line of best fit).

of sand (Fig. 2). The remaining 30%, along Langa Island, was sandy, with no vegetation along the present water-line. In both habitats at the height of the rainy season, the water level extended up to or beyond the shrubs and trees growing higher along the river bank.

Dolphin occurrence

We observed the study site for 211 h over 26 days and dolphins were present 52% of the time (range per day=16.2 96.2%, SD=21.7%). We recorded 2333 surface run/dive sequences by 251 groups of dolphins. To determine sighting frequency, daylight hours were broken into 15-min blocks, beginning at 0545h and at 1815h. Surface run (i.e., sighting frequency) decreased from dawn to dusk (Spearman's rho = −0.678, $P<0.001$, R = 0.66; Fig. 3).

Habitat use

On 44 occasions, we were able to determine from which direction, upstream or downstream, dolphins entered the study site. They arrived from downstream in 39 instances (89%) and from upstream on five occasions (11%). On departing from the study area, dolphins swam downstream on 21 occasions (55%) and upstream 17 times (45%). Only once did dolphins enter the study area from one direction (downstream) and continue steadily across the study site (disappearing upstream). On the two occasions when we observed dolphins in the Hoo Sahong Channel, they did not venture far up the channel, instead remaining within sight until they returned to the main river.

To examine the spatial patterns of habitat use, we calculated the total number of surface runs seen for each quadrat. To compensate for unequal quadrat

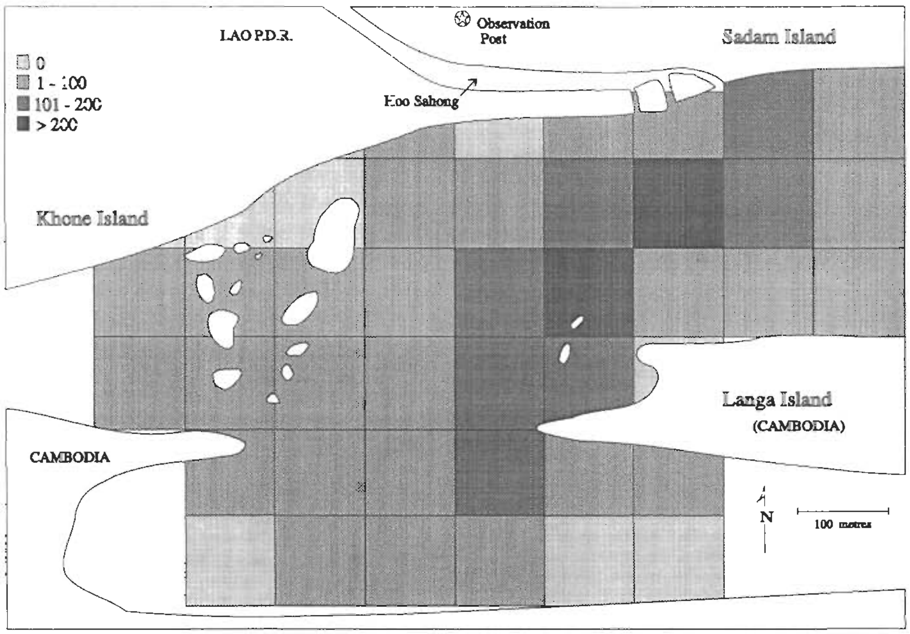

Figure 4. Irrawaddy dolphin use of the study area (number of surface runs).

sizes, we multiplied the number of surface runs in partial quadrats by the percentage of the full quadrat area. The average number of surface runs per quadrat was 58.2 (n=41; range: 0–300; SD=82.5; Fig. 4). The most used quadrats span the main river from near the channel mouth (rocky shore) to Langa Island (sandy shore). The number of surface runs per quadrat was not significantly correlated to depth, but dolphins were seen more than expected in depths of 5–24.9 m, and less than expected in depths >25 m.

Dive duration and respiration rates

We calculated the duration of 277 group dives. The mean dive duration was 115.3 s (SD=59.1, range=19 s to 7 min 11 s). Mean dive duration did not vary by group size. Mean dive duration was significantly longer (142.0 s) when boats were within 100 m than when boats were not present (110.6 s; $F=10.17$, $df=1$, $P=0.002$). Sample sizes were inadequate to test for differences between boat types or speeds. To put this in context, paddle boats were within the study area a mean of 12.03 min per boat, compared to only 2.47 min for small motor boats. Paddle boats were in the study area 89% of the time, and small motor boats were within 23%. About 4.5 paddle boats and 5.5 small motor boats per hour were within or passed through the study area.

To analyse the relationship between dive duration and water depth, categories of <10 m, 10–19.9 m, 20–29.9 m, and >29.9 m were established. The longest dive times were in the shallowest and deepest waters ($F=2.66$, $df=3$, $P=0.049$). A Tukey's-B multiple comparison test found a significant difference in dive times between water depths of <10 m and 20–29.9 m. Surface direction (north, south, east, west or non-directional) and group cohesiveness (distance between any dolphins: <1 m, 1–3 m, 3–10 m, 10–50 m, and 50–100 m) were not correlated with dive duration.

The mean number of respirations per dolphin on each surface run was 1.96. The respiration rate did not vary significantly with boat presence, the distance dolphins surfaced from boats (between 50–100 m or <50 m), or water depth.

Group size and cohesiveness

Group size ranged from 1 to 7, with a mean of 3.02. However, there was one group of about 17 dolphins at the study area seen on an initial visit. Group cohesiveness was not correlated with boat type (paddle, small motor, or large motor) or boat speed (slow, medium, or fast).

Swimming and foraging behaviour

Dolphins surfaced parallel to the river flow (frequency: east=479, west=506) more often than perpendicular (frequency: north=19, south=50). They surfaced in more than one direction on 39% of the 1719 surface runs. We saw no repeated pauses on the surface or slow swimming in a manner that

Table 1. Surface activities of Irrawaddy dolphins in the Mekong River of Laos, March–April, 1994.

Activity	Number of occurrences
Pectoral fin wave	181
Unidentified splash	155
Spitting water	111
Tail wave	79
Surface with most of head showing	48
Pectoral fin slap	33
Leap part way out of water	32
Sideways roll	19
Pause at surface	16
Tail slap	15
Slow surfacing	15
Bubble blowing	12
Fast surfacing	10
Spyhop	4
Breach	3
Body contact with another dolphin	2

would suggest resting. Dolphins tended to surface closer to slow boats more often than fast ones ($X^2=9.98$, df=2, $P=0.007$), but there were no difference between paddle boats and large motor boats.

Typical surfacings were interspersed with discreet surface activities such as tail slapping, rolling sideways, splashing, and spitting water (Table 1). These activities occurred on 14% of surface runs. The occurrence of one or more surface activities during a surface run was not associated with the presence or absence of boats. However, there were fewer than expected occurrences of surface activities when large motor boats were within 100 m and there were more than expected surface activities when dolphins were in the company of paddle boats ($X^2=11.69$, df=2, $P=0.003$). Neither boat speed (slow, medium or fast) or the distance dolphins surfaced from boats (<50 m or 50–100 m) were associated with the presence of surface activities. There were significantly more occasions of surface activity after shorter dives than longer ones (using five categories of dive time; $X^2=18.37$, df=4, $P=0.001$). More surface activities than expected occurred in water ≤ 10 m deep than in water >10 m deep ($X^2=16.32$, df=3, $P<0.001$). Three quadrats (33, 34, and 43) had the highest rates, where 30–47% of surface runs contained one or more surface activities (Fig. 5).

On two occasions, fresh fish parts (a head and a swim bladder) were recovered from the vicinity of the dolphins. The fish head was identified by a local researcher as a carp, pha mak ban (*Cosmochilus harmandi*; I. G. Baird pers. comm.), a species found

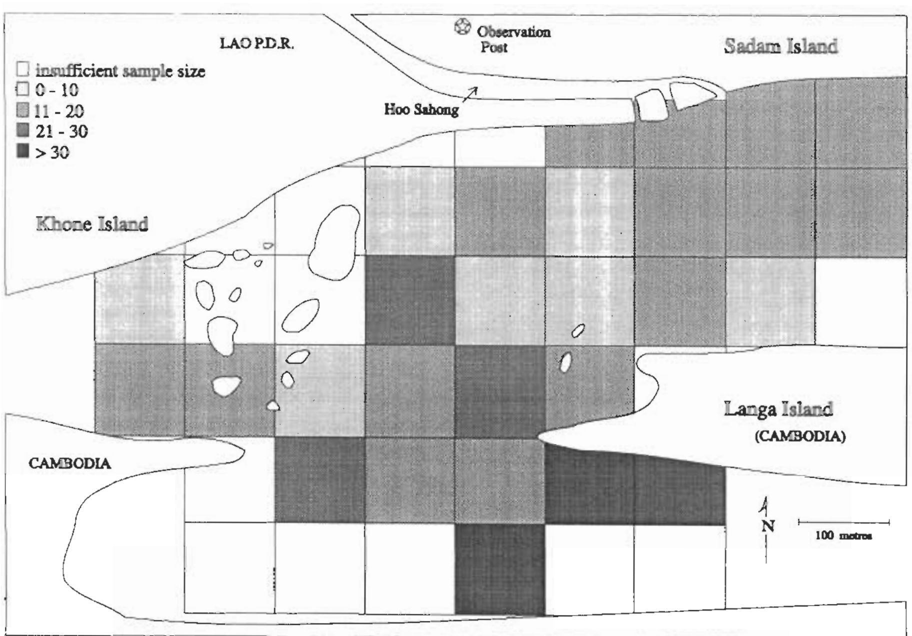

Figure 5. Percentage of surface runs during which surface activities were displayed by Irrawaddy dolphins.

locally in a study by Roberts (1993). Villagers said the species is common year-round. The fish head included the large dorsal spine and weighed 330 g. Numerous fish heads of several species have been similarly retrieved by local residents (Baird & Mounsouphom, 1994). The swim bladder was dragged around (intentionally or perhaps still attached to the fish being consumed) by the dolphin for several minutes before it was found floating freely. River terns (*Sterna aurantia*) were seen daily, hovering above the dolphins, sometimes swooping down to collect scraps from the water surface.

Discussion

Daily and seasonal movements

Irrawaddy dolphins were seen daily in this study, most often in the early hours, with a decrease in their presence towards evening. Tas'an & Leatherwood (1984) also found diurnal movement patterns for Irrawaddy dolphins in the Mahakam River in Indonesia. Other cetaceans exhibit diurnal movements and behaviours, although the extent to which these are regulated internally or by their prey species, which also could have marked diurnal rhythms, is unclear (Klinowska, 1986). The diurnal feeding patterns of other cetaceans vary by species, season, habitat, and prey type (e.g., Best & da Silva, 1989; Hua *et al.*, 1989; Bräger, 1993). If the study area is important for foraging, the use pattern of the area could suggest diurnal feeding. While observer fatigue cannot be ruled-out as an explanation for this decrease, we believe this to have had negligible impact because dolphins were sighted easily. Other factors that could have affected sighting frequency (e.g., water surface conditions, cloud cover, vessel traffic) did not have a similar daily trend. Since only a portion of the dolphins' daily range was surveyed, it is difficult to make conclusions on their full-scope of behaviours and movement patterns. Resting, travelling and social behaviour could have taken place in habitats upstream or downstream that were used preferentially later in the day.

Irrawaddy dolphins are present year-round in the Mekong River, and become less common at the study site during the high water season (Baird & Mounsouphom, 1994). Irrawaddy dolphins appear to spread-out over a larger area during high water, making use of the new habitat available, and possibly following prey species into larger tributaries (e.g., Sekong River; Baird & Mounsouphom, 1994). Both daily and seasonal movement patterns are important to consider in designing sighting surveys and comparing research results because they could vary significantly at different times of the day or year.

Habitat use

Dhandapani (1992) described the habitat of the Irrawaddy dolphin in India as rivers, estuaries, backwaters, brackish water lagoons, and mangrove creeks. This characterisation holds true for the rest of its range as well. While Irrawaddy dolphins are reported to remain within about 1.6 km of the coast (Morzer Bruyns, 1966; Dawbin, 1972), they are known also from waters further than 5 km from shore in the Gulf of Thailand (M. Andersen, pers. comm.). In the Mahakam River of Kalimantan, Indonesia, Kreb (1999) found Irrawaddy dolphins most often in areas of medium to low water levels, and in tributaries. In the lower Mekong River, preferred habitats near sandbars were at the confluences of lakes, rivers and streams (Lloze, 1973). Large, deep pools are inhabited by Irrawaddy dolphins further up the Mekong in Laos and Cambodia, especially in the dry season (Baird *et al.*, 1994).

The maximum depth measured at the study site, 35.4 m, is in-line with the depths suggested by Tana (1995) and Pantulu (1973). Baird & Mounsouphom (1994) reported that villagers in Laos and Cambodia have identified five deep-water pools between Kratie and the Lao border, where dolphins live in considerable numbers, especially in the dry season. The water temperature at our study site, 31°C, is slightly higher than other water temperature reported for Irrawaddy dolphins, of 25 to 30°C (Morzer Bruyns, 1971).

Other studies suggested shallower water depths for Irrawaddy dolphin. Depths of 2.5–18 m were preferred in the Gulf of Carpentaria, Australia (Freeland & Bayliss, 1989), 3.5–12 m in the Mahakam River (Tas'an *et al.*, 1980), and 6–18 m in other unspecified areas (Morzer Bruyns, 1966). In this study, 12% of surface runs were in water 10 m and 48% were in depths of 10–20 m. Water depth preference likely differs considerably with the specific habitat and environmental conditions.

While collecting data, we noticed a high level of use at the tributary mouth, especially around a floating marker signifying one end of a fixed gillnet (Fig. 4). This is likely an area of high productivity due to water mixing. This area of high use extends across the river to the tip of the sandy Langa Island, perhaps a similar environment to the sandbars mentioned in other studies. According to the headman of Hang Sadam, dolphins used to be seen more often near the channel mouths. It is important to keep in mind the dynamic nature of the habitat and that the measurements taken during this study are temporally specific, as are dolphin behaviours and patterns of dolphin and vessel use of the area.

More information about water depth and the relative dolphin use of the habitat could help the community to enhance their conservation plans. As dolphin use of the current no-fishing reserve is low, this reserve may not contribute to minimizing dolphin incidental catch, a concern outlined in Baird *et al.* (1994) and Stacey & Leatherwood (1997). To enhance dolphin conservation through these reserves, the communities could alter the boundaries of the current reserve or add further reserves.

Group size

There are several advantages of group living, including more efficient foraging, feeding, and predator avoidance, and access to breeding opportunities and social relationships. Group sizes differ between seasons, depending on the prey being pursued (Würsig & Würsig, 1979). In this study, relatively small group sizes were normal, while aggregations occur periodically, likely in response to environmental changes such as prey density or social factors. The group sizes reported for this study do not imply a social group, since group size was defined spatially, by the observed distance between dolphins. The group size and function from the point-of-view of the dolphins cannot be ascertained, because sounds or other interactions could have occurred that were not detected.

This mean group size was similar to Irrawaddy dolphins in other locations. In the Chilka Lake and Mahakam River, group sizes were <10, and usually 1 4 (Annandale, 1915, Tas'an *et al.*, 1980). In the Van Diemen Gulf area of northern Australia, the mean group size was 1.6 while that in the western Gulf of Carpentaria, was 1.9 in the dry season and 1.8 in the wet season (Freeland & Bayliss, 1989). In the Ayeyarwady River, the mean group size was 3.5 (Smith *et al.*, 1997).

Diving characteristics

Comparisons of dive time was difficult without knowledge of the behavioural state of the dolphins and environmental conditions. There are no previous field studies documenting Irrawaddy dolphin dive durations in the wild; however, S. Leatherwood (pers. comm.), on a visit to a Thai oceanarium, recorded Irrawaddy dolphins diving for up to 5 min 20 s (compared to the maximum of 7 min, 11 s for group dive duration in this study; individual dive duration would be slightly longer).

Very likely, foraging is an important behavioural variable that influences dive time. Foraging activities (searching for, pursuing, and capturing prey) of aquatic mammals are largely carried-out while diving. In general, long dives are associated often with foraging, and shorter dives with resting or other activities (Würsig & Würsig, 1979). In deep water, cetacean foraging dives can be limited by the breath-holding capability of the animal. Group size, which may relate to foraging activities, as discussed earlier, did not correlate with length of dives.

Dive durations are an important component in calculating cetacean population estimates based on sighting surveys, and can vary with time of day, season, location, environmental conditions, group size and composition, and presence of vessels (Leatherwood *et al.*, 1982). Respiration patterns also could vary with activities and be used to categorize behavioural states. The information on dive durations and surface patterns will be valuable baseline information for use during sighting surveys, until more site-specific information can be obtained in areas under investigation.

Foraging and swimming behaviour

Based on the dolphins' pattern of spending extended periods of time in the relatively small area, repeated direction changes, and the lack of through travel, we believe the study site was used almost exclusively for foraging during daylight hours. Repeated dives in varying directions in one general location have been attributed to foraging in other studies (Shane, 1990).

In the dry season, small migratory cyprinid fish are caught in abundance by villagers at the study site (Baird & Mounsouphom, 1994). Villagers believe these are important in the diet of Irrawaddy dolphins and report that dolphins often eat the lower portions only of larger fish, leaving the dorsal and pectoral spines behind. Baird & Mounsouphom (1994) suggested that Irrawaddy dolphins follow the cyprinids swimming downstream at the beginning of the wet season. Villagers reported that fish leave the tributaries and return to the mainstream Mekong when the water levels begin to go down, at the same time that dolphin sightings in the main river become more frequent (Baird & Mounsouphom, 1994). We saw dolphins in the Hoo Sahong Channel for the first time on 16 April 1994, which, according to Hang Sadam's headman, is the day that the migration of *Pangasius spp.* began.

Besides the fish head and swim bladder, we saw one other incident that strongly suggested foraging. In proximity to where two dolphins had been surfacing, a fish approximately 30 cm in length jumped through the air in an arc. Seconds later, one dolphin surfaced very quickly where the fish had landed. The headman of Hang Sadam suggested that dolphins could not feed successfully on their own, and therefore usually were seen in groups. He believed that spitting water, as we frequently observed during the study, is associated with feeding. Marsh *et al.*, (1989) reported that Irrawaddy dolphins and belugas (*Delphinapterus leucas*) expel water from their mouths in a coherent column, unlike the more diffuse spitting by other odontocetes. Villagers also suggested that Irrawaddy dolphins chase fish into nets, and thus help the fishers. This type of cooperative fishing with Irrawaddy dolphins was described in the Ayeyarwady River, Myanmar, by Smith *et al.* (1997).

Activities that take place on the surface of the water also help interpret the animals' overall behavioural state. Some dolphins exhibit considerable surface and aerial behaviours in conjunction with feeding and socializing (e.g., Würsig & Würsig, 1979, Norris & Dohl, 1980). In this study, dolphins showed more instances of surface activity after short dives, rather than long dives, when they may have been feeding. Surface activities were seen most often in the shallower areas. Whether shallow water was preferred for socializing, or whether socializing would take place when feeding was relatively unproductive (as perhaps is the case in shallow water) cannot be determined from this study. In Chilka Lake, Irrawaddy dolphins swam frequently onto a sand bar at the edge of the lake and rolled around in shallow water. They moved to deeper water if there was any disturbance on shore (Annandale, 1915). Morzer Bruyns (1971) observed one Irrawaddy dolphin in a group jump clear of the water.

Dolphins surfaced an average of 2 times between longer dives of an average duration of 115.3 s. Surface activities were recorded on 14% of group surface runs. Other researchers described the surfacing behaviour of Irrawaddy dolphins. Baird & Mounsouphom (1994) said that Irrawaddy dolphins in Laos surfaced 3–4 times in succession, then dove for 30–60 s. Morzer Bruyns (1971) described the dolphins as breathing two, three or five times every 10 s, following a deep dive of 20–70 , or sometimes up to 3 min. He reported that they travel a few hundred metres to almost 1 km per deep dive and are usually quiet, requiring vigilance to be seen.

Dolphin/vessel interactions

Blane & Jaakson (1994) summarized several cetacean responses to boats i.e., reduced feeding, disruption of social groupings, shortened surfacings, displacement from feeding areas, and avoidance of high speed fishing boats. Among river dolphins, impacts have been reported for the Ganges River dolphin (*Platanista gangetica*; Smith, 1993) and Baiji (*Lipotes vexillifer*; Zhou & Li, 1989). Cetacean dive duration has been used in other studies as an indicator of disturbance from boats. Beluga dive time was longer in the presence of boats (Blane & Jaakson, 1994). However, blow intervals of fin whales (*Balaenoptera physalus*), were shorter in the presence of boats (within 0.25 km) than when boats were absent (Stone *et al.*, 1992).

In this study, three indicators suggested potential short-term impact. First, when boats were within 100 m of dolphins, mean dive durations were significantly longer than when boats were absent. Second, dolphins tended to surface closer to paddle boats than to large motor boats. Third, there were fewer than expected occurrences of surface activities when large motor boats were within 100 m, and more than expected in the presence of paddle boats (however, this difference could result simply from paddle boats, due to their slow speed, spending more time in the presence of dolphins). Krebs (1999) found that Irrawaddy dolphins always moved away from a motorized research vessel. We believe that large motor boats, used to tow logs and transport people, were the most disruptive to dolphin behaviour patterns. These boats were not seen often, but there is potential for increased traffic related to logging activities. Potential vessel disturbance of dolphins may have a seasonal component if dolphins, as suspected, spend more of their time in the rainy season in smaller tributaries and in the flooded forest, presumably away from heavy vessel traffic. Dedicated dolphin watching trips would likely not be undertaken during the rainy season, when dolphins are harder to find and the increased current flow makes navigation difficult.

The village of Hang Khone had 10 motor boats and about 30 paddle boats at the time of the study. Villagers explained that dolphins used to come close to paddle boats, but have become scarcer in general since the arrival of power boats in 1987, and do not generally surface near them. According to the headman of Hang Sadam, Irrawaddy dolphins will only enter the Hoo Sahong Channel to feed if there are few boats present, especially motor boats. He added that motor boats have negatively affected dolphins, but generally, dolphins avoid them.

Quantifying cause and effect relationships between the presence of boats and cetacean behaviour is difficult. The narrow temporal and spatial scope of this study added to the challenge. The study area appeared to be used primarily for foraging and perhaps socializing; vessel impacts could be different when dolphins rest, travel, or use a different foraging habitat. Seasonal differences could exist, especially given the dynamic nature of this habitat. The methods of data collection also had shortcomings. Boats were only recorded as being present if they were within 100 m, dive durations could not be measured for individuals, and because boats, especially motor boats, travel quickly through the study area, there was little time to ascertain the interactions. While vessels cause some short-term impacts, we do not know if they will result in long-term consequences (e.g., feeding efficiency); such assessments require detailed long-term studies.

Plans for boat use and dolphin-based tourism will benefit from several findings. Guidelines to minimize impacts should be based on results about dolphin behaviour in proximity to boats. The knowledge of the dolphins' diurnal use of the study area (declining as the day progresses) is also informative for tourism plans. Given that dolphins tend to surface closer to paddle boats than power boats, perhaps dolphin watching would be better carried-out in paddle boats.

Future research

Many of the results, such as vessel traffic levels, dolphin group size, dive time, habitat use, and behaviour, can be used as baseline data to measure changes over time. Future monitoring should include dedicated observations, as time permits throughout the year, of group size, habitat use, time of day, and behaviour. Photo-identification efforts should be refined and targeted to make population estimates. This study was limited spatially and temporally, covering just a small area during the transition from the dry to wet season. Much could be learned if the study was expanded to other areas of the Mekong River system and across the seasons.

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Appendix I

Photo-identification was conducted opportunistically on portions of 16 days when dolphins remained relatively stationary on the Lao side of the river. We used a 4 m native wooden boat, with no outboard engine. While the stern person paddled to a position near the dolphins, the bow person used a Canon EOS 630 SLR auto-advance camera with a date back and 100–300 mm lens to photograph them with black and white Neopan 1600 ISO film. Photographs were taken of either side of the back and dorsal fin area. For analysis, contact sheets and 10.16 cm × 15.24 cm prints of the more promising photographs were examined for unique dolphin markings under an 8-power magnifying loupe, as suggested by Würsig & Jefferson (1990).

We took 629 photographs to photo-identify individuals. We could distinguish relatively large nicks (greater than about 5 cm) and the general shape of the fin in 47 (7.5%) of these photographs. Other photographs were too distant, out of focus, portrayed an angled view, or did not show the dorsal fin. In only 11 photographs were we able to identify potential characteristics of relatively smaller nicks or any scars, scratches or pock marks. These 11 represent six encounters with at least two different animals and possibly up to six.

While photo-identification has been a useful technique in many marine cetacean applications (Würsig & Jefferson, 1990), it may be less useful with some river dwelling dolphins, due in part to their behaviour. For example, dolphins in this study surfaced unpredictably, stayed low in the water, and only surfaced at most twice in succession, reducing our ability to obtain quality photographs.

In northeastern Australia, 58% of photographs of Irrawaddy dolphins taken by Parra & Corkeron (2000) were suitable for analysis because dolphins were habituated to the presence of boats. In studies of tucuxi (*Sotalia fluviatilis*), 19% of photographs were suitable for individual identification (Pizzorno *et al.*, 1995). These higher rates of useable photographs are due, in part, to the use of motorized boats which enabled researchers to maintain a closer distance to the dolphins. Much of the time on the water in Laos was spent paddling to get close to the animals. By the time we were nearby, they often moved to a different site. Conversely, a motor boat in Laos may could have made it difficult to approach the dolphins closely. Because nicks and other markings are generally small relative to those on larger cetaceans, we recommend the use of a finer-grain film (slower than 1600 ISO as suggested by Würsig & Jefferson, 1990) for any future photo-identification studies of Irrawaddy dolphins.