Impact of tour boats on the behaviour and energetics of bottlenose dolphins (*Tursiops truncatus*) off Choros Island, Chile

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ABSTRACT:

The aim of this study was to examine how the activities and energetics of bottlenose dolphins off Choros Island, Chile, are affected by boats. Swimming speeds and movements of dolphins were recorded via theodolite tracking (n=21.3 observation hours). The results show that close boats (<100 m) affect the behaviour of bottlenose dolphins more strongly than boats further away (>100 m). The activity budget of dolphins did not change significantly with distant boats compared to controls. Close boats, however, induced a decrease of feeding (from 6% to 0%), resting (15% to 5%) and social behaviour (15% to 5%). The proportions of high-speed swimming (5% to 11%) and slow swimming (20% to 38%) increased. In the presence of close boats, dolphins were observed 6 times more frequently to leap and 3.6 times more frequently to tail-slap than under control conditions – an indication of disturbance. Dolphins responded to close boats with evasive manoeuvres similar to predator avoidance. With more than two close boats, animals swam approx. 37% faster than without close boats – a horizontal avoidance strategy. Diving as a vertical avoidance strategy constituted 16% of dolphin reactions towards close boats. In 14% of the cases, there was a simultaneous occurrence of horizontal and vertical avoidance behaviour. That was mostly the case, when several boats stayed a long time in the proximity of the dolphins. An energy consumption of 2.93 W kg^{-1} was calculated. This corresponds to a daily energy demand of 50.6 MJ per dolphin assuming 200 kg body mass. With boats at close range, the mean power requirement of dolphins was around 15.4% higher than during controls. With close boats, dolphins used a third of their energy budget to avoid boats by swimming at high speed. In the light of these findings, recommendations for dolphin-watching guidelines are given

KEYWORDS: BOTTLENOSE DOLPHIN, WHALE WATCHING, DOLPHIN WATCHING, BEHAVIOUR, ACTIVITY BUDGET, ENERGETIC, ENERGY BUDGET

INTRODUCTION

Watching whales and dolphins in their natural habitat has increased throughout the world. Since bottlenose dolphins are common in coastal regions, they are visited frequently by tour boats. Boats can affect the behaviour of dolphins. To what degree their presence changes the dolphins' energy budget was still unknown.
Therefore, the aim of the present work was to examine how the activities and energetics of bottlenose dolphins are affected by boats. Furthermore, the focus was on the different reactions of dolphins to boats far away and nearby as well as on the dolphins' strategies to avoid boats.

METHODS

Within the framework of my Ph.D. thesis, observations were conducted in Chile on the uninhabited Choros Island (29°16'S / 71°32'W) in the summer months of 2000/2001 (YAZDI 2005). Swimming speeds and movements of the dolphins were recorded via theodolite tracking. The observation point was located in the South of the island on a cliff about 43 m high. With excellent weather conditions sightings of dolphin groups were possible as far as 2.3 km. There was a resident community of 35 to 40 bottlenose dolphins, which stayed in the south of Choros Island (NUÑEZ MONTANER 2000, HANSHING 2001) during most of the observation time (>88%).

A typical dolphin watching vessel was a wooden fishing boat with a length of 8 m (Figure 1), being able to bord 6 to 10 passengers. The outbord engines had 15 to 55 horsepowers.

Figure 1: A typical fishing boat with tourists on bord during dolphin watching off Choros Island.

Focal groups were defined as „any group of dolphins observed in apparent association, moving in the same direction and often, but not always, engaged in the same activity“ (SHANE 1990). Group behaviour was recorded by assessing which activity (Table 1) all or most members of the group were engaged in (focal group sampling: MANN 1999, MANN 2000) and scoring all behaviour events, like leaps and tail slaps in a group (incident sampling: ALTMANN 1974, MANN 1999). If the group splitted up during the data recording, I always followed the larger group (group follow: MANN et al. 1999).

Behaviours of dolphins were recorded continously (continous recording: MARTIN & BATESON 1993) during a scan which lasted normally 10 min (after MANN 2000). Scans were shorter when dolphins left the observation area or when the observer lost the focal group after a long period of diving. If any of the parameters changed during data recording, like activity or boat number, the scan was devided in smaller sections. Swim speed was calculated for each section, on the basis of the exact position and time measurements, using a theodolite (ATS 105, PENTAX®GMBH) and HUSKY HUNTER II field computer.

In my previous physiological studies (YAZDI 1998, YAZDI et al. 1999) energy expenditure of two trained bottlenose dolphins via respirometry was determined. Dolphins performed a variety of activities before surfacing in a metabolic hood to breathe. Based on the oxygen consumption, the power requirements of dolphins during swimming at different speeds could be calculated.
During these behavioural studies mean swim speeds for each activity and the proportion of time spent for a specific activity were determined to calculate the energy budget of wildlife bottlenose dolphins, using a third-degree polynomial function for computing the power input [W kg^{-1}] (YAZDI et al. 1999).
The energy expenditure of leaps was determined on the basis of the assessed leap heights which require a defined speed (YAZDI 2005).

Table 1. Definitions of described activities of bottlenose dolphins

Activity	Definition
resting	floating motionless at the surface or swimming very slowly ($\leq 1.4\ s^{-1}$) without any predominant direction; no leaps.
swimming slowly	swimming in one direction at a speed of $>1.4\ m\ s^{-1}$ to $3.2\ m\ s^{-1}$; leaps are possible.
high-speed swimming	swimming in one direction at a speed of $>3.2\ m\ s^{-1}$; leaps are common.
diving	staying under water >20 s; after submerging dolphins stay a certain time at the water surface and then descend as a group; a stay at the water surface of up to 2 min is considered as "diving"; leaps during surface time are possible.
feeding	swimming with numerous direction and speed changes; leaps are common; surface feeding is mostly accompanied by flying and feeding birds.
socializing	dolphins are in physical contact with each other, (e.g. stroking, hitting, swimming with body contact) and/or synchronized behaviour; leaps are common.

RESULTS & DISCUSSION

The results of this study show that close boats (<100 m) affect the behaviour of bottlenose dolphins more strongly than boats further away (>100 m). Whereas dolphins reacted to distant boats in 44% (n=23) of observations, they responded to close boats 95% (n=82) of the time.
Their activity budget did not change significantly with distant boats compared to controls (Figure 2). Close boats, however, induced a decrease of feeding (from 6% to 0%), resting (from 15% to 5%) and social behaviour (from 15% to 5%). The proportions of high-speed swimming (from 5% to 11%) and slow swimming (from 20% to 38%) increased.

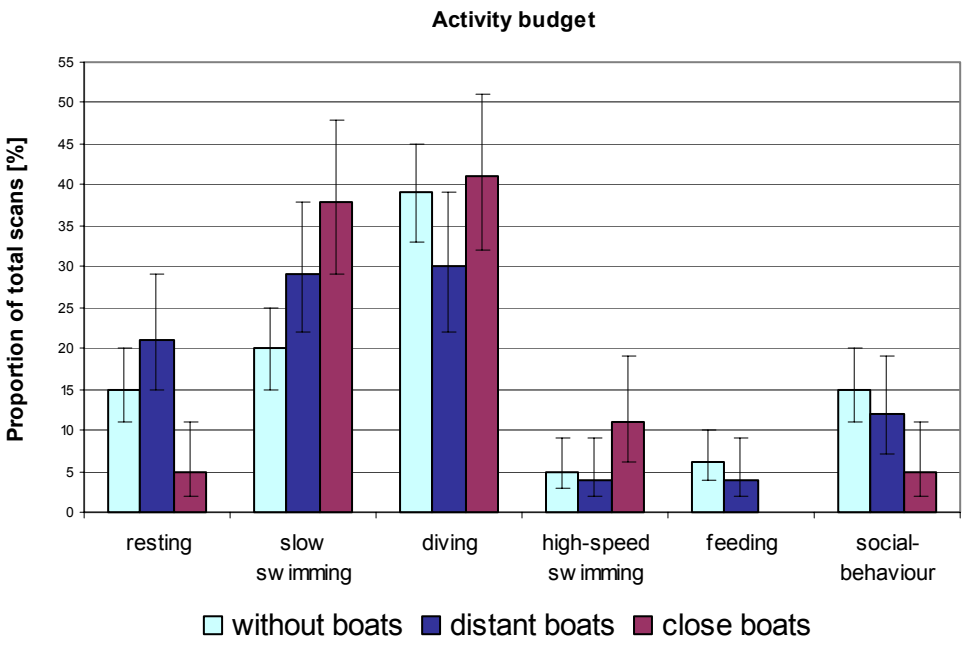

Figure 2: Activity budget of bottlenose dolphins off Choros Island in the sommer months (Jan 20 to March 30, 2001) during an observation time between 9 a.m. and 5 p.m. The proportions result from the frequency of activities on the basis of 3min-sampling. Error bars indicate the 95%-confidence intervals (after WILSON 1927, decribed in NEWCOMBE 1998) of the respective proportions. Number of 3min-scans: without boats: n = 242; distant boats: n=115; close boats: n=104). Definitions: without boats (=control): there is no boat in the observation area; distant boats: theres is at least one boat in the observation area, but not closer than 100 m to the dolphin group; close boats: there is at least one boat closer than 100 m to the dolphin group.

Close boats caused behavioural changes 3.5 times more often than controls. With a constant number of close boats, resting changed to diving and social behaviour to slow swimming ($p<0.05$). In addition, dolphins reacted with frequent speed changes: slow swimming changed to high-speed swimming and vice versa.

As a result of an increasing number of boats in the proximity, the transitions of slow swimming to high-speed swimming and slow swimming to diving showed an increase (Figure 3). If the animals were diving, they most often maintained this activity. However, dive time decreased with the presence of close boats by 45% (Figure 4; without boats: $\tilde{x}$ = 108 s; with close boats: $\tilde{x}$ = 59 s), while the duration at the surface remained unchanged (without boats: $\tilde{x}$ = 35.8 s, with boats: $\tilde{x}$ = 39.0 s). Off Choros Island, all types of diving behaviour strongly associated with feeding constituted 53% of the controls. With close boats, however, these kinds of submergings were not observed.

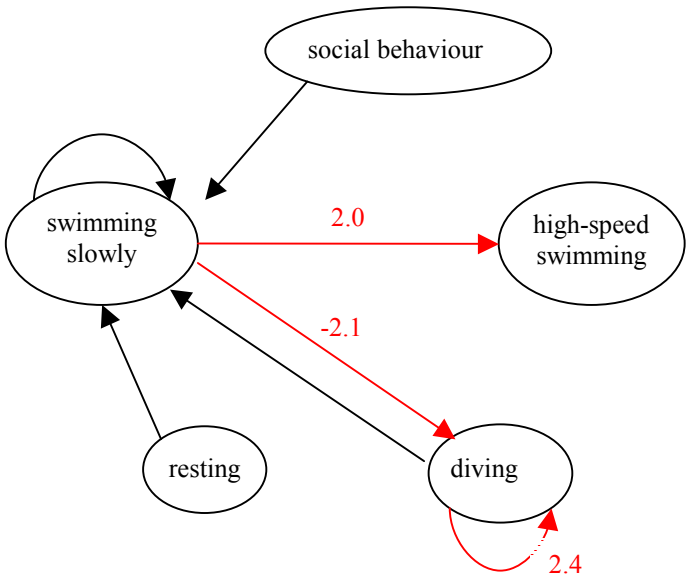

Figure 3: Behavioural changes of bottlenose dolphins as a result of an increasing number of boats in the proximity of dolphins. Red arrows indicate significant sequences ($p<0.05$); numbers indicate significant *z*-values (calculated after BAKEMAN & GOTTMAN 1997).

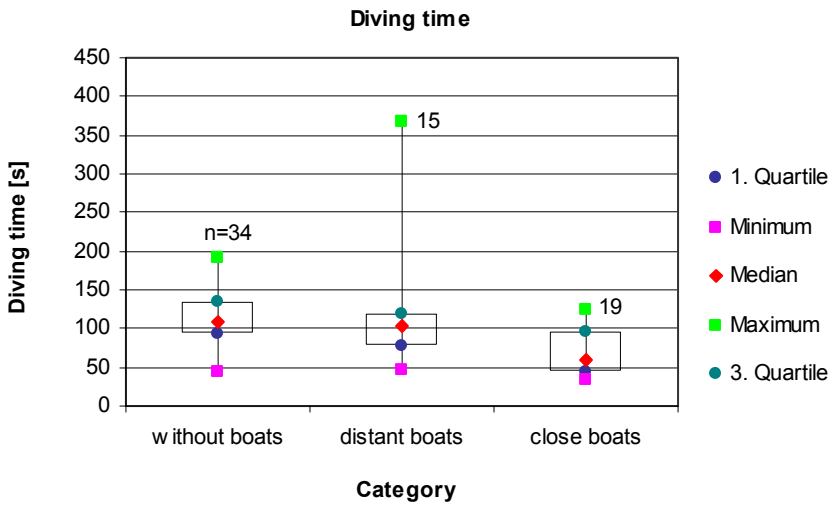

Figure 4: Distribution of diving times (without boats: $\tilde{x}$ = 108 s, distant boats: $\tilde{x}$ = 103 s, close boats: $\tilde{x}$ = 59 s; n total = mean value of 186 dives) Statistical comparison with Mann-Whitney U-Tests. Adjustment of the significance level with Bonferroni: $\alpha/3=0.0167$. (Without boats – distant boats: $p=0.4533$, without boats – close boats: $p<0.0001$; distant boats – close boats: $p=0.0075$).

In the presence of close boats, dolphins were observed 6 times more frequently to leap (when swimming at the surface between dives) and 3.6 times more frequently to tail-slap (when swimming slowly) than under control conditions – an indication of disturbance.

Bottlenose dolphins off Choros Island responded to close boats with evasive manoeuvres similar to techniques used for avoiding predators. They mostly showed horizontal avoidance in 37% (n=82) of the cases. This also includes weak reactions such as changes of movement patterns during slow swimming. In the absence of boats, dolphins swam slowly often in a

zigzag-pattern (59%; n=27) usually within their preferred residence area. With boats, however, movements predominantly followed (71%; n=51) a direct path – most frequently to the west or northwest of Choros Island as boats always approached from the east. Primarily dolphins left their preferred residence area, when many boats stayed for a longer time in their surroundings.

The number of close tour boats had a significant influence on the mean swim speed of the dolphins (Figure 5). With more than two close boats, animals swam approx. 37% faster (3 – to 5 close boats: $\tilde{x} = 2.6$ m s^{-1}) than without close boats (without/ distant boats: $\tilde{x} = 1.9$ m s^{-1}).

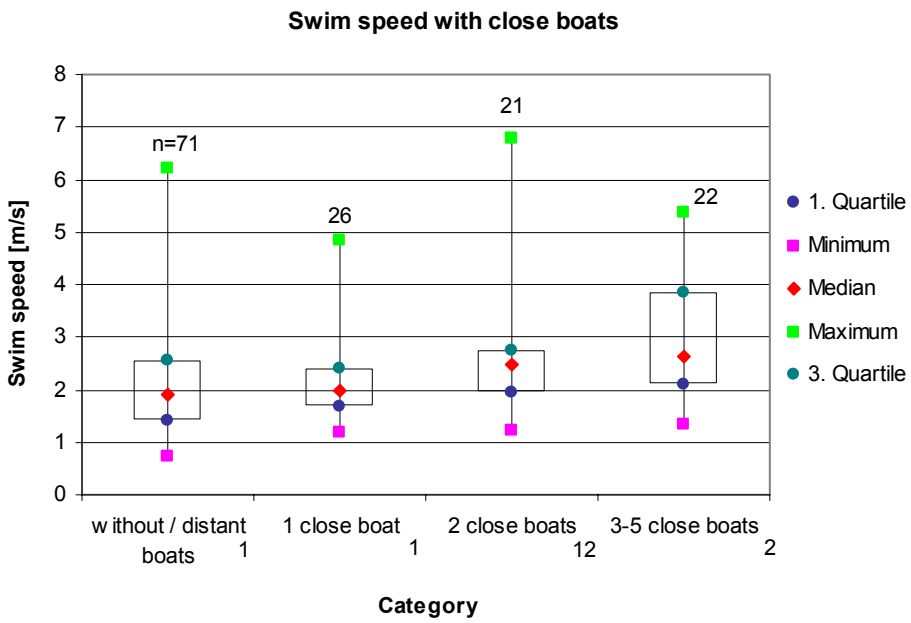

Figure 5: Distribution of swim speeds with close boats (without / distant boats: $\tilde{x} = 1.9$ m s^{-1}; 1 close boat: $\tilde{x} = 2.0$ m s^{-1}, 2 close boats: $\tilde{x} = 2.5$ m s^{-1}, 3 to 5 close boats: $\tilde{x} = 2.6$ m s^{-1}; n total = 140 sections; statistical comparison with Kruskal-Wallis-Test (df=1). Adjustment of the significance level with Bonferroni-Holm for 6 pairs. Equal numbers next to the boat categories indicate, which speeds do not differ significantly from each other.

Without boats, dolphins swam long distances and straight at high speed. With boats the distances (without boats: $\tilde{x} = 842$ m; with boats: $\tilde{x} = 501$ m) and the durations (without boats: $\tilde{x} = 3.0$ min; with boats: $\tilde{x} = 1.5$ min) of the high-speed tracks were significantly shorter. There was a trend to movements in zigzag pattern. Here a second strategy of horizontal avoidance was displayed: escape.

Bottlenose dolphins off Choros Island showed an increase of group dispersion or a tendency to split into subgroups, when exposed to more than two boats (Figure 6). Possibly group dispersion is a further avoidance strategy of dolphins: scattered emerging positions make movements more unpredictable. Furthermore, individuals or subgroups could follow different avoidance strategies, causing the splitting of a group.

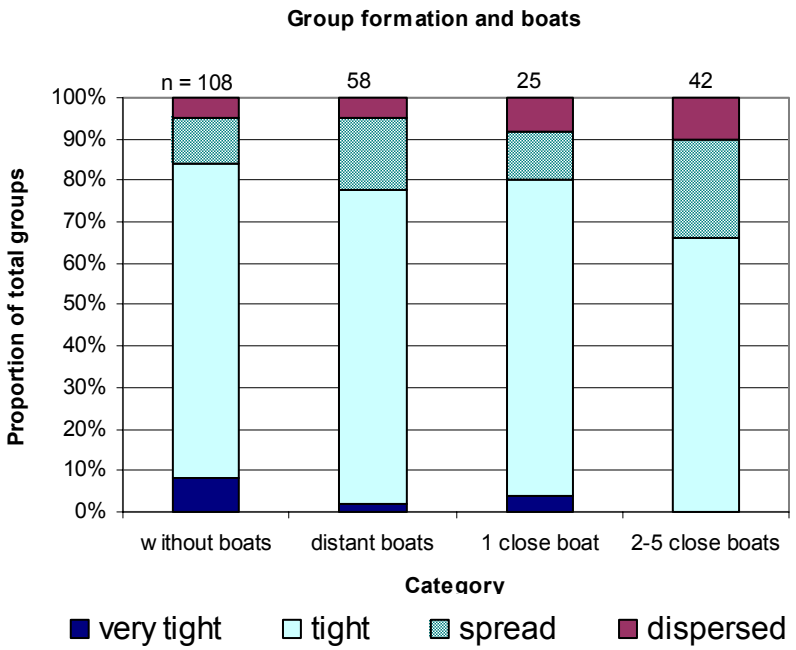

Figure 6: Group formation of bottlenose dolphins off Choros Island in the presence of boats. Statistical comparison with chi-square-test: without boats – 2 to 5 close boats: significant ($p<0.05$); all other distributions are not different from the control ($p>0.05$); n = 233 groups. Definitions: without boats (=control): there is no boat in the observation area; distant boats: there is at least one boat in the observation area, but not closer than 100 m to the dolphin group; 1 close boat: theres is one boat closer than 100 m to the dolphin group; 2 to 5 close boats: there are between 2 and five boats closer than 100 m to the dolphin group; very tight: the mean distance between dolphins of a group is less than one body length (<3 m); tight: the mean distance between dolphins of a group is between one and two body lengths (3 to 6 m); spread: the mean distance between dolphins of a group is between two and five body lengths (6 to 15 m); dispersed: the mean distance between dolphins of a group is more than five body lengths (>15 m).

Diving as a vertical avoidance strategy constituted 16% of dolphin reactions (n=82) towards close boats (Figure 7, Figure 8). In 14% of the cases, there was a simultaneous occurrence of horizontal and vertical avoidance behaviour, for example when dolphins dived and swam westward, in order to leave the boat traffic area. That was mostly the case, when several boats stayed a long time in the proximity of the dolphins.

Based on activity budget, average swim speeds, and leap frequencies of the bottlenose dolphins off Choros Island, an energy consumption of 2.93 W kg^{-1} was calculated. This corresponds to a daily energy demand of 50.6 MJ per dolphin with 200 kg of body weight. Animals utilized 36% of their energy for the execution of their daily activities.

A leap to a height of 9 m costs a dolphin 79.5 KJ, corresponds to approximately 0.25% of its daily resting metabolism. If the power of leaps is averaged over all group members, they constituted only 1% of the total energy consumption.

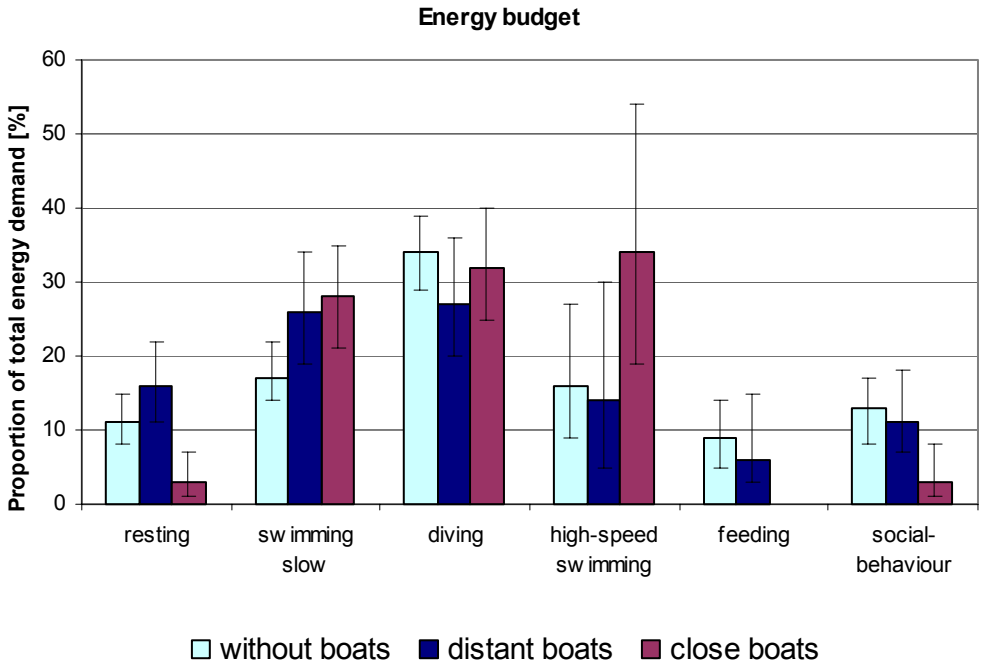

Figure 7: Energy budget of bottlenose dolphins off Choros Island in the sommer months (Jan 20 to March 30, 2001) at an observation time between 9 a.m. and 5 p.m. The hight of the columns indicate the proportions of the total energy demand per boat category. Proportions are calculated on the basis of the average swim speed of dolphins within the specific activities and the power of leaps, assuming a body weight of 200 kg. Error bars indicate the 95% confidence intervals (after WILSON 1927, decribed in NEWCOMBE 1998) of the respective proportions. (Total energy demand per dolphin: without boats = 586 W; distant boats = 564 W; close boats = 676 W). Definitions: without boats (=control): there is no boat in the observation area; distant boats: theres is at least one boat in the observation area, but not closer than 100 m to the dolphin group; close boat: theres is one boat closer than 100 m to the dolphin group.

With boats at close range, the mean power requirement of dolphins was around 15.4% higher than during controls. The quantifiable additional momentary costs amounted to 324 kJ per hour, which corresponds to the energy content of approximately 65 g fish. With close boats, dolphins used a third of their energy budget to avoid boats by swimming at high speed (Figure 7).

In the light of these findings, following recommendations for dolphin-watching guidelines are given:

1.) The number of boats in the proximity of dolphins (<100 m) should be restricted to a maximum of two boats. Other whale watching boats should wait with engines off in a minimum distance of 100 meters until a vessel in the close range of dolphins has left.
2.) Boats should keep a minimum distance of 100 meters, if bottlenose dolphins show feeding activity.
3.) Boats should keep a minimum distance of 50 meters, if bottlenose dolphins show resting, social behaviour or tail slaps.
4.) After arriving at the dolphin group, boatmen should turn off the engine or drive with idle speed.

5.) During slow swimming boats could follow the dolphin group slowly in the parallel path to the travel direction of dolphins in a minimum distance of 30 meters.
6.) If dolphins increase their speed (>3.2 m s^{-1}) boats should not follow the group any more and finish the watching activities.

Guidelines would not only provide for the protection of the animals on a long-term basis, they would also increase the probability of satisfying encounters between tourists and these small cetaceans.

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