Aquatic Mammals 1995, **21.3,** 171–181

Behavioral reactions of bottlenose dolphins to the *Mega Borg* oil spill, Gulf of Mexico 1990

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Summary

The behavior of bottlenose dolphins *Tursiops truncatus* in and near the 1990 *Mega Borg* oil spill off Galveston, Texas, was assessed via aerial surveys from 15–18 June 1990. Opportunistic observations were made 6–9 days after the initial June 9 spill of an estimated 17.4 million liters of light-grade, Angolan crude oil. Nine dolphin groups were tracked with a video camera for a total of 5.6 hours. Three oil conditions were considered: sheen, slick, and mousse. Results indicate that bottlenose dolphins could detect slick and mousse oils but did not react to lighter sheen oil. Groups hesitated and milled upon encountering slick oil, eventually diving under or in small patches but continuing through extensive areas. These results contrast with experimental results reported for captive dolphins which consistently avoided entering slick oil. Dolphins detected and consistently avoided contact with mousse oil by swimming under or around it. Dolphin group integrity appeared to break down near mousse oil. Observations suggest that dolphins may respond to thick oil types by swimming closer together, decreasing respiration rates, and increasing dive times and rates of reorientation. The greatest concern is that bottlenose dolphins apparently detect but do not consistently avoid entering slick oil, and may not detect sheen oil, thereby increasing their vulnerability to potentially harmful exposure to oil chemicals. This study contributes to the limited data base on wild dolphin responses to oil spills and presents a methodological framework for future studies assessing the effects of oil spills on cetaceans.

Introduction

Little is known about the reaction of wild bottlenose dolphins *Tursiops truncatus* to oil, although studies of captive bottlenose dolphins exposed to controlled oil spills indicate that animals can detect and avoid thick, dark oil (Geraci *et al*., 1983; Smith *et al*., 1983). Most non-captive reports of cetaceans near oil spills represent descriptive, anecdotal observations. These include several species of mysticetes and odontocetes that have been opportunistically observed feeding or travelling through oiled water with no apparent change in behavior (Goodale *et al*., 1979; Geraci, 1990). This study presents results from a systematic approach used to monitor the behavioral response of wild bottlenose dolphins to three oil conditions during the 9 June 1990 *Mega Borg* oil spill off Galveston, Texas. The *Mega Borg* was carrying 155 million liters of light-grade, Angolan crude oil (American Petroleum Institute (API) gravity index of 38.9) at the time of an onboard explosion 91 km SSE of Galveston (Research Planning Inc., 1992) (Fig. 1). She lost approximately 17.4 million liters largely within the first 24 hours after the explosion. While most of the oil burned up, an estimated 151 000 liters of crude oil spread in a north, northwesterly direction (Kennicutt *et al*., 1991).

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Methods

Behavioral descriptions of bottlenose dolphins in and near the *Mega Borg* oil spill were made from a DeHavilland Twin Otter aircraft circling at an altitude of 460 m on four days from 15–18 June 1990. Verbal descriptions by three observers were recorded onto a PMD 430 Marantz tape recorder. A fourth observer video recorded dolphins and observer voices with a high resolution, eight-mm Sony CCD-V99 video camera. The following information was recorded during each circling of the plane when possible: (1) orientation and estimated distance of dolphins to oil, (2) general behavior of dolphins, (3) surfacing respirations, (4) estimated swimming speed of dolphins (slow, medium, fast), (5) inter-animal distance, (6) group size, and (7) any boat or other activity occurring near dolphins.

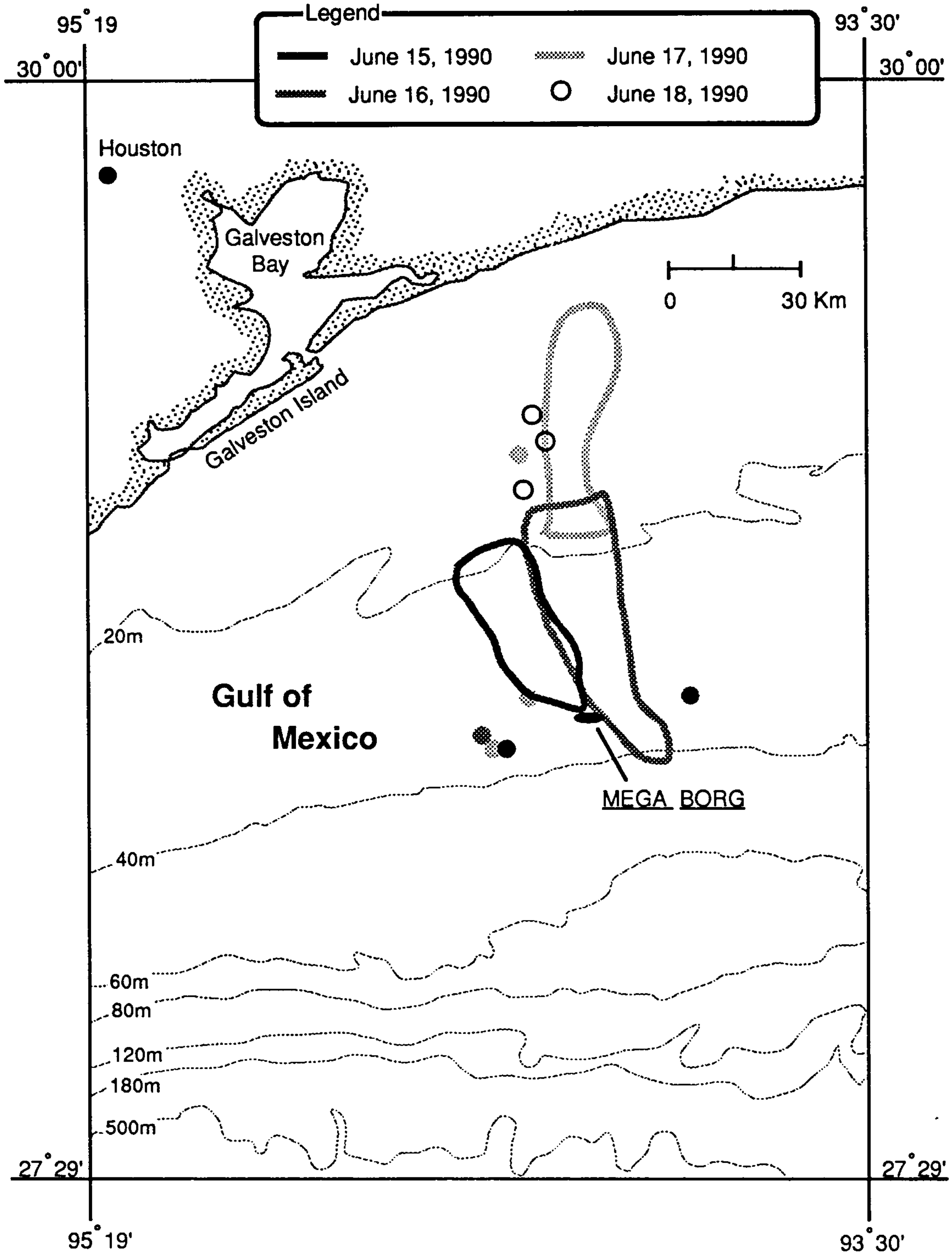

Figure 1. Approximate extent of main *Mega Borg* oil spill in study area as interpreted from aerial surveys conducted 15–17 June 1990, as well as initial sighting locations of dolphin groups on all days of the study (shading of circles correspond to dates in legend). While this figure shows the main oil spill areas, other smaller areas of sheen, slick, and mousse were present as described relative to dolphin sightings in the text.

General behavior was classified as travelling, milling, resting, or socializing (two or more animals within one-quarter body length of one another) (Shane *et al.*, 1986; Silber & Smultea 1990). A group was defined as dolphins behaving synchronously within seven body lengths of one another. Dolphins were generally observable at or just below the water surface throughout the period of observation.

Three oil conditions (types) were considered based on water surface characteristics observable from the aircraft (Anon., 1981): (1) slick (a thick, cohesive, iridescent oil which dolphins displaced while surfacing, (2) sheen (a light luminescent oil), and (3) mousse (a thicker dark-brown, frothy oil). Oiled areas were also characterized by shape and size into 'patches' (round or irregularly shaped isolated areas of oil) and 'strips' (elongated bands <6 m wide). Most spilled oils initially form continuous slicks which, via weathering processes such as evaporation and dissipation, thin into sheens or emulsify into mousse (Anon., 1981). Location and progression of the oil spill and initial sightings of dolphin groups are shown in Fig. 1.

To determine movement of dolphins in relation to oil, rates of reorientation were calculated by summing the absolute values of changes in group orientation (measured in degrees magnetic from a gyro-stabilized orientation display in the cockpit) and dividing by the total number of observation minutes (min) in each oil or interface type. An interface was defined as a period of three minutes while dolphins crossed between oil types. The three-minute designation was chosen to have potential for isolating periods of unusual behavior which might last for only several dolphin surfacing sequences. Orientation of dolphin groups was recorded approximately once per circling of the aircraft (roughly every minute when dolphin heading was aligned with that of the aircraft). Respiration rate per minute was calculated based on video footage for those groups which could be followed repeatedly with a high degree of certainty. A respiration was assumed to occur each time an animal broke the water surface, since actual blows could not be ascertained from the flight altitude. Inter-animal distance (between nearest neighbors within a group) was measured in dolphin lengths (one body length (BL) equals approximately 3 m) and was recorded each time spacing between dolphins changed by >0.25 BL. Distance between individuals was determined using calipers calibrated to dolphin body length based on video footage. By combining vocal descriptions with video footage, dolphin movements and orientations relative to oil were plotted; scales on maps were approximate based on visual estimates using dolphin size as reference. Statistical tests were generally not applied to the data due to small sample sizes.

Results

A total of 5.6 hours of behavioral observations were collected from nine groups of bottlenose dolphins. Group size ranged from 3–18 individuals, and observation sessions ranged in duration from 12–70 minutes. Reorientation rates and inter-animal distances were calculated for most groups (Fig. 2, Table 1). Group integrity and calm weather conditions facilitated the calculation of respiration rates for two groups (Table 1). Petroleum fumes could be smelled by observers in the aircraft while circling dolphins in oil spill areas.

A summary of results is followed by three case studies including a brief description and figure of the behavior and movement of the dolphin groups with the widest and most prolonged exposure to oil types. References to dolphin groups by date and time are made in the general results and presented in more detail in the case studies and Table 1. For descriptions of additional case studies, see Smultea & Würsig, 1991; 1992.

Dolphin groups encountered mousse interfaces characterized by a narrow strip or small patch of mousse on 10 occasions: seven times they dove under the mousse, two times they swam around it, and once a non-focal group of two dolphins surfaced within the edge of a mousse patch. However, eight of 10 of these encounters were made on the same group, or subgroups of a group, during one observation session (18 June: 08:44–09:54 hrs). With this consideration, dolphins appeared able to detect and avoid mousse to a significant degree (Binomial $P=0.01$); yet narrow strips of mousse did not impede movement.

Dolphins seemed to detect slick oil although reactions varied. They hesitated or swam parallel to an extensive slick area before entering it for the first time on two of two occasions. Of the seven encounters with strips of slick oil ranging in width from 3–6 m, four times dolphins surfaced within the strip and three times they dove under it (Binomial $P=0.27$). All of these encounters except two represent different groups and observation sessions. Thus, unlike encounters with strips of mousse, tactile avoidance of slick oil strips was not apparent, and dolphins invariably continued through slick areas.

Dolphins did not appear to detect or be affected by sheen oil (with the possible exception of changing respiration rates on 17 June: 16.28–17:19 hrs; Table 1). Dolphins were once observed entering sheen oil from apparently oil-free water with no overt change in behavior or orientation (17 June: 16:28–17:19 hrs). By comparison, a group of

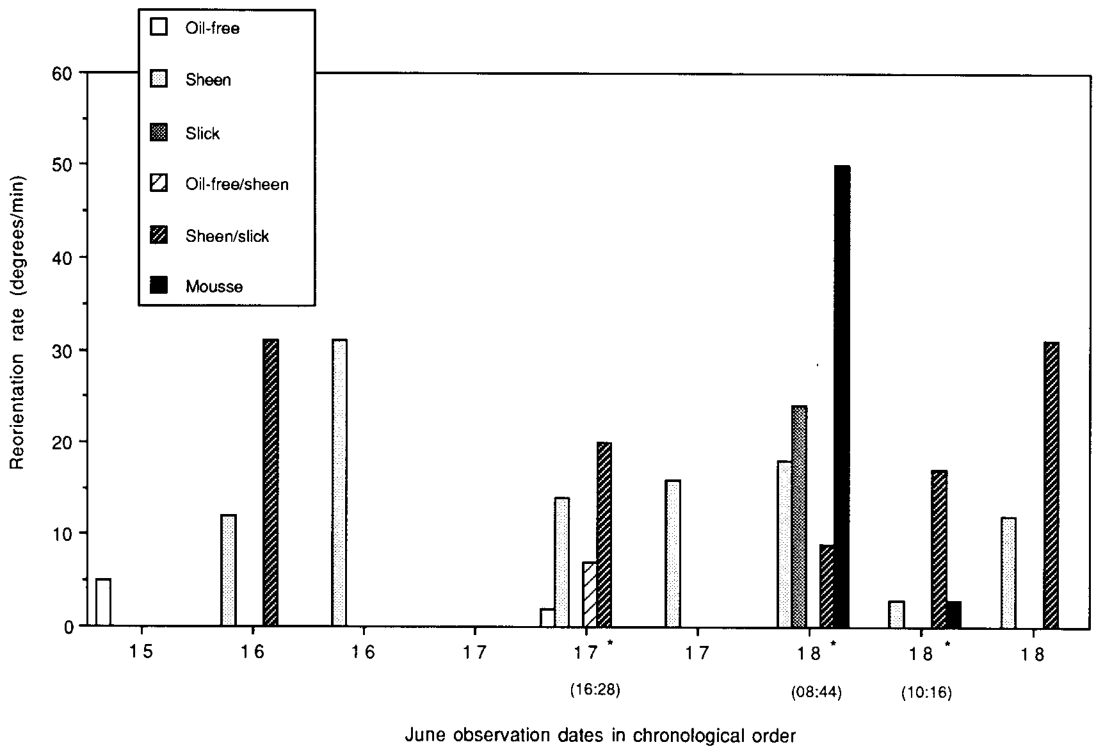

Figure 2. Mean reorientation rates (degrees per minute) of dolphin groups based on water surface type (* denotes case study discussed in text; initial sighting in parentheses underneath).

dolphins swam through and surfaced in a narrow strip of algae with no apparent hesitation (17 June: 17:28–17:48 hrs). Dolphin groups were observed within sheen on four occasions, engaging in what seemed to be 'normal' behavior, including brief bouts of socializing, aerial activity, 'investigative' behavior, and bow riding a vessel.

Overall, the highest rates of reorientation within groups occurred at interfaces between oil types (Fig. 2), particularly between mousse oils on 18 June (08:44–09:54 hrs), although rates were variable. The higher rate of reorientation in interfaces may be related to detection of oil.

Spacing among individuals generally decreased in heavily oiled areas relative to oil-free and light oil areas, although there was considerable variance around the means (Table 1). Spacing between dolphins was greatest ($\bar{x}$=2.6 BL) for a group of dolphins observed in oil-free water. The three closest spacings occurred in slick (0.4 BL) and sheen/slick interfaces (0.5 and 0.6 BL).

Dolphin group integrity appeared to break down near mousse oil. Upon encountering a mousse interface, a dolphin group split into asynchronous subgroups when some animals hesitated to pass under the strip of mousse (18 June: 08:44–09:54 hrs). These separations resulted in a slightly higher inter-animal spacing value for the mousse interface relative to sheen/slick interface and slick areas (Table 1). A similar pattern occurred when a group of three dolphins increased mean inter-animal spacing to 1.0 BL when passing under a mousse interface into an extensive sheen area (the dolphins had previously been spaced 0.4 and 0.6 BL in slick and sheen/slick interface areas, respectively (18 June: 10:16–10:48 hrs). The relatively looser spacing at the mousse interface may have been related to the animals passing directly into sheen after the mousse, where they immediately spread-out. The tendency for dolphin groups to separate at mousse interfaces contributed to a relatively higher inter-spacing distance in these areas.

Limited data suggest that dolphins may stay below the surface longer, and thereby decrease blow rates when in oiled versus non- or slightly oiled water. For example, one group of dolphins respired less frequently after passing from oil-free water into sheen oil (17 June: 16:28–17:19 hrs). (Table 1). A second group respired less while in slick oil compared to a return to sheen oil (18 June:

Table 1. Summary of mean inter-animal distance within groups and respiration rates of bottlenose dolphins based on oil types. Inter-distance values are mean body lengths (BL) where one BL = 3.0 m, n = no. measurements. Respiration rates (RR) are mean no. of blows per minute with total sample in time in minutes in parentheses

Date, Time [Total time, min]	Focal group size	Oil-free water	Sheen oil	Slick oil	Oil-free/ sheen interface	Sheen/ slick interface	Slick/ sheen interface	Mousse interface	Comments
15-Jun 11:07–11:19 [12]	3–4	2.6 ± 3.1 n=26	—	—	—	—	—	—	No oil in area
15-Jun 13:12–13:51 [39]	3–10	—	0.8 ± 1.2 n=84	—	—	—	—	—	In sheen oil only; extensive slick oil area within 350 m
16-Jun 11:30–12:12 [42]	3–11	—	0.9 ± 1.1 n=135	—	—	—	—	—	In sheen oil only; extensive slick oil area within 550 m
17-Jun 12:11–12:58 [47]	3–11	—	1.5 ± 1.5 n=84	—	—	—	—	—	In sheen oil only; extensive slick oil area within 400 m
17-Jun* 16:28–17:19 [51]	3–4	1.3 ± 0.8 n=15	1.8 ± 2.2 n=172	—	1.6 ± 1.7 n=24	0.5 ± 0.5 n=18	—	—	Initially in oil-free water, subsequently in sheen and near slick oils. Dove under 1 of 1 strip of slick oil
17-Jun 17:28–17:48 [20]	4–18	—	1.3 ± 5.8 n=376	—	—	—	—	—	In sheen oil only. Dove under algae strip
18-Jun* 08:44–09:54 [70]	3–11	—	1.7 ± 2.3 n=139	1.1 ± 1.6 n=91	—	1.1 ± 2.2 n=86	1.2 ± 2.4 n=7	1.4 ± 2.1 n=35	Initially in sheen and subsequently slick oils; mousse nearby. Surfaced within 1 of 1 strip of slick oil. Of 7 encounters with strips or patches of mousse, 5 times dove under it and 2 times swam around it
		RR = 2.3 (1.8)	RR = 1.7 (14.6)						
18-Jun* 10:16–10:48 [32]	3	—	1.0 ± 0.7 n=108	0.4—0.1 n=6	—	0.6 ± 0.5 n=51	—	1.0 ± 1.0 n=16	Initially in sheen and slick oils; mousse nearby. Surfaced within 1 of 1 strip of slick oil. Dove under 2 of 2 mousse strips
			RR = 1.5 (5.0) **RR = 2.6 (3.5)	rr = 1.8 (17.4)					
18-Jun 11:38–12:01 [23]	3–11	—	1.6 ± 2.0 n=69	—	—	2.1 ± 2.6 n=29	—	—	In sheen oil only; slick oil nearby. Of 2 encounters with strips of slick oil, surfaced within first strip and dove under the second strip

* = Case study discussed in text, ** = second encounter with sheen oil.

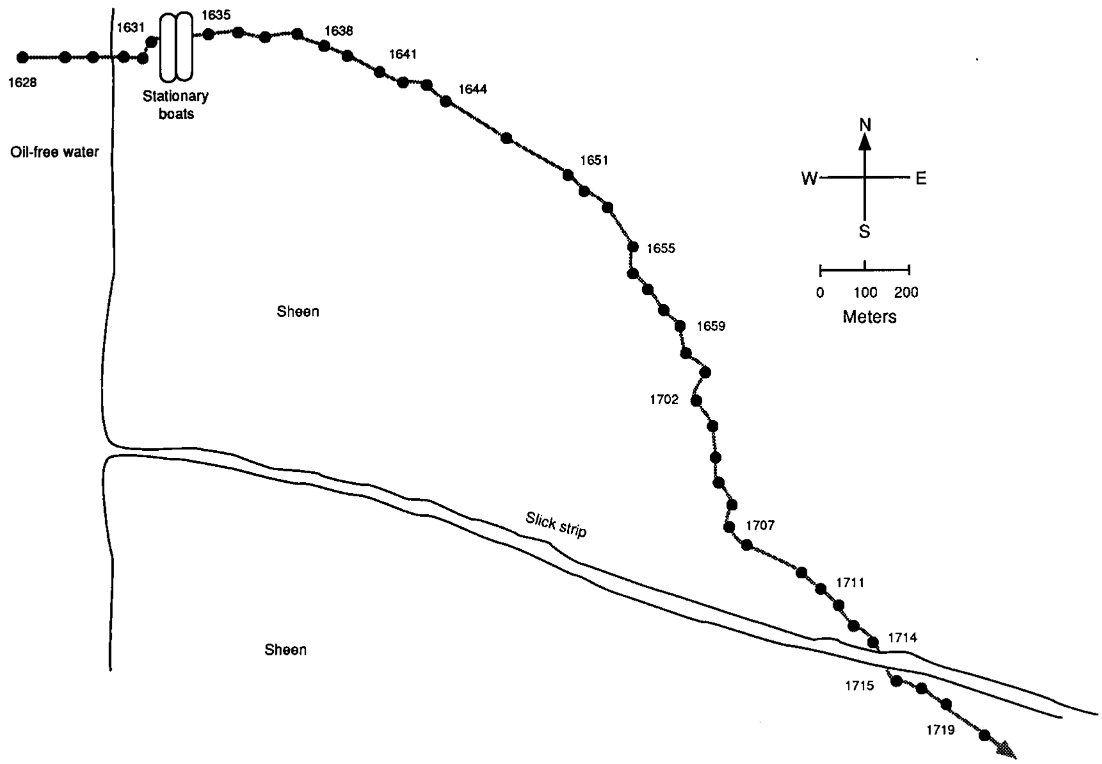

Figure 3. Tracks of a group of three to four bottlenose dolphins relative to oil spill, 17 June 1990: 16:28–17:19 hrs. Initial position: 28°46.4′N, 94°15.2′W.

10:16–10:48 hrs). However, these small sample sizes are not adequate for final evaluations of blow rates relative to surface oil.

Case Studies

17 June: 16:28–17:19 hrs. A group of four dolphins was initially sighted at 16:28 in apparently oil-free water as they approached an extensive sheen area (located approximately 250 m to the west) and two stationary super tankers (Fig. 3). The dolphins travelled fast through the oil-free water/sheen interface, generally maintaining their heading until within 30 m of the two ships at 16:33. At this time, the dolphins spread apart, slowed, and eventually dove under the tankers after shifting course to parallel the ships for a short period. At 16:43 one dolphin deviated from course to investigate a piece of plastic. Travel speed varied from medium to slow, with a general overall heading to the south-east. Upon approaching a 3–4 m wide strip of slick oil to within 200 m, the dolphins closed ranks, shifted course, and obliquely approached the slick from 17:07–17:14. The dolphins eventually dove under the slick strip at 17:15, when all four animals swam the closest inter-dolphin spacing ($\bar{x}=0.5$ BL) observed throughout the 51-minute session. The dolphins also appeared to increase their swimming speed just before and after passing under the strip of slick oil. The group subsequently moved quickly and obliquely away from the slick strip and was last sighted approximately 75 m beyond the slick.

The highest overall rate of reorientation occurred at the sheen/slick interface (20°/min for 3 min), with an intermediate rate while swimming through sheen (14°/min for 40 min) (Fig. 2). The lowest reorientation rates occurred at the oil-free water/sheen interface (7°/min for 3 min) and in the oil-free water (<1°/min for 2 min). Space between individual dolphins was closest ($\bar{x} \pm$ s.d. $=0.5 \pm 0.5$ BL, $n=18$) at sheen/slick interfaces (Table 1). Inter-individual spacing was greatest while swimming in sheen ($\bar{x} \pm$ s.d. $=1.8 \pm 2.2$ BL, $n=172$) and in the oil-free/sheen interface ($\bar{x} \pm$ s.d. $=1.6 \pm 1.7$ BL, $n=24$). Respiration rates also differed with dolphins in oil-free water breathing $\bar{x}=2.3$ blows/min (time = 1.8 min), and in sheen breathing less at $\bar{x}=1.7$ blows/min (time = 14.6 min) (Table 1).

18 June: 08:44–09:54 hrs. While groups varied in size from 3–11, observations concentrated on a group of 7–8 dolphins initially sighted in sheen

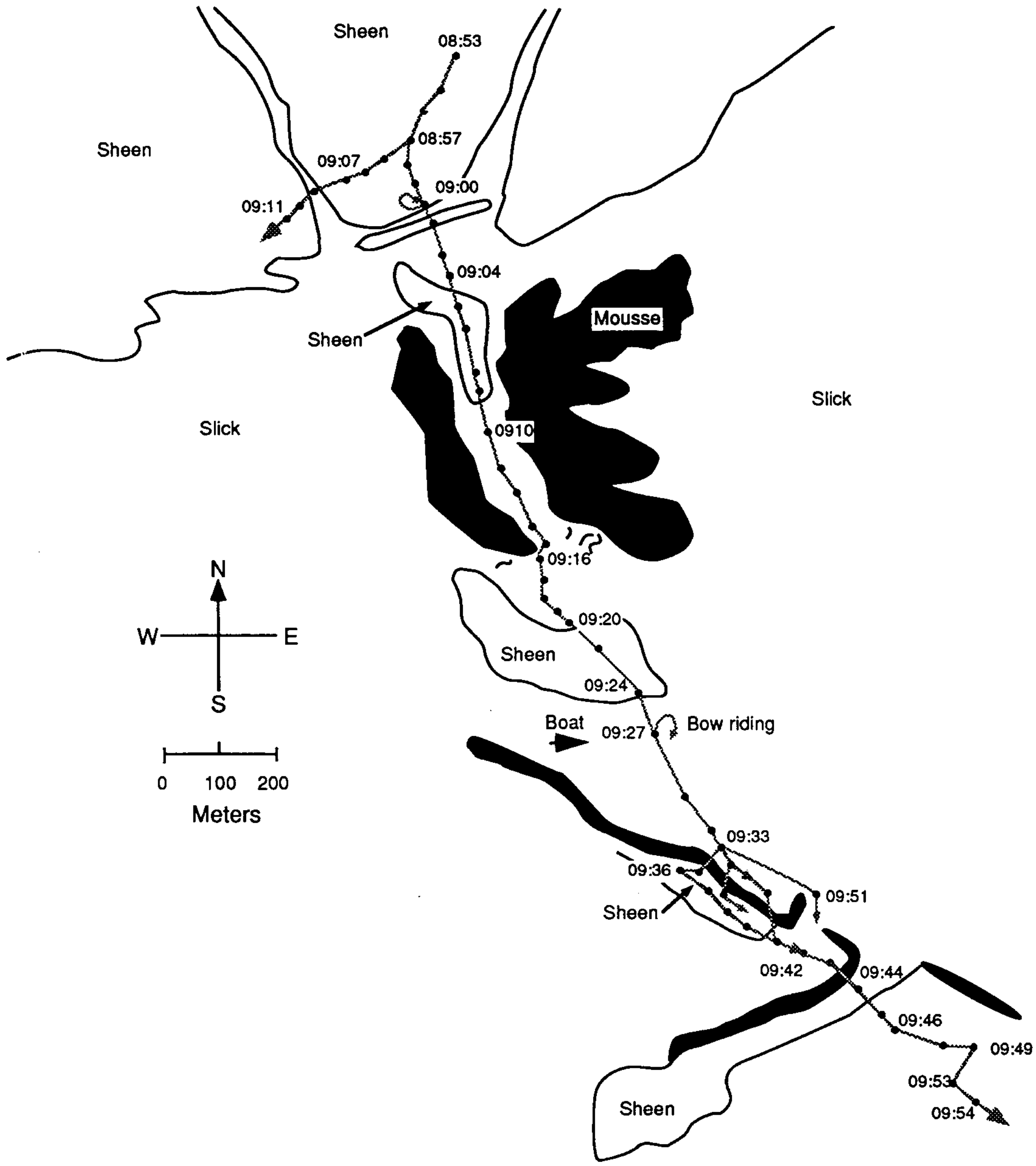

Figure 4. Tracks of groups of three to 11 bottlenose dolphins relative to oil spill, 18 June 1990: 08:44–09:54 hrs. Initial position: 29°18.6′N, 94°08.9′W.

between two strips of slick oil, 300 m north of an extensive slick containing patches of mousse (Fig. 4). The group slowly and synchronously approached the large slick until within 18 m, when at 09:00 the dolphins began milling close together. Based on analysis of video footage, the group hesitated and changed orientation several times at this interface before entering the slick area.

The most evident changes in orientation occurred during two encounters with mousse oil. At 09:15 the dolphins swam around a 3 m-wide corner of mousse which protruded into their path while remaining in slick oil. At 09:27 two dolphins turned and briefly rode the bow wave of a passing vessel, then resumed their course; this behavior suggested that the dolphins were not behaviorally repressed by the slick

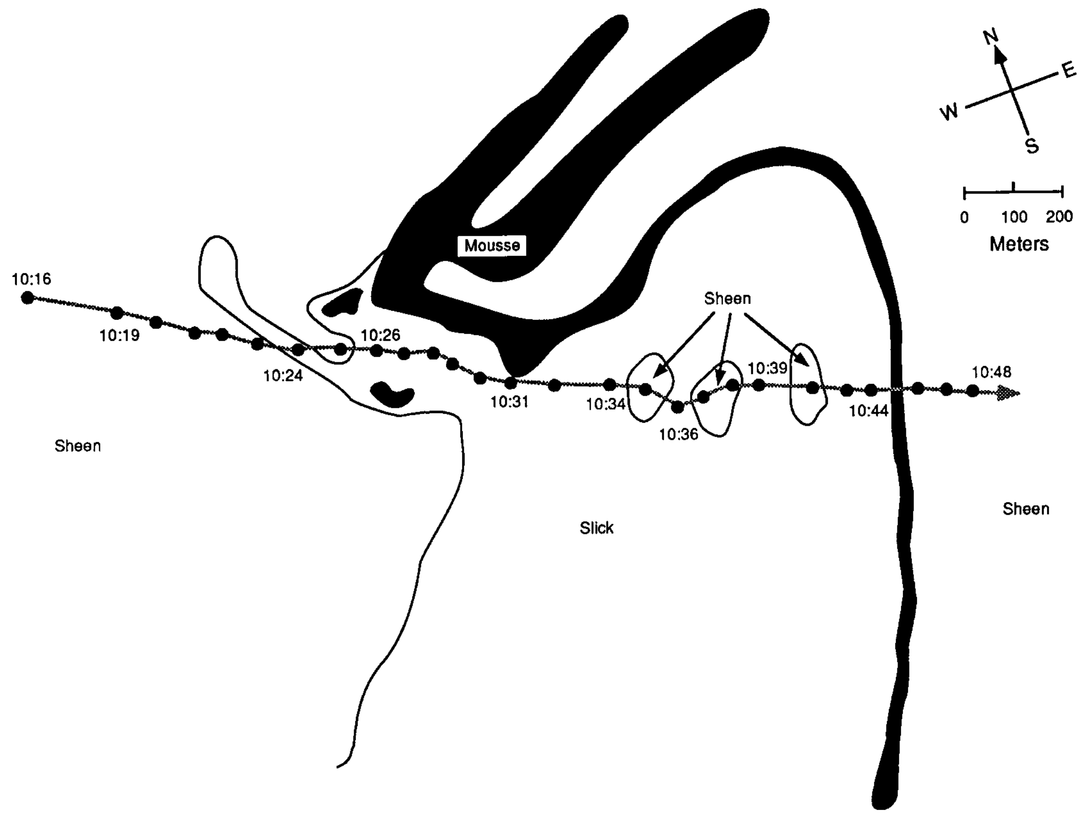

Figure 5. Tracks of a group of three bottlenose dolphins relative to oil spill, 18 June 1990: 10:16–10:48 hrs. Initial position: 29°01.2′N, 94°10.1′W.

oil. At 09:33 the dolphins approached another strip of mousse which ran obliquely to their heading. At this point, the group split-up, with each subgroup responding differently to the mousse. Three animals dove under the mousse at 09:34 and milled on the other side in a narrow sheen area until 09:36 before continuing to parallel the mousse strip. Two other subgroups paralleled the strip of mousse before diving under at 09:37 and 09:39, respectively. These dolphins rejoined the firsts subgroup of three at 09:42. At 09:43 the group split up again as two dolphins dove directly under another mousse strip running perpendicular to their path; the other dolphins hesitated to go through but eventually dove under to rejoin the lead group at 09:49. At 09:51 a trailing group of two dolphins swam around a break in the mousse.

The highest rate of reorientation (50°/min for 12 min) for this observation session occurred at mousse interfaces (Fig. 2). The reorientation rates in sheen and slick oils were similar (18°/min for 5 min and 24°/min for 9 min, respectively. The lowest rate of reorientation occurred at sheen/slick interfaces (9°/min for 15 min). Inter-animal spacing was tighter in slick oil and sheen/slick interfaces ($\bar{x} \pm$ s.d.$=1.1 \pm 1.6$ and 1.2 ± 2.2 BL, respectively, $n=91$ and 86) than in sheen areas ($\bar{x} \pm$ s.d.$=$ 1.7 ± 2.3 BL, $n=139$ (Table 1). The mean separation distance between dolphins in mousse interface was relatively intermediate ($\bar{x} \pm$ s.d.$=1.4 \pm 2.1$ BL, $n=35$).

18 June: 10:16–10:48 hrs. Three dolphins were initially sighted in an extensive sheen area approximately 500 m west of a 1.5-km wide and several-km long oil slick containing strips and patches of mousse (Fig. 5). The group maintained a steady medium speed and a generally synchronized east heading throughout observations. The dolphins first paralleled a 6-m wide strip of slick oil before surfacing within it at 10:24. At 10:31 the dolphins dove 1 m in front of and under a mousse patch while remaining in slick oil. Between 10:34–10:44, the group passed through three sheen patches with little overt change in orientation except at the first sheen/slick interface. At 10:44 the dolphins began socializing just before diving under a strip of mousse at 10:45 into an extensive sheen area, where they began to separate. This degree of socializing and inter-animal spacing had not been observed during the previous 29 min.

Although the group appeared to maintain its heading throughout observations, slight deviations from course at the sheen/slick interface resulted in a reorientation rate of 17°/min (for 3 min) (Fig. 2). The reorientation rates in mousse interfaces and sheen areas were lower at 3°/min (for 3 and 7 min, respectively). Inter-animal spacing was greatest in sheen and mousse interfaces ($\bar{x} \pm$ s.d. $= 1.0 \pm 0.7$ and 1.0 ± 1.0 BL, respectively, $n = 108$ and 16) (Table 1). Inter-animal spacing decreased while in slick oil and in sheen/slick interfaces ($\bar{x} \pm$ s.d. $= 0.4 \pm 0.1$ and 0.6 ± 0.5 BL, respectively, $n = 6$ and 51). The respiration rate in sheen prior to entering the slick area was 1.5 blows/min (for 5 min) (Table 1). The blow rate increased slightly while in slick oil ($\bar{x} = 1.8$ for 17.4 min) and was highest after passing into sheen again ($\bar{x} = 2.6$ for 3.5 min).

Discussion

Field observations near the *Mega Borg* oil spill indicate that bottlenose dolphins can probably detect slick and mousse oils, but do not consistently avoid contact with most oil types except mousse. Results showed that dolphins did not avoid slick oil in most circumstances, but rather continued swimming through extensive oil areas despite what appeared to be 'cleaner' water nearby. This is similar to field observations of bottlenose dolphins in oil spills reported by other investigators near Texas (Shane, 1977; Shane & Schmidly, 1978; Gruber, 1981). It is possible that some overriding behavioral motivation, such as feeding, induced dolphins to swim through oil, or that bottlenose dolphins have become accustomed to oil due to the extent of oil-related activity in the Gulf of Mexico (over 4500 oil and gas platforms occur in US Gulf of Mexico continental shelf waters west of Alabama (Mullin *et al.*, 1991)). It is also possible that extensive slick areas were too large for dolphins to feasibly avoid.

Observations of decreased spacing between dolphins in slick and sheen/slick areas suggest that bottlenose dolphins may respond to certain detectable stimuli by swimming closer together. That inter-individual spacing was similarly greater in oil-free and sheen areas than in slicks and sheen/slick interfaces indicates that dolphins may not be able to detect sheen or are indifferent to its exposure. Narwhals *Monodon monoceros* responded to ice-breaking ships by huddling closer together, interpreted as fear/avoidance behavior (Finley *et al.*, 1990). Our observations suggest that dolphins huddled closer together possibly in response to a noxious stimulus.

Limited data of the present study may suggest that bottlenose dolphins have lower respiration rates when in oiled than in non-oiled waters, although we cannot make a final evaluation due to the small sample size. A similar respiration pattern was exhibited by a bottlenose dolphin associated with the July 1990 Apex oil spill in the Galveston Bay area of Texas. This adult female, accompanied by a newly born calf, spent significantly ($P < 0.05$) longer periods below the water surface when in oiled versus non-oiled water (Smultea & Würsig, 1991; 1992). Gray whales *Eschrichtius robustus* also tended to decrease time at the surface, respired less frequently and faster, and modified swim speeds when swimming through natural oil seep slicks (Kent *et al.*, 1981; Evans, 1982). Decreased respiration rates and longer dive durations may represent a dolphin's attempt to minimize contact with surface oil.

Bottlenose dolphins in captivity appear to respond differently to oil than non-captive animals. Trained bottlenose dolphins exposed to oil could not detect light oil sheen but could detect thick dark oil based on visual, tactile, and presumably echolocation cues (Geraci *et al.*, 1983; Smith *et al.*, 1983), consistent with field observations in this study. However, unlike the present results, captive studies showed that dolphins completely avoided surfacing in or swimming beyond slick oil after a few brief, initial tactile encounters.

Most information about the effects of oil exposure on marine mammals comes from studies of fur-bearing mammals. Studies indicate that sea otters *Enhydra lutris* exposed to the *Exxon Valdez* oil spill in 1989 experienced high incidences of emphysema, petroleum hydrocarbon toxicosis, abortion, and stillbirths (Williams *et al.*, 1990; Williams & Davis, 1995). It was suggested that skin absorption, inhalation, and ingestion were all likely to contribute to systemic accumulation of petroleum hydrocarbons. The highest rates of sea otter mortality occurred during the first three weeks of the spill, when the oil was most toxic.

The most immediate threat to cetaceans is inhalation of toxic fumes rather than absorption through skin or food, especially near the source of a fresh oil spill (Geraci & St. Aubin, 1985; Geraci, 1990; Neff, 1990). Inhalation of concentrated petroleum vapors may cause inflammation of mucous membranes, lung congestion, or even pneumonia (Hansen, 1985). Inhaled volatile hydrocarbons may also accumulate in the blood and tissues, inducing liver damage and neurological disorders (Gerci & St. Aubin, 1982). The fact that oil fumes permeated the air inside the observation plane 6–9 days after the initial spill suggests that the bottlenose dolphins observed in this study were exposed to some vapors, the volatility of which was not ascertained.

The greatest concern with regard to the observations in this study is that bottlenose dolphins did not consistently avoid entering slick and sheen oils, thereby increasing their vulnerability to potentially harmful exposure to oil chemicals. Würsig (1990) suggested that coastal dolphins and porpoises in general may be behaviorally susceptible and sensitive to stress potentially related to oil spills, simply due to their preference for restricted coastal habitats. Additional systematic studies of the behavior of dolphins and other cetaceans in and near oil spills are needed to further evaluate and interpret responses to oil. There is still much to be assessed in terms of the short- and long-term physiological effects of oil on dolphins and other cetaceans. This study contributes baseline information on the behavioral response of wild bottlenose dolphins to oil, and provides a methodological framework for gauging the reactions of cetaceans to oil spills.

Acknowledgements

We thank Larry Hansen, Gerald Scott, Keith Mullin, Wayne Hoggard, and Carol Roden of the US National Marine Fisheries Service for logistic help and advice; and the Gulf of Mexico region of the US Minerals Management Service Environmental Studies Section for releasing the Twin Otter aircraft from other duties. Anna Forest, Dagmar Fertl, and Thomas Jefferson helped with data analysis. Spencer Lynn computerized oil-dolphin distribution figures from hand drawings and helped with computer data entry, statistics, and manuscript preparation. Fred Felleman, Nathalie Patenaude, and one anonymous reviewer provided helpful comments on the manuscript. This work was supported by US National Marine Fisheries Service Contract RF-90-1113 to Bernd Würsig and the Texas A&M University Contracts and Grants Research Foundation. It represents contribution No. 20 of the Texas A&M University Marine Mammal Research Program.

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