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SHORT COMMUNICATION

AN UNUSUAL REACTION AND OTHER OBSERVATIONS OF SPERM WHALES NEAR FIXED-WING AIRCRAFT

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Introduction

Data on the reactions by cetaceans to aircraft flying overhead (or in the near vicinity) are limited (e.g., Richardson et al. 1995, Patenaude et al. 2002). This information is important for assessing potential effects of aircraft on federally protected species, such as sperm whales (*Physeter macrocephalus*) particularly in association with offshore oil and gas exploration in the northern Gulf of Mexico (NGOM) and elsewhere. As noted in the draft recovery plan for the sperm whale, "the severity of the threat is unknown for sound-producing factors (including aircraft) related to the oil and gas industry" (NMFS 2006). Sperm whales in the NGOM are well-known to occur in areas of intense oil and gas exploration and development activities (e.g., Jochens et al. 2006). Helicopters (as well as work boats) are used to transport workers to and from operating offshore platforms in the NGOM. These helicopter operations occur between the water's surface and altitudes of ~2,135 m (e.g., Daskalakis and Martone 2004). Low altitudes are flown during approaches to and departures from offshore platforms. The NOAA Fisheries currently includes in its biological opinions, a conservation recommendation that permit holders maintain helicopter traffic over the NGOM at altitudes above 305 m, if practicable, to avoid disturbance to whales and sea turtles. It is projected that an average rate of 25,000-55,000 helicopter operations will occur annually in the Central Planning Area (including the Mississippi River Delta area, a known high-use area by sperm whales, particularly females and their calves) (MMS 2006). The frequency of such flights is anticipated to continue increasing as the number of operating offshore structures increase.

Reported behavioral reactions by sperm whales to aircraft are sparse, highly variable, and largely anecdotal as summarized in Table 1. Observers since the whaling era began have noted that sperm whales tend to be skittish (Whitehead 2003). When documented, sperm whale reactions to both planes and helicopters range from no reaction (Clarke 1956, Gambell 1968, Green et al. 1992) to reactions such as increased surface intervals and dramatic behavioral changes (Clarke 1956, Fritts et al. 1983, Mullin et al. 1991, Würsig et al. 1998, Richter et al. 2003, 2006). Given the lack of supporting data for either case, it is important that these types of data are collected and consolidated into a cohesive document. Therefore, the specific objectives of our paper are to report our visual observations of sperm whale reactions to straight-line aircraft fly-bys (i.e., passes), to report a unique observation of a recognized "stress behavioral reaction" exhibited by sperm whales during an overhead circling by small fixed-wing aircraft, and to provide a summary review of published related studies.

Materials and Methods

Cetacean observations were made during a series of multi-year, line-transect aerial surveys for cetaceans conducted within 45 km from shore of the main Hawaiian Islands. Specifics of the survey protocol and general area descriptions are detailed in Mobley et al. (2000). Briefly, surveys occurred over waters less than 2,000 m in bottom depth (Mobley et al. 2000) using small aircraft (1993, Cessna 172; 1994 and 1995, Skymaster; and 1998, Partenavia) at an altitude of 245 m and a speed of 185 km/hr. Four personnel were aboard the aircraft during all flights: a pilot, a data recorder, and two observers. Time, location and altitude information were recorded in real time using a computer linked to an altimeter and global positioning system every 30 sec and manually whenever a sighting occurred. A Hi 8-mm video camera and a 35-mm camera with 300 mm telephoto lens were used to document unusual sightings and behavior.

Response (reaction or no reaction) by cetaceans during an initial pass was noted as required by the NMFS research permit obtained for the surveys. A "reaction" to the aircraft was defined as an overt change in the initially observed orientation or behavior of at least one animal in a group; for example, an abrupt dive associated with a splash or display of the tail flukes, a breach, a tail slap, etc. (similarly described by Green et al. 1992, Würsig et al. 1998, Patenaude et al. 2002). After the initial pass of a sighting, the aircraft sometimes circled over or near (usually within ~200 m lateral distance) the sighting so that observers could verify species, group size, and species composition. For the purposes of this report, "adult" refers to non-calf whales.

TABLE 1. *Summary of available information on reactions of sperm whales to low altitude overflying aircraft.*

Location	*Aircraft*	*Altitude (m)*	*Behavior Description*	*Reference*
the Azores	Sikorski S55 helicopter	~4.6-27 m	4 sperm whales marked with 'Discovery-type' marks shot from a standard rifle during two different flights; apparent "unconcern" until a down-draught of rotors caused much agitation of the water, causing the whales to quickly dive and simultaneously defecate	Clarke (1956)
South Africa	Cessna 310H	~150 m	Whales seemed unaware of aircraft flying overhead (number not specified)[a]	Gambell (1968)
northern Gulf of Mexico	Beechcraft (Model AT-11)	alternating altitudes of 91 m and 229 m	Circling often (number not specified) disturbed whales by causing changes in direction, dive patterns, and increased speed of movement; one observation of breaching possible response	Fritts et al. (1983)
northern Gulf of Mexico	Twin Otter	~230 m	Some (number unspecified) whales affected by flyovers and dove immediately while other animals remained at the surface	Mullin et al. (1991)
Oregon and Washington	DeHavilland Twin Otter	~65 m	No reaction by 24 observed groups	Green et al. (1992)
northern Gulf of Mexico	Twin Otter	Usually ~230 m	7 (28%) of 25 groups changed behavior when approached to within 305 m	Würsig et al. (1998)
the Bahamas	Cessna 172	50-245 m	Group of six sperm whales (including one calf) closed ranks and one whale turned on its side to apparently look up towards aircraft circling overhead	C. MacLeod, pers. comm., Beaked Whale Research Project, University of Aberdeen, Lower Right, 59 Jute Street, Aberdeen, AB24 3EX, U.K.
Kaikoura, New Zealand	Fixed-wing aircraft	Aircraft recorded as present when flying circular pattern at least 150 m above whale(s)	Study of impacts of aircraft-based whale-watching on male sperm whales from small vessel (n=116) and from shore (n=29). Transient males delayed time to first click (vocalization) and reduced surfacing time near aircraft, while residents slightly increased their surface time near aircraft. No alteration of frequency of heading changes by residents or transients. Results indicated aircraft presence combined with other factors (e.g., season, year) contributed to slight changes in behavior.	Richter et al. (2003, 2006)
Kauai, Hawaii	Cessna 172, Skymaster, Partenavia	~233-269 m	3 of 8 groups (<360 m lateral distance) reacted to fly-by by abruptly diving. One group of 11 (including one calf) closed flanks, slowed down, formed a reverse marguerite with calf in middle, then dove while aircraft circled overhead for 6 min.	Present study

[a] *General statement based on review of daily diaries kept by pilots operating spotting aircraft associated with whaling operations during 1966, 1967 and 1968.*

Results

Data were obtained from observations of 24 sperm whale groups totaling 109 individuals (mean = 4.6 whales, sd = 5.3, range 1-20). An additional three sightings with no lateral distance data were excluded from analyses; none of these groups demonstrated a visible reaction to the aircraft. Nine calves were sighted in six of the 24 groups. Most (n = 13) of the 24 sightings were made from the Skymaster, 10 from the Partenavia, and 1 from the Cessna. During initial passes, aircraft altitude ranged from 233-269 m and lateral distance to whale sightings ranged from 103-3,427 m (n = 24).

Responses to aircraft passes

A reaction to the initial pass of the aircraft was observed during three (12%) of 24 sightings: two from the Skymaster (both single adult whales) and one from the Cessna 172 (a group of four adult whales). All three reactions consisted of a hasty dive and occurred < 360 m lateral distance from the aircraft. Of the eight groups seen < 360 m lateral distance from the aircraft, three (38%) reacted to the passing aircraft; no reactions were noted for the remaining 16 sightings at lateral distances > 360 m from the aircraft (n = 21). No reaction was observed during the two closest (103 m and 208 m lateral distance) initial passes (both by the Skymaster) (Figure 1A). However, a reaction by the closest of these initial sightings (103 m lateral distance) occurred during a subsequent resighting 3 min later while the Skymaster circled overhead. This response is described below and is based primarily on Hi 8-mm video, photographs, and field notes.

Response to circling aircraft

While surveying at 235 m altitude (50 km north of Kaua'i), a single sperm whale was sighted from the Skymaster and no reaction to the initial pass was seen. Subsequently, the aircraft turned to estimate group size and confirm species identification. During this time, the aircraft increased altitude and began circling the location of this individual to look for more animals. About 3 min later, a group of 11 sperm whales (10 adults plus 1 calf) surfaced in the same area. The aircraft continued circling this group for ~ 6 min at distances of 0-500 m (laterally) and altitudes of 245-335 m. All whales were visible at or near the water's surface throughout most of the observations. One adult estimated to be ~ 1/3 longer than the other adults and not associated closely with the calf was assumed to be a mature male (bull) based on its relative body length (Rice 1989). After the aircraft circled overhead for about 4 min, the whales ceased forward movement, moved closer together in a parallel flank-to-flank formation (Figure 1B), and formed a fan-shaped semi-circle with heads facing out and flukes toward the middle of the semi-circle (Figure 1C). The bull was on the left outer edge of the semi-circle and the calf remained near the middle of the group. Maximum distance between individuals over the course of the observation decreased from about six body lengths to one, thereby, concentrating the group as a whole around the calf. During this time, one whale was seen on its side with its mouth agape. The entire episode lasted about 9 min from initial sighting to the unique behavioral observation.

Discussion

We interpreted the aforementioned group's formations as an agitation, distress, and/or defense reaction to our circling aircraft. This interpretation is based upon behavioral events displayed by sperm whales in situations of distress, reacting to perceived or actual threats, such as killer whales (*Orcinus orca*) (e.g., Arnbom et al. 1987, Pitman et al. 2001), false killer whales (*Pseudorca crassidens*) (Palacios and Mate 1996), short-finned pilot whales (*Globicephala macrorhynchus*) (Weller et al. 1996, Pitman et al. 2001), sharks (Best et al. 1984), whalers (Nishiwaki 1962, Caldwell et al. 1966, Berzin 1971), and vessel approaches (Palacios and Mate 1996). The characteristic responses to killer whales are individuals coming to the surface, swimming fast toward one another, and clustering actively and tightly (Whitehead 2003), similar to the behavior we observed. The semi-circle "fan" formation we describe is similar to defensive "marguerite"- and "spindle"-like formations reported by other researchers (Nishiwaki 1962, Berzin 1971, Arnbom et al. 1987, Weller et al. 1996, Pitman et al. 2001). Weller et al. (1996) observed open-mouth behavior (akin to our observation) by sperm whales, and interpreted this as a discrete distress response to harassment by short-finned pilot whales, based on obvious distress behavior reported by other researchers. In our observations, the mouth agape may have been a distress response to our aircraft. This same whale was swimming on its side, possibly to look up at the aircraft.

The tight parallel formation we observed is often a precursor to socializing events (during which animals huddle together and rub against each other), but also to defensive responses such as the fan formation we observed (D.M. Palacios, NMFS/Pacific Fisheries, Environmental Laboratory, Pacific Grove, California, pers. comm.). Thus, huddling may provide an opportunity for information transfer and reassurance between group members. For the group we observed, this behavior might have increased defensive capabilities by minimizing exposure of the flanks (particularly the calf) to a perceived threat. Similar behaviors by a group of six sperm whales (including one calf) in the Bahamas occurred when a Cessna 172 passed, then circled directly over the group at an altitude of about 50-245 m (C.D. MacLeod, Beaked Whale Research Project, Lower Right, Aberdeen, AB24 3EX, United Kingdom, pers. comm.). The group closed ranks and one individual turned on its side to apparently look up towards the aircraft.

In general, it is difficult to identify behavioral reactions during brief observation periods such as short overflights by aircraft; furthermore, some subtle changes in behavior (i.e., in respiration) are not evident without statistical analysis (e.g., Richardson et al. 1995). Thus, it is possible that sperm whales we observed may have exhibited reactions we did not recognize or see because they occurred after we had passed.

Reactions of sperm whales to perceived threat stimuli may be context dependent. Berzin (1971) described three separate fright reactions related to the level of the perceived threat: dive, aggregate at surface, and flight/flee. Pitman et al. (2001) further suggested that sperm whales often dive in the presence of boats (perhaps a mild response) vs. aggregate if the threat is immediate, forming a rosette when groups are small (typically < 9 whales). The three apparent dive responses we reported may have been a "mild fright" response to the brief passes by our aircraft. In contrast, the two group formations we described appear to have been fright responses to persistent overhead circling by the aircraft and resemble the "spindle" group formed in response to an immediate perceived threat (Pitman et al. 2001).

Received sound levels of our aircraft near sperm whale

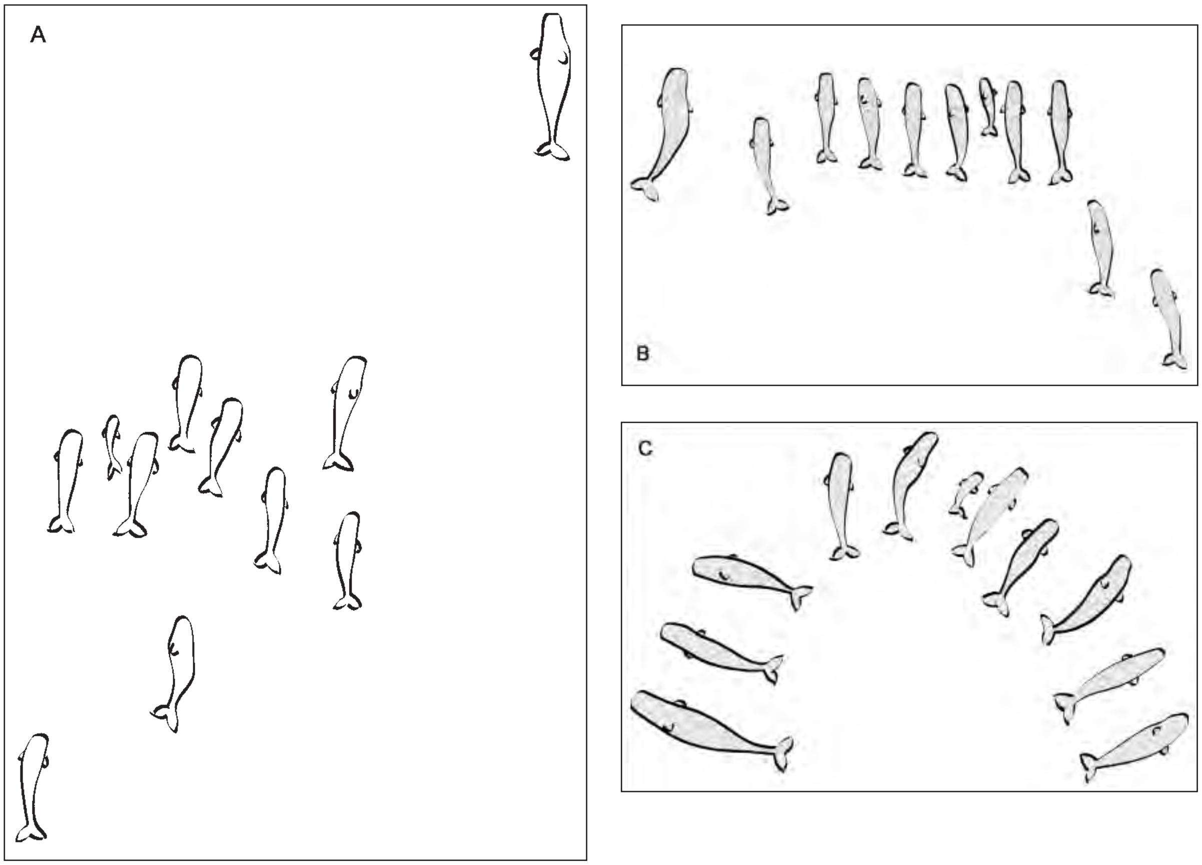

Figure 1.
Chronological group formations exhibited by a group of 11 sperm whales (including one bull and one calf) while a Skymaster aircraft circled overhead on 9 April 1994 from 1146h to 1155h (see text):
(A) No reaction, 1151h;
(B) Flank to flank parallel formation, 1153h;
(C) Semicircle formation, 1154h. Scale is approximate.

sightings were not available, and cannot be realistically calculated for our data, given the variation and complexities involved in estimating aircraft-to-surface and sub-surface sound propagation (see Richardson et al. 1995). However, available data indicate that the expected frequency range and dominant tones of sound produced by our aircrafts overlap with the known low-end frequency range of sperm whale vocalizations (< 0.1 to 30 kHz; see summaries by Richardson et al. 1995 and Ketten 1998). Snell's Law predicts a 26° sound cone from the vertical for the transmission of sound from air to smooth-surface water (Urick 1972, Richardson et al. 1995). The angle of this cone becomes greater in Beaufort wind force > 2. Based on altitudes, the group of 11 sperm whales with the unusual reaction described above presumably received both acoustic and visual cues (the aircraft and/or its shadow) from the circling aircraft, as they were located directly under the aircraft and/or well within Snell's predicted sound cone. The other 24 sperm whale groups that were passed once by our aircraft were outside (104–3,427 m lateral distance) the theoretical 26° sound cone (lateral distance 54–62 m); however, whales near this sound cone (within roughly several hundred meters) may have heard the overflying aircraft via scattering associated with the rough sea surface at the time (Beaufort wind force 3-4).

Based on other studies of cetacean responses to sound (Richardson et al. 1995, Patenaude et al. 2002), we believe that our observed reactions to brief overflights by the aircraft were short-term and probably of no long-term biological significance. Although isolated occurrences of this type are probably not biologically significant, repeated or prolonged exposures to aircraft overflights have the potential to result in significant disturbance of biological functions, especially in important nursery, breeding or feeding areas (Richardson et al. 1995). Activities involving aircraft that might result in harassment of sperm whales include military training exercises, helicopter overflights associated with offshore oil and gas exploration and development (for example, in the NGOM), recreational/ecotourism flights (for example, off Hawaii and New Zealand) and research surveys.

This limited description sheds light on the need to systematically document behavioral responses by cetaceans to aircraft, particularly by protected species, such as the endangered sperm whale. There is also a need to document received sound levels of aircraft by whales, and to record and compare whale behavior before, during and after controlled overflights, ideally of the same individual(s), to provide increased statistical power to account for the inherent variation among individuals. The latter approach has been used during land-based observations of humpback whales circled by research aircraft near Hawaii (Smultea et al. 1995) and to some extent from land-based sites and small vessels where sperm whales occur near shore (Richter et al. 2003). It is typically difficult to determine the reactions of cetaceans to overflights, since most observations have been from the disturbing aircraft itself (Richardson and Würsig 1997) or a small nearby vessel. These observation platforms limit and potentially confound what can be observed, and can preclude isolated comparison of behavior before, during, and after aircraft disturbance. Such data could also be collected by tracking whales with non-invasive tags (such as the D-tag developed by Johnson and Tyack 2003) capable of recording received sound levels and water depth among other data (such as changes in orientation of the animal in the water); this technique could ideally be combined with non-intrusive behavioral observations (e.g., theodolite tracking from shore).

In summary, based on our and others' observations, the biological significance or consequences of the potential impact of aircraft overflights on cetaceans warrants further, ideally systematic studies. These studies should be conducted with the following goals: consideration with respect to environmental planning purposes; implementation of monitoring and mitigation measures; and deliberation in decision-making regarding regulations affecting marine mammals.

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