Hawaiian Melon-headed Whale *(Peponacephala electra)* Mass Stranding Event of July 3-4, 2004

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Photo by Gretchen Johnson

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA Technical Memorandum NMFS-OPR-31
April 2006

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April 2006

U.S. Department of Commerce
Carlos Gutierrez, Secretary

National Oceanic and Atmospheric Administration
Vice Admiral Conrad C. Lautenbacher, Jr. USN (Ret),
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National Marine Fisheries Service
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Suggested citation:

Southall, B. L., R. Braun, F. M. D. Gulland, A. D. Heard, R. W. Baird, S. M. Wilkin and T. K. Rowles. 2006. Hawaiian melon-headed whale (*Peponocephala electra*) mass stranding event of July 3-4, 2004. NOAA Technical Memorandum NMFS-OPR-31. 73 pp.

A copy of this report may be obtained from:

Office of Protected Resources
NOAA, NMFS, F/PR2
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Silver Spring, Maryland 20910

Or online at:

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Executive Summary

On July 3-4, 2004, between 150-200 melon–headed whales (*Peponocephala electra*) occupied the shallow waters of Hanalei Bay, Kauaʻi, Hawaiʻi for over 28 hours. Attendees of a canoe blessing observed the animals entering the Bay in a single wave formation at 0700 hrs[1] (local time) on July 3, 2004. The animals were observed moving back into shore from the mouth of the Bay at 0900 hrs. The usually pelagic animals milled in the shallow confined bay and were returned to deeper water with human assistance. The animals were herded out of the Bay with the help of members of the community, the Hanalei Canoe Club, local and federal employees, and volunteers/staff with the Hawaiian Islands Stranding Response Group beginning at 0930 on July 4, 2004 and were out of visual sight by 1030 hrs.

Only one animal, a calf, was known to have died (on July 5, 2004) following this event. The animal was noted alive and alone in the Bay on the afternoon of July 4, 2004 and was found dead in the Bay the morning of July 5, 2004. On July 7, 2004, a full necropsy, magnetic resonance imaging, and computerized tomography examination were performed on the calf to determine the manner and cause of death. The combination of imaging, necropsy and histological analyses found no evidence of infectious, internal traumatic, congenital, or toxic factors. Although cause of death could not be definitively determined, it is likely that maternal separation, poor nutritional condition, and dehydration contributed to the final demise of the animal. Although we do not know when the calf was separated from the female, the movement into the Bay, the milling and re-grouping may have contributed to the separation or lack of nursing especially if the maternal bond was weak or this was a primiparous calf.

Environmental factors, abiotic and biotic, were analyzed for any anomalous occurrences that would have contributed to the animals entering and remaining in Hanalei Bay. The bathymetry is similar to many other sites within the Hawaiian Island chain and dissimilar to that which has been associated with mass strandings in other parts of the U.S. The weather conditions appear to be normal for this time of year with no fronts or other significant features noted. There was no evidence for unusual distribution or occurrence of predator or prey species, or unusual harmful algal blooms. Weather patterns and bathymetry that have been associated with mass strandings elsewhere were not found to occur in this instance.

This event was spatially and temporally correlated with Rim of the Pacific Exercises (RIMPAC) which is a biennial, sea control/power projection fleet exercise that has been conducted since 1968 and involves U.S. forces and forces from various Rim-of-the-Pacific nations. Official sonar training and tracking exercises in the Pacific Missile Range Facility (PMRF) warning area did not commence until approximately 0800 hrs (local time) on July 3 and were thus ruled out as a possible trigger for the initial movement into the Bay.

However, the six naval surface vessels transiting to the operational area on July 2 intermittently transmitted active sonar [for ~ 9 hours total from 1315 to 0030] as they approached from the south. The potential for these transmissions to have triggered the whales' movement into Hanalei Bay was investigated. Analyses with the information available indicated that animals to the south and east of Kauaʻi could likely have detected active sonar transmissions on July 2, and reached Hanalei Bay on or before 0700 on July 3,

[1] This time is set by reliable observations and a canoe blessing ceremony

2004. However, data limitations regarding the position of the whales prior to their arrival in the Bay, the magnitude of sonar exposure, behavioral responses of melon-headed whales to acoustic stimuli, and other possible relevant factors preclude a conclusive finding regarding the role of sonar in triggering this event. Propagation modeling suggest that transmissions from sonar use during the July 3 exercise in the PMRF warning area may have been detectable at the mouth of the Bay. If the animals responded negatively to these signals, it may have contributed to their continued presence in the Bay. The U.S. Navy ceased all active sonar transmissions during exercises in this range on the afternoon of July 3, 2004. Subsequent to the cessation of sonar use, the animals were herded out of the Bay.

While causation of this stranding event may never be unequivocally determined, we consider the active sonar transmissions of July 2-3, 2004, a plausible, if not likely, contributing factor in what may have been a confluence of events. This conclusion is based on: (1) the evidently anomalous nature of the stranding; (2) its close spatiotemporal correlation with wide-scale, sustained use of sonar systems previously associated with stranding of deep-diving marine mammals; (3) the directed movement of two groups of transmitting vessels toward the southeast and southwest coast of Kauaʻi; (4) the results of acoustic propagation modeling and an analysis of possible animal transit times to the Bay; and (5) the absence of any other compelling causative explanation. The initiation and persistence of this event may have resulted from an interaction of biological and physical factors. The biological factors may have included the presence of an apparently uncommon, deep-diving cetacean species (and possibly an offshore, non-resident group), social interactions among the animals before or after they entered the Bay, and/or unknown predator or prey conditions. The physical factors may have included the presence of nearby deep water, multiple vessels transiting in a directed manner while transmitting active sonar over a sustained period, the presence of surface sound ducting conditions, and/or intermittent and random human interactions while the animals were in the Bay.

MASS STRANDING EVENT IN HANALEI BAY, KAUA‘I, JULY 3-4, 2004

Introduction

On July 3-4, 2004, between 150 and 200 melon–headed whales (*Peponocephala electra*) occupied the shallow waters of Hanalei Bay, Kaua‘i, Hawai‘i for over 28 hours. The group was observed by attendees of a canoe blessing quickly entering the Bay as a wave across the mouth of the Bay with animals side by side at 0700 hrs[2] (local time) on July 3, 2004. The animals made at least one movement out of the Bay before 0900 because they were observed moving back to shore from the mouth of the Bay at 0900 hrs by a life guard reporting for duty (Souza, interview with life guard). Once back in the Bay, the animals exhibited spy hopping and tail slapping behaviors, as well as vocalizations. The usually pelagic animals stayed in the shallow, confined Bay and were returned to deeper water with human assistance. With the help of volunteers and staff of the Hawaiian Islands Stranding Response Group, the Hanalei Canoe Club, community members and the federal and state authorities, the group of animals was herded out of the Bay beginning at 0930 on July 4, 2004 and was out of visual sight by 1030 hrs. On the afternoon of July 4, a lone animal was observed swimming in the Bay. A melon-headed whale calf was found dead in Hanalei Bay on July 5, 2004 and the carcass was flown to California for scanning and necropsy, which occurred on July 7, 2004. This event was coincident with military training exercises in the Hawaiian Islands, and therefore immediate interaction between the National Marine Fisheries Service and the US Navy commenced on the day of the event initiation. By evaluating factors for which there was information, this investigation focused on the overall event and its three sub-portions: 1) Why did the animals move into the Bay?; 2) Why did the animals remain in the Bay?; and 3) Why did the calf die?

[2] This time is set by reliable observations and a canoe blessing ceremony

Background on species and sightings

Melon-headed whales (*Peponocephala electra*) are small odontocetes found in tropical and warm-temperate waters throughout the world (Perryman *et al.*, 1994) with a general distribution from 20°S to 20°N (Jefferson and Barros, 1997). Melon-headed whales prefer deep, equatorial ocean waters (Watkins *et al.*, 1997), and are thought to feed deep in the water column because one of their primary prey, mesopelagic squid, are found in waters up to 1,500 m (4,920 ft) deep (Jefferson and Barros, 1997). Most knowledge about the biology of this species comes from mass strandings (Perryman *et al.*, 1994).

Melon-headed whales have been seen over a range of depths (255-4,407 m) off all the main Hawaiian Islands (Shallenberger, 1981; Baird *et al.*, 2003; Huggins *et al.*, 2005). An analysis of sighting distribution in relation to effort from 2000-2005 indicates that melon-headed whales in Hawai‘i are found more frequently in depths greater than 2,000 m (Huggins *et al.*, 2005). Huggins *et al.* (2005) reported that only one of 18 encounters with melon-headed whales occurred off the island of Kaua‘i in these surveys (Table 1). However only about 11% of the total search effort was off that island, and much of the search effort was in relatively shallow water (Baird, unpublished). Aerial surveys for humpback whales from 1993-1999, reported only three sightings with a total number of 127 animals observed (Mobley *et al.*, 1999a). From 2001 – 2004 the same surveyors reported only one sighting of 10 individuals (Mobley 2001, 2002, 2003, 2004). However, discriminating between melon-headed whales and pygmy killer whales in the field is difficult and may have lead to misidentifications in these aerial surveys.

Median melon-headed whale group size around the main Hawaiian Islands from boat-based surveys was 305 individuals, with a range from 17-800 animals (Huggins *et al.*, 2005). Watkins *et al.* (1997) reported groups of only 10-14 for the Caribbean. Although no studies of social organization have been undertaken, it appears that large groups tend to consist of many closely-spaced subgroups (Jefferson and Barros, 1997) that come together to socialize or for calving. Melon-headed whales are often seen with other species of cetaceans, including Fraser's dolphins (*Lagenodelphis hosei)* (Mullin *et al.*, 1994), rough-toothed dolphins (*Steno bredanensis*) (Huggins *et al.*, 2005), and short-finned pilot whales *(Globicephla macrorhynchus)* (Migura and Meadows, 2002). Little is known about this species elsewhere in its range, due to its inaccessibility and apparent avoidance of vessels (Huggins *et al.*, 2005).

Two abundance estimates have been reported from Hawaiian waters. Based on a shipboard line-transect survey of the entire Hawaiian Islands Exclusive Economic Zone (EEZ) in 2002, Barlow (2006) calculated an estimate of 2,950 melon-headed whales in Hawaiian waters, though the estimate is very imprecise (CV = 1.17). Data from 12 aerial surveys in 1993, 1995, and 1998, were used to estimate abundance, resulting in an estimate of only 154 melon-headed whales (CV = .88) (Mobley *et al.*, 2000). This study underestimated the total number of melon-headed whales within the U.S. EEZ off Hawai‘i, because areas around the Northwestern Hawaiian Islands (NWHI) and beyond 25 nautical miles (46.3 km) from the main Hawaiian Islands were not surveyed. Since melon-headed whales are found more frequently in waters deeper than 2,000 m, the aerial surveys likely covered only the inshore

Table 1. Search effort by island area from Baird/Cascadia Research small-boat surveys (Huggins *et al.*, 2005; Baird, unpublished). Effort is greatest and in deeper water off the island of Hawai‘i than around other islands, which is reflected in differences in number of sightings.

Island area	Dates	# km on effort	# days effort	# hrs on effort
Hawai‘i	Apr 2002	1,089	10	75
	Sep/Oct 2002	1,649	20	154
	May 2003	1,791	15	108
	Oct 2003	2,495	24	173
	Sep-Dec 2004	4,656	42	290
	Jan/Feb 2005	2,089	17	124
	Sub-total	13,769	128	922
Kaua‘i/Ni‘hau	May/Jun 2003	3,222	24	195
	Oct/Nov 2005	2,194	24	145
	Sub-total	5,416	48	340
Maui/Lana‘i	Feb -Apr 2000	1,600	23	158
	Nov/Dec 2000	2,032	21	150
	Jan-Mar 2001	2,102	28	203
	Apr 2002	785	9	64
	May 2003	1,659	16	107
	Sub-total	8,178	97	682
O‘ahu	Apr/May 2002	860	9	57
	May 2003	1,789	13	111
	Sub-total	2,649	22	168
Total		**30,012**	**295**	**2,114**

part of the range of this population. Ongoing photo-identification efforts from 2000-2005 have documented over 300 distinctive individual melon-headed whales from around the main Hawaiian Islands (Huggins *et al.*, 2005). Photographs are available for a mark-recapture population estimate around the main Hawaiian Islands, but these analyses have not yet been undertaken (Baird, unpublished). Inter-island movements from Kaua‘i to Hawai‘i have been documented based on photo-identified individuals, and genetic samples from at least 82 animals are available for future stock structure analyses (Baird, unpublished). Even though increased attention has been paid to this species in recent years, detailed information about the population structure and abundance of these animals is still largely unknown (Huggins *et al.*, 2005).

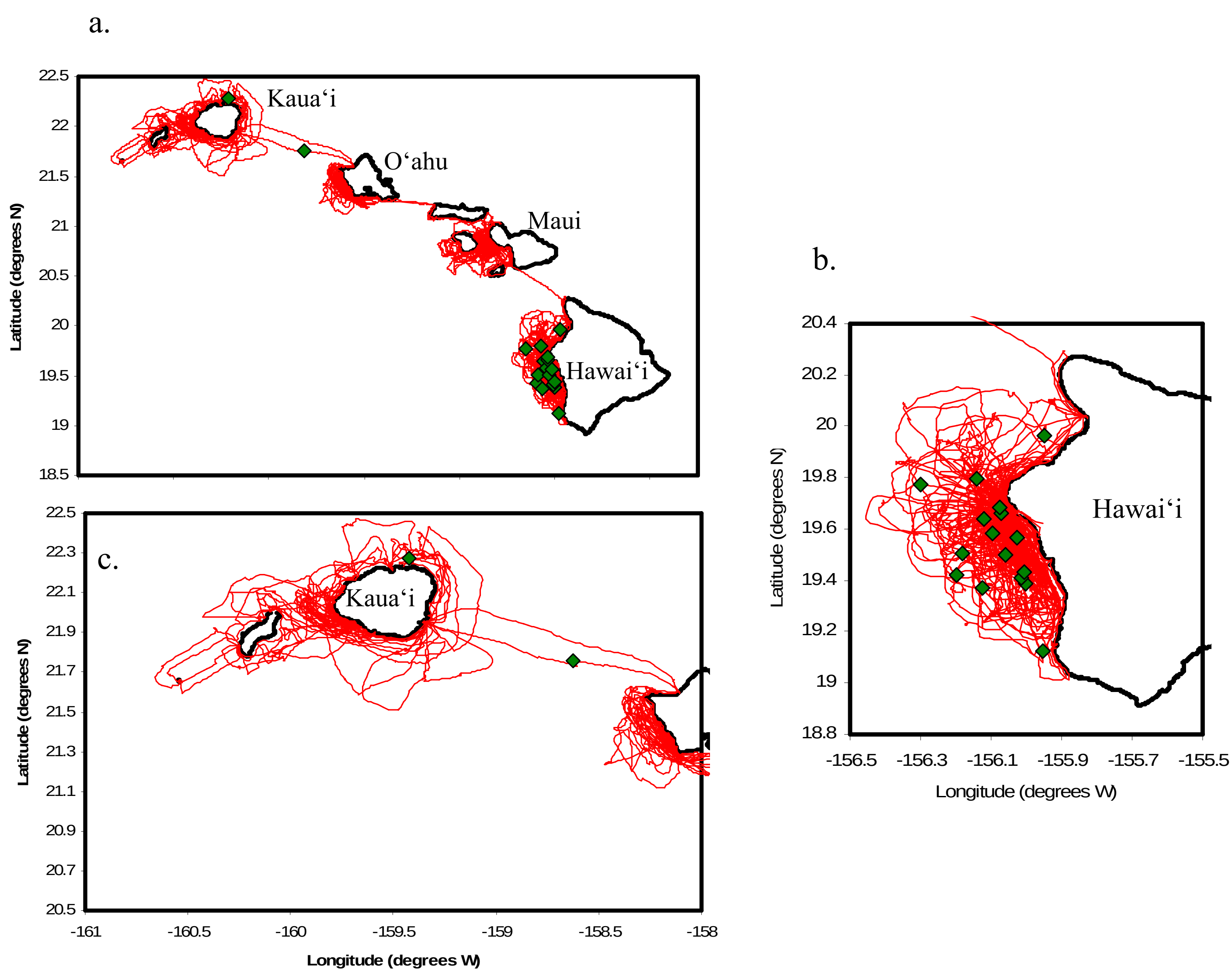

Figure 1. Maps showing distribution of melon-headed whales (green diamonds) and survey effort (red lines) from small boat surveys a) around the main Hawaiian Islands, b) off the coast of Hawai'i, and c) off the coast of Kaua'i from 2000 through 2005 (Baird, unpublished).

Historical Strandings

Marine mammals that mass strand are usually more social and pelagic animals which are often less accustomed to shallow or in-shore habitats (Geraci and Lounsbury, 1993; 2005). The causes of mass strandings are varied and more often than not unexplained. They may occur when animals move into shallow waters following specific weather or oceanographic events, extreme tidal events, predator detection at the outlet of the area, due to illness or injury of individuals, when animals become trapped or confused chasing prey, or the effort of a group to help an already injured or stranded member.

Minimum Number	Date	Location	Scenario	References
60	1841	Hilo Bay, Hawai'i	Animals driven ashore	CDD; Peale 1848; Tomich 1986
109	Oct 1957	Heng-chun, Taiwan	Live Stranding	Yang 1964, 1976; Wang *et al.* 2001
150	Aug 1958	Crowdy Heads, Australia	Live Stranding	Dawbin 1963; Dawbin *et al.* 1970; Noble and Fraser 1970
4	Apr 1964	Palmyra Atoll, Line Islands	Stranding	Brownell *et al.* 2006
250	23 Mar 1965	Suruga Bay, Japan[3]	Animals in bay; driven ashore	Nishiwaki and Norris 1966
231	Nov 1972	Malekula Island, Vanuatu	Live Stranding	Rancurel 1973,1974; CSLP 1973
6	Sep 1974	Aldabra Atoll, Seychelles	Stranding Questionable	Best & Shaughnessy 1981; Leatherwood *et al.* 1991.
87	11 Aug 1976	Moreton Island, Queensland, Australia	Large # animals nearshore; Live Stranding	Bryden *et al.* 1977; Bannister *et al.* 1996; Cannon 1977.
148	13 Oct 1976	Playa Tambor, Costa Rica	2000 animals in bay; Stranding	Lodi *et al.* 1990
135	6 Jan 1982	Aoshima Beach, Japan	Live Stranding	Miyazaki 1983; Morimitsu 1983
240	16 Apr 1987	Piracanga Beach, Brazil	Live Stranding	Da Silva *et al.* 1987; Lodi *et al.*1990; Siciliano *et al.* 1987.
30	19 Feb 1990	Akashi Beach, Japan	Live Stranding	Brownell *et al.* 2006
5	Nov 1993	Kwajelein Atoll, Marshall Islands	Animals in lagoon 1-2 wks prior; Live Stranding	Reeves *et al.* 1999
6	Before Oct 1994	Lembel Strait, Indonesia	Stranding	Rudolph *et al.* 1997
7	Nov 1995	Point Plomer, New South Wales, Australia	Live Stranding	Bannister *et al.* 1996
120	Dec 1997	Eurong Beach, Fraser Island, Australia	Live Stranding	Anonymous 1999.
3	17 Feb 1998	Playa Tucacas, Venezuela	Live Stranding	Bolanos and Villarroel 2003.
50	11 Feb 2001	Hasaki, Japan	Live Stranding	Cetacean News 2001
15	14 Feb 2001	Oarai, Japan	Live Stranding [some of same animals as 11 Feb]	Brownell *et al.* 2006.
171	10 Mar 2001	Nakatane, Japan	Live Stranding	Brownell *et al.* 2006
91?	24-25 Feb 2002	Hasaki, Japan	Live and Dead Stranding	Brownell *et al.* 2006

[3] It was reported that 500 animals came into the bay and half were captured. Other details unknown.

150+	3 Jul 2004	Hanalei Bay, Hawai'i[4]	Live Stranding	This report
9	1 Nov 2005	Sal Island, Cape Verde Archipelago	Live Stranding	Brownell *et al.* 2006
26	22 Jan 2006	Asahi, Japan	Live Stranding	Brownell *et al.* 2006
3	22 Feb 2006	Ichinomiya and Isumi, Japan	Live Stranding	Brownell *et al.* 2006
120	28 Feb 2006	Ichinomiya, Japan	Live Stranding	Brownell *et al.* 2006
5	26-29 Mar 2006	Vero Beach and Hutchinson Island, Florida	> 20 animals nearshore; live and dead stranding	NMFS stranding database

Table 2. List of melon-headed whale (*Peponocephala electra*) mass strandings worldwide, as recorded in the Cetacean Distribution Database, National Museum of Natural History, Smithsonian Institution.

Melon-headed whales are known to strand both in single stranding events and in mass stranding events in numbers of 100 or more individuals per event (Miyazaki *et al.*, 1995). A mass stranding is an event which involves two or more cetaceans (excluding female/calf pairs) which are found ashore alive or dead and which are spatially and temporally correlated (Wilkinson, 1991; Geraci and Lounsbury, 1993). Table 2 provides a list of mass stranding events of more than three individuals of melon headed whales using data obtained from cited references, the Cetacean Distribution Database (Smithsonian Institute), and Brownell *et al.* (2006). A recent report (Brownell et al, 2006) lists a total of 25 mass stranding events or near mass stranding events from 1841 to 2006 including this event with 6 of those events reported after 2004 (Table 2). In many cases, actual beach mass strandings for this species are preceded by large numbers of live animals near shore or in bays or lagoons. The actual number of animals that beach stranded or died in these events has ranged from 4 to 250 animals. At least 50% of the reported mass strandings have included more than 100 animals per event. Mass stranding events were documented involving more than 200 melon-headed whales on Piracanga Beach, Brazil in 1987 (Da Silva *et al.,* 1987) and 231 animals in Malekula Island, Vanuatu in 1972 (Rancurel, 1973). There was one additional mass event in Hawaii in 1841 which was described as animals driven ashore in Hilo Bay, Hawai'i (Peale, 1848). The only other mass events involving 3 or more of this species in the United States were animals that were seen close to the shores of Sebastian, Florida on March 26, 2006 and 5 animals that stranded on Vero Beach and in Stuart, Florida on March 29, 2006.

Historically, of the 17 species of cetaceans regularly documented around the main Hawaiian islands, the most commonly stranded species in Hawai'i are the humpback whale (*Megaptera novaeangliae*), the spinner dolphin (*Stenella longirostris),* the pygmy sperm whale (*Kogia breviceps*), the striped dolphin *(Stenella coeruleoalba),* and the sperm whale *(Physeter macrocephalus)*[5]. Melon headed whales are not a common species to strand in Hawai'i, with

[4] This is considered a live stranding.
[5] These data were obtained from the Cetacean Stranding Database, compiled by National Marine Fisheries Service, Office of Protected Resources, NOAA.

Minimum Number	Date	Location	Scenario	Sources
60	1841	Hilo Bay, Hawai‘i	Animals driven ashore	CDD; Peale 1848; Tomich 1986
1	Before 1875	Hawai‘i	Unknown	True 1889; Van Beneden and Gervais 1880
1	24 Mar 1955	Wailupe Circle, O‘ahu	Stranding	CDD; Shallenberger 1981
1	27 Jun 1964	Kahuku, O‘ahu	Stranding	CDD; Nishiwaki and Norris 1966; Dawbin, Noble and Fraser 1970.
1	15 Jun 1965	Lahaina, Maui	Stranding	CDD; Nishiwaki and Norris 1966; Maldini *et al.* 2005
1	17 Dec 1966	Off Mahukona, Hawai‘i	Capture	Anon 1966
1	27 Aug 1971	Keehi Lagoon, O‘ahu	Stranding	CDD; Shallenberger 1981
1	17 Sep 1971	Kahuku, O‘ahu	Stranding	CDD; Shallenberger 1981
1	14 Jul 1976	Punaluu, O‘ahu	Dead Stranding	CDD; SEAN 2001
1	26 Sep 1978	12 miles off Waianae, O‘ahu	Capture	CDD
1	26 Oct 1978	15 miles off Pokai Bay, O‘ahu	Capture	RLB
1	12 Aug 1982	Kihei, Maui	Stranding	RLB
1	Jun 1983	Makaha, O‘ahu	Stranding	Nitta 1991; Maldini *et al.* 2005
1	26 Aug 1985	Mokuleia, O‘ahu	Live Stranding	CDD; Consiglieri 1985; Maldini *et al.* 2005
1	24 Mar 1986	Paia, Kuau Bay, Maui	Dead Stranding	CDD; Consiglieri 1986; Maldini *et al.* 2005
1	15 Oct 1988	Mokueia, O‘ahu	Stranding	Nitta 1991; Maldini *et al.* 2005
1	10 Jan 1993	Ko Olina Resort, O‘ahu	Dead Stranding	CDD; NMFS 1993; Maldini *et al.* 2005
1	Jun 1995	Brennecke's Beach, Kaua‘i	Stranding	Maldini *et al.* 2005
1	May 1996	Makaha, O‘ahu	Stranding	Maldini *et al.* 2005
1	11 Apr 1998	Keauhou Bay, Hawai‘i	Live Stranding	Maldini *et al.* 2005
1	10 Sept 2001	Mokuleia, O‘ahu	Stranding	NMFS Stranding Database; Maldini *et al.* 2005
2	19 Aug 2003	Hauula Beach, O‘ahu	Live Stranding	NMFS Stranding Database
1	25 Aug 2005	Waimanalo, O‘ahu	Stranding	NMFS Stranding Database

Table 3. List of melon-headed whale (*Peponocephala electra*) strandings and captures in Hawai‘i as recorded in the Cetacean Distribution Database, National Museum of Natural History, Smithsonian Institute and the Marine Mammals Stranding Database, National Marine Fisheries Service. This table also includes captures from near shore waters as a minimal indication of species presence in near shore waters.

only 17 confirmed strandings of 18 individuals recorded for all the Hawaiian islands from 1964 to 2005 (Table 3 and Fig. 2)[6]. However, there was no major effort to report strandings until the late 1970s, and even then, there was not continuous consistent effort for detection or reporting of marine mammal strandings through the 1980s and early 1990s. From the mid-1990s to present there has been an organized network and regional attention paid to consistent reporting and documentation of strandings. From 1995 to 2005 (excluding this event), 7 individual melon headed whales have been reported stranded, 5 on Oʻahu, 1 on Kauaʻi, and 1 on Hawaiʻi. It must be noted that in the historic reports, most strandings have occurred on Oʻahu which has had more consistent historical reporting effort. Previously there have been three mass events involving melon-headed whales reported in Hawaiʻi, a suspected drive fishery or hunt in 1841 in which 60 whales were driven ashore by natives in Hilo Bay, Hawaiʻi (Peale, 1848), a capture of two individuals in 1978 in Oʻahu, and a live stranding of two adult males in August 2003 in Oʻahu. The exact details of the animals in the 1841 event milling in shallows or near shore before the capture or drive are unknown. Despite records of melon-headed whale strandings elsewhere in the world, there has been only one other mass event in the United States in the last thirty years. Therefore, the Hanalei Bay stranding event of 2004 was anomalous for the U.S.

[6] These data were obtained from the Cetacean Distribution Database, compiled by the Marine Mammal Program, National Museum of Natural History, Smithsonian Institution, the Cetacean Stranding Database, compiled by NMFS, Office of Protected Resources, NOAA, and Brownell *et al*. 2006.

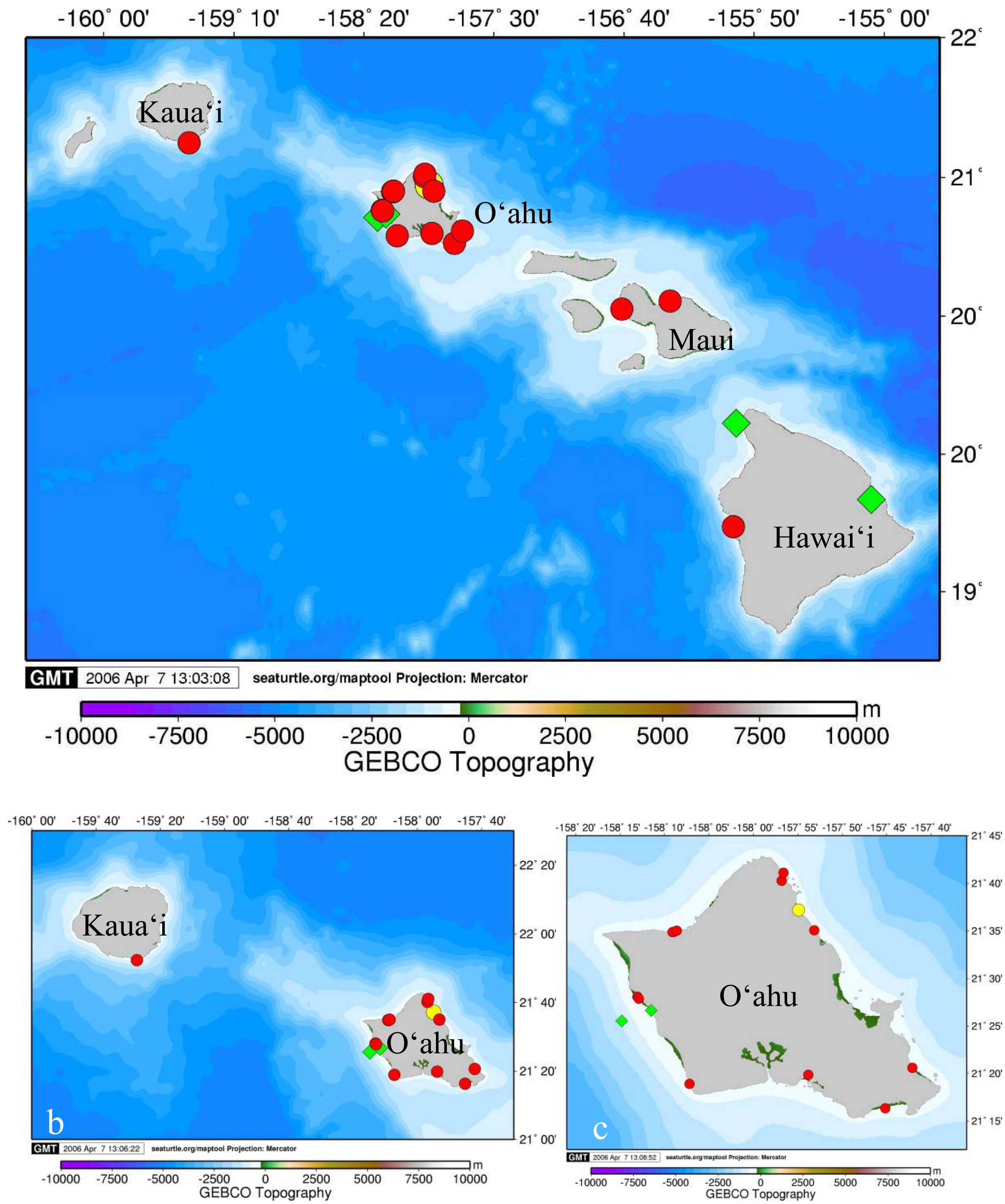

Figure 2. All recorded instances of melon whale strandings and captures in: a) the main Hawaiian Islands; b) on O'ahu and Kaua'i, and c) on O'ahu. These data are summarized in Table 3. Red circles are strandings of single animals, the yellow circle is a mass stranding of 2 adult males, and the green diamonds represent captures of live animals, both at sea and near shore. Bathymetry data from the GEBCO Digital Atlas, British Oceanographic Data Centre.

Overview of Events

The group of melon–headed whales entered the Bay at around 0700 hrs (local time) July 3, 2004, a time fixed by a canoe blessing ceremony and reliable observations (personal communication from beach interviews). The animals entered the Bay side by side in a single wave formation. The animals initially came into the SSW portion of the Bay and were first spotted approximately 91 m (100 yards) off shore from the Pine Trees area (see Fig. 3a). Table 4 provides a timeline of the activities and the progression of the event and Figures 4 and 5 provide images of the event (provided by Jean Souza).

People were entering the water intermittently and chaotically throughout the day and interacting with the whales. During this time, the animals separated into as many as four subgroups, with individuals moving between groups. At approximately 1600 hrs Kaua‘i police and Division of Conservation and Resources Enforcement (DOCARE) arrived and ordered people from the water. During most of the day, the animals stayed between the Pavilion and pine trees areas with approximately 550-731 m (6-800 yards) between groups (see Figure 3b). The smaller groups coalesced back into one large group once

Table 4. Timeline of melon-headed whale movements in this event as reported in field reports received by NMFS.

Event	Time	Date
Group of whales enter SW part of Bay – 91 m from shore	0700	July 3, 2004
Group of whales moved cohesively from East side of Bay to center and then headed out of Bay, but immediately turned around and returned to the East side of the Bay	0900 (when lifeguard came on duty)	July 3, 2004
The large group split into up to 4 smaller subgroups, which spread out over 600-800 yards between the Pavilion and the Pine Trees to the South; public (human) interaction with whales	Throughout day	July 3, 2004
Kaua‘i police and DOCARE ordered public away from animals; animals reformed into one cohesive group within 100 yards of shore near Pavilion beach Park	1600	July 3, 2004
Animals noted swimming in tight circles	After 1600	July 3, 2004
NMFS and HSRG personnel arrived in Kaua‘i, assessed situation, and noted that no animals had stranded; developed intervention plan	2030	July 3, 2004
Volunteers hold beach watch near group	Throughout night	July 3-4, 2004
Herding of group to open water begins (8 canoes and 30+ kayaks)	0930	July 4, 2004
Group of whales departed Bay and were no longer in sight	1030	July 4, 2004
First reports of lone young animal (calf) in Bay	1300	July 4, 2004
Animal stranded and pushed back out	Before 0900	July 5, 2004
Calf found dead	0900-1000	July 5, 2004
Calf shipped via Federal Express to California	afternoon	July 5, 2004
Calf necropsied	N/A	July 7, 2004

people left the water. When the group was spotted 69 m (75 yards) from the Pavilion on the Southeast part of the Bay at around 1920 hrs (local time), the animals were observed to be swimming in tight circles (Fig. 4a). There were no reports of fresh injuries on the animals or of any predators (*e.g.*, sharks or killer whales) seen in and at the mouth of the Bay. Tail slapping behavior, large amounts of whistling vocalization and some spy

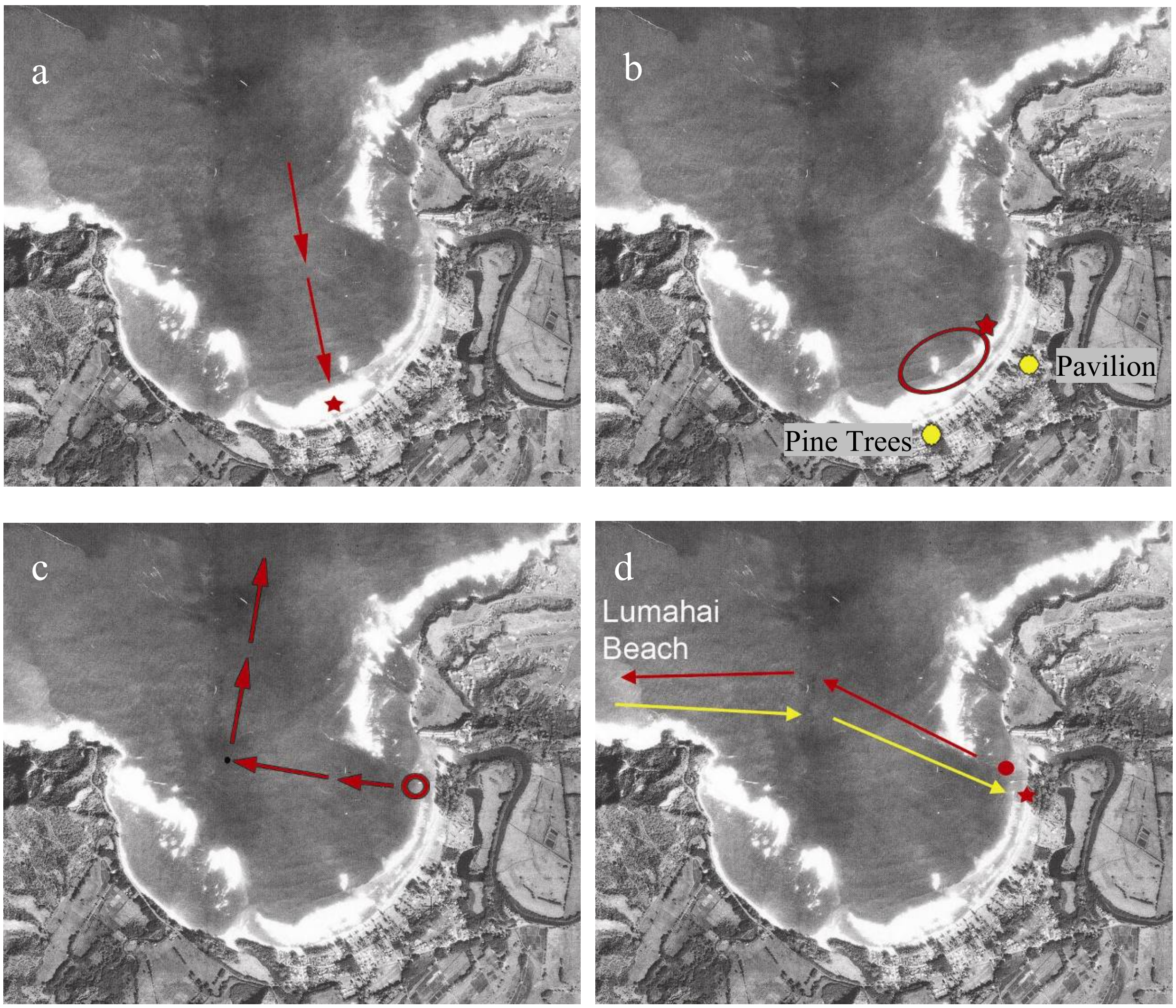

Figure 3. Maps of animal movements in the Hanalei Bay stranding event. Aerial photograph from the US Geologic Survey. a) The animals entered the Bay and were first observed at 0700 on July 3 (red star); b) Between 0930-1600 the animals moved (red ellipse) in several subgroups between the Pavilion and the pine trees (yellow circles), forming back up into a cohesive group around 1600 (red star); c) At dawn on July 4, animals were observed near the pier (open circle); After 0930, using the lau, the animals were herded across the Bay and out into deeper water; d) The calf was first observed by the pier at 1300 on July 4 (red dot), was found stranded at Lumahai Beach on the morning of July 5, pushed out, and later stranded on July 5 by the pier in Hanalei Bay (red star).

hopping continued for several hours. The animals remained in the Bay overnight, and on the morning of July 4, 2004, were observed south of the pier and within 182 -274 m (2-300 yards) of the boats that extended from the end of the pier to the SW. The animals made little effort to move south and west along the shore.

Due to the coincidence of this event with the Rim of the Pacific naval exercises, NMFS initiated discussions with the US Navy early in the event and continued discussions with the U.S. Navy throughout the event. The findings and actions relative to U.S. Navy activities are discussed later in this document.

At daylight on July 4, 2004 the animals were observed in the same position in one large group. Therefore the decision was made to implement the plan to herd the animals out of the Bay with coordinated human intervention. On July 4, 2004, at 0930 hrs (local time) a '*lau*' or floating strand of woven vines (Fig. 4b) about 213 m (700 feet) long was tied between two canoes and used to herd animals out of the Bay (Fig. 3c). A further 30-40 kayaks were positioned behind the canoes and *lau* to assist in encouraging the animals out from inside the pier and moored boats. Once the *lau* drifted within 9 m (10 yards) of the group, the animals moved toward it. After calmly investigating the *lau*, nosing up to it, the animals turned NNW away from the *lau* toward the opposite shore. Three to five larger animals swam ahead of the group toward the far side of the Bay where they found shallow water again and then turned north toward open water. As the lead animals and group gathered speed additional canoes and the kayaks extended the U–shape of the towed *lau* and moved north toward open water behind the animals. The animals exited the Bay at a rapid pace exhibiting porpoising behavior into deeper water and were out of sight of the beach observers at approximately 1030 hrs.

Figure 4. Photos of the events surrounding the strandings. a) animals swimming in tight circles; b) Kainoa Forrest of Hanalei Canoe Club demonstrates twisting the beach morning glory vine to make the *lau*; c) and d) deploying the *lau*; e) NOAA staff tracking the movements of the whales out of Hanalei Bay

Figure 5. Photos of the events surrounding the strandings con't. f) impromptu public outreach and education station set up by NOAA staff; g) Marlee Breese of the Hawaiian Islands Stranding Response Group (HISRG) giving media interviews; h) Dr. Bob Braun of HISRG and Kainoa Forrest of Hanalei Canoe Club addressing the community volunteer participants.

A single small cetacean was first reported at 1300 hrs (local time; approximately 2.5 hours after the group left the Bay) on July 4, 2004 alone near the pier. The animal was observed for approximately an hour and then it was lost from sight as it traveled from the Hanalei Bay area northwest to Lumahai Beach. The animal was found stranded alive on Lumahai Beach early in the morning on July 5, 2004, but was pushed back into the water (Fig. 3d). The animal was then found dead at around 0900 – 1000 hrs (local time) again near the pier in Hanalei Bay (Fig. 6). The carcass was retrieved and held in cold storage until shipment to California for diagnostic imaging (not available in Hawaii), for necropsy and for tissue collection.

Figure 6. A young melon-headed whale calf was found dead on July 5, 2004 in Hanalei Bay. Photo by Gretchen Johnson.

Post-Mortem Examination

The animal was a Code 2 (fresh dead) male, 115 cm in length with vibrissae present along the rostrum (see Level A form in Appendix 1). The animal weighed 17.5 kg. Fetal folds were evident along the body, and the umbilical slit was partially closed. These features indicate that this animal was young and likely approximately one week old. The calf was stored on ice (July 5, 2004), was shipped to the Marine Mammal Center (TMMC), Sausalito, California. Once the carcass arrived at the Marine Mammal Center, it was taken to Raytel Imaging, San Francisco, for magnetic resonance imaging and computerized tomography (CT) scanning (July 7, 2004). After scanning, the carcass was taken back to the Marine Mammal Center for gross necropsy and collection of tissues for histopathology, bacteriology and banking. Histopathology was completed at the University of California, Davis.

Imaging

Magnetic resonance imaging (MRI) prior to dissection was performed using a GE Genesis Signa 1.5T MRI using GE XL 9.0 software. T1-weighted scans of the sagittal and axial planes were collected for the head. In addition, the following pulse sequences were performed: T2* gradient echo in the coronal and axial planes, T2 fast spin echo (FSE) in the coronal plane, and T2 fluid attenuation inversion recovery (FLAIR) in the coronal and axial planes. T2-weighted axial and T2 FSE coronal scans were collected for the thoracic region. Computed tomography (CT) was performed with a GE Lightspeed CT. Images collected of the chest region (source of 140 kV at 120 mA) were contiguous and collimated to 5 mm. Images of the temporal bone (source of 120 kV at 100 mA) were also contiguous but collimated to 1 mm. Both imaging modalities were used to evaluate morphology prior to gross necropsy to visualize and evaluate auditory and auditory pathway pathology in light of the coincidence with RIMPAC activities.

Images showed incomplete cerebral myelination that was consistent with the neonatal developmental stage. Localized hemorrhages were not observed in the parenchyma, subarachnoid spaces, or intraventricular spaces; there was no indication of subdural hematoma formation (Fig. 7). Hemorrhage was not apparent in any of the acoustic fats (*i.e.*, melon and fats associated with the lower jaw). The auditory bullae appeared grossly normal and the persistence of cochlear fluid permitted the cochlea to be visualized (Fig.8). Associated sinuses and Eustachian tubes appeared clear except for a localized region of hyperintensity involving the Eustachian tube and associated air spaces of the right auditory bulla, potentially corresponding to localized fluid accumulation (measuring 7 x 9 x 10 mm). Although partially located within the pneumatized bone, it is not contiguous with the cochlea. Airspace consolidative changes characterized by hyperintensity were observed in approximately 75% of the right lung (Fig. 9) and to a lesser extent in the ventral (caudal) portion of the left lung lobe. The main bronchi appeared clear and free of debris. The skeletal system was free of fractures, and structural or congenital deformities of either the soft tissue or skeletal system were not detected. There was no evidence of internal trauma.

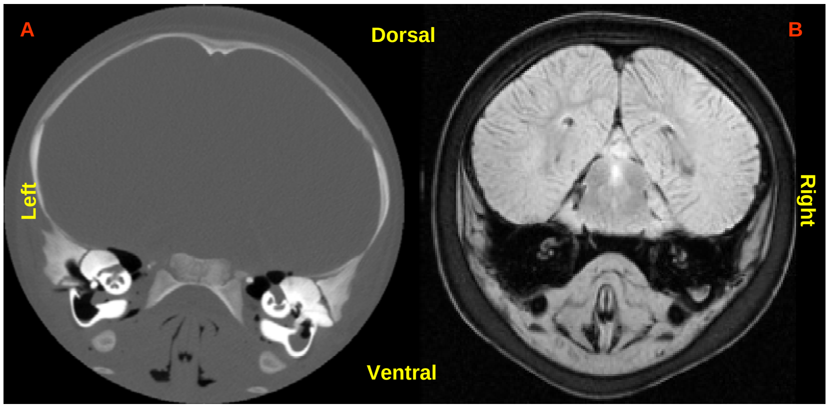

Figure 7. Images demonstrating normally developed brain without indication of hemorrhage, lesion or subdural hematoma. (A) CT scan and (B) T2* GRE scan through the brain, auditory bullae, and associated air spaces.

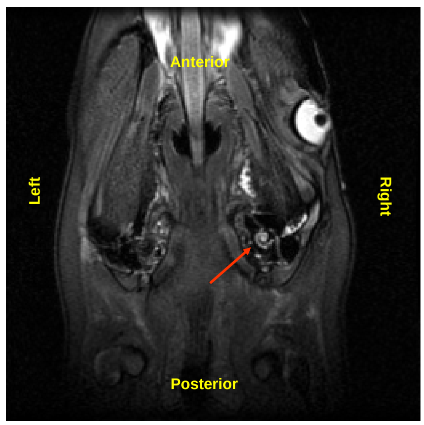

Figure 8. Coronal MRI image collected with the T2 FLAIR pulse sequence. The red arrow indicates the position of the cochlea. Some localized fluid accumulation appears in the Eustachian tube and associated sinus.

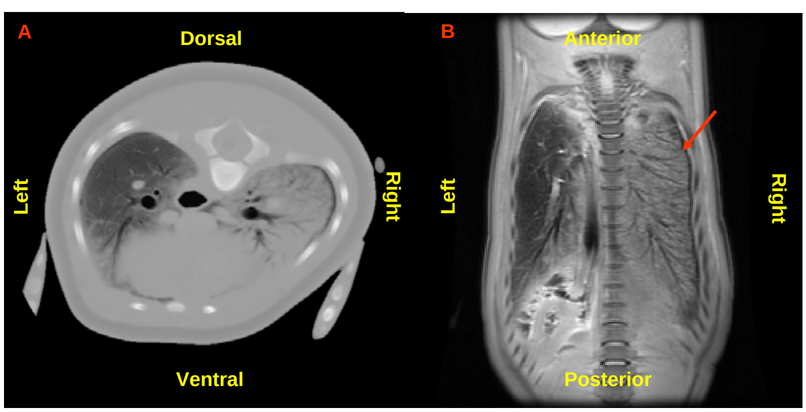

Figure 9. (A) CT and (B) MRI collected with T2 FSE pulse sequence demonstrating consolidative changes of the right lung, and to a lesser degree, in the left lung.

Gross Findings

In several areas the skin was flaking off the underlying tissue (interpreted as post mortem decomposition). The body was thin with concavity caudal to the skull. The melon was poorly developed. The esophagus, all of the chambers of the stomach, and the intestines were empty. There was scant adipose tissue in the abdominal cavity, around the kidneys, and in the coronary groove. Therefore, this young whale likely had not nursed for some time prior to its death. It was not possible to determine whether this animal had ever nursed; however the amount of zymogen depletion and overall condition of the calf indicate that it was not nursing well prior to the morning of July 3, 2004. The thymus was well developed, and there was no evidence of atrophy or depletion that can occur if there is poor nutrition or stress early in neonatal life. This calf was known to be separated from the female upon exit of the group from the Bay, but it cannot be determined whether separation from the female occurred while the animals were in the Bay or prior to the group's entrance into the Bay. The empty gastrointestinal tract and the poor body condition do not necessarily mean separation from the female but they do indicate abnormal nursing or maternal care.

Approximately 6-8 circumferential fetal folds were found present along the body (Figs. 10 and 11) and the flukes were folded under at the tips. The umbilical vein, the urachus and umbilical arteries were partially patent. The umbilicus was absent (Fig. 12) and the umbilical slit was partially closed. The umbilicus had begun to regress and the ductus arteriosus was completely closed. Along the inner body wall, the umbilical slit was surrounded by a small amount of fibrous tissue (Fig. 13) consistent with healing. Several vibrissae were present along the rostrum. These features indicate that the animal was young, but not newborn.

Figure 10. Left lateral view of whale carcass

Figure 11. Fetal folds on right side of carcass

Figure 12. Umbilical scar on ventrum of carcass

Figure 13. Internal view of healing umbilical scar.

Several, 1.0 - 5.0 cm long, linear, depressed areas of skin with slightly raised, dark grey edges were found along the chin and ventral mandible. Several, shallow, gray linear depressions were present along the ventrum, at midline and adjacent to the umbilicus and genital slits. Rake marks were present on the right side of the head lateral and anterior to the right eye and over the body. A single circumferential, linear depression extended circumferentially around

Figures 14a and b. Circumferential linear lesion in skin.

the head at the level of the eye (Figs. 14a and b). There was no evidence of hemorrhage associated with this single circumferential linear depression.

There was a small amount of light tan, foamy fluid in the distal trachea and main stem bronchi. The right lung lobes were slightly collapsed, diffusely mottled dark red and purple, rubbery and exuded foamy fluid and a large amount of blood on cut section (Fig. 15). The anterioventral, medial dorsal and margins of the left lung lobes were markedly collapsed, and approximately 50-60% of the left lung was dark purple and rubbery. The remaining areas of left lung were dark pink and aerated. All sections of lung floated in formalin. The heart weighed 141 g (0.8 % of body weight), the right ventricle was 0.8 cm thick, the left ventricle was 1.0 cm thick, and the interventricular septum was 1.0 cm thick. The ductus arteriosus was closed and the foramen ovale was fenestrated. The thymus extended partially up the trachea and several lobes were observed just distal to the larynx.

Figure 15. Dorsal view of lungs removed from thorax.

The head was sectioned transversely at 1 to 2 cm increments and the sections examined grossly. Selected sections were also examined histologically. There was no evidence of hemorrhage along the mandibular adipose tissue, skeletal muscle, within the sinuses, or inner ear cavities (Fig. 16).

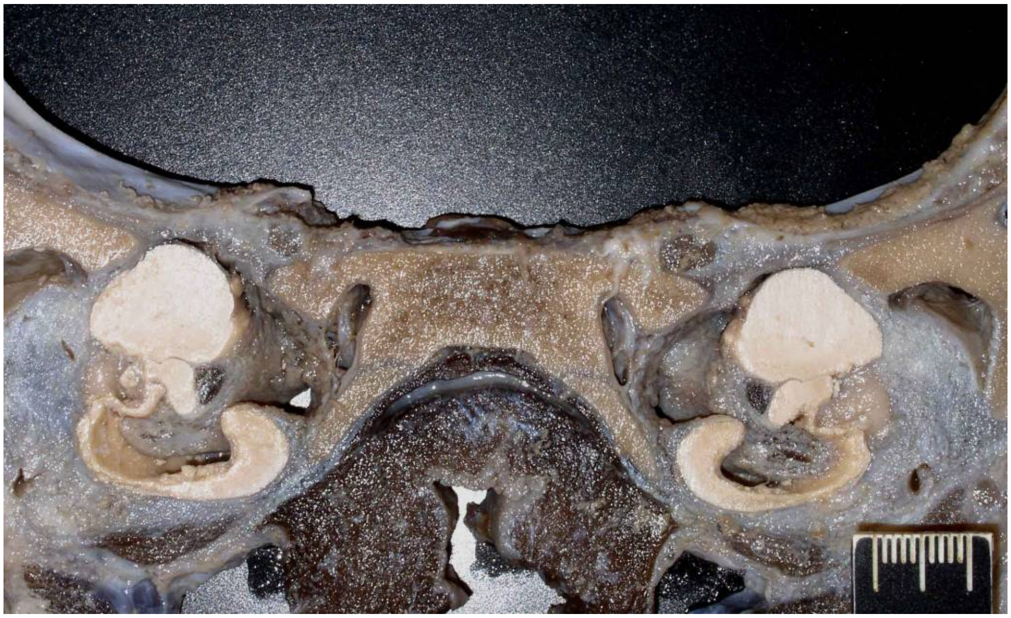

Figure 16. Sagittal section of the frozen, formalin-fixed head at the level of the ears, showing absence of hemorrhage. The scale is on the right side and indicates 1 cm.

Based on the presence of fetal skin folds, presence of vibrissae, degree of umbilical regression, length (reported birth lengths for melon headed whales are around 100 cm), and appearance of organs, the calf was estimated to be approximately a week old. All tissues examined were appropriately developed for a newborn cetacean including immature testes and brain. Sections of lung were either fully or partially aerated. The meconium had been completely excreted, which occurs within the first few days of life in most species. The umbilicus had begun to regress and the ductus arteriosus was completely closed. All of these findings are consistent with a young animal.

Histopathology

Samples of the lungs, heart, trachea, aorta, thymus, salivary gland, thyroid glands, tongue, esophagus, stomach, duodenum, jejunum, ileum, colon, pancreas, spleen, liver, kidney, ureter, urinary bladder, blubber, adrenal glands, skin (multiple sites), eye, blubber, muscle (multiple sites), testes, brain, and the mediastinal, sternal, axillary, and mesenteric lymph nodes were examined histopathologically.

Histopathological review of the lungs indicated the calf had bronchopneumonia and passive congestion. Bronchopneumonia is a common finding in stranded cetaceans (Lowenstine, personal observations) and in mild cases is often related to the act of stranding or being trapped in shallow water. There was leukocytosis in the lungs and in a few places, the interstitial walls were mildly expanded by neutrophils (acute interstitial pneumonia). These interstitial changes were interpreted to be secondary to acute systemic inflammation. The left lung lobes were partially atelectic. This could be related to acute constriction or plugging of the left main stem bronchi or partial failure of alveolar expansion after birth *(atelectasis* *neonatorum)*. The right lung lobes were diffusely congested and edematous consistent with lying in right lateral recumbency (Fig. 17) [note this animal was packed and shipped immediately after finding the carcass, therefore this may be a result of the position during transport]. Small numbers of aspirated squames are normally found in the lungs of neonatal animals and can be present in the lungs weeks after birth.

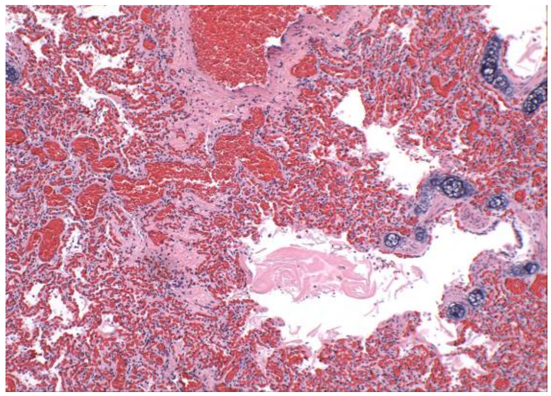

Figure 17. Hemotoxylin and eosin stained section of right lung showing congestion and atelectasis.

Acute myofiber degeneration and necrosis was found in the heart. This is a common finding in stranded animals and has been attributed to elevated endogenous catecholamine release in other animals and humans (Turnbull and Cowan, 1998). Mild hepatic lipidosis, which is often related to inanition or poor *in utero* nutrition in young animals, was found in the liver. There was marked lymphoid depletion in the spleen. The lymphoid atrophy may be related to the mild inflammation in the skin, lungs, or small intestine, or could be reflective of the animal's poor nutritional condition and debilitation, though the thymus was not similarly depleted. The presence of moderate extramedullary hematopoiesis found in the animal's spleen is a normal finding in cetaceans. Superficial bacterial colonization and necrosis of the distal umbilical vein and artery with fibroplasia confirmed the grossly-observed normal regress of the umbilicus; and testes morphology was consistent with an infantile developmental state. Other findings included: meningeal congestion in the brain, congestion in the kidneys, inflammation in the jejunum, and mild zymogen depletion in the pancreas. The zymogen depletion also supports the young age or inanition. Congestion and mild hemorrhages in multiple organs are common non-specific terminal findings in stranded odontocetes.

The skin lesions on the ventral mandible were acute and suggestive of external trauma. Interestingly, there was epithelial necrosis and adjacent intracellular edema in addition to the abrasions and ulcerations. These lesions can be associated with toxic injury to keratinocytes. Given the underwater topography of the area in which this animal stranded, this change could have been related to contact with coral. Similar lesions have been reported in humans following contact with coelenterates (Letot *et al.*, 1990). The thin linear indention extended circumferentially around the head and was not associated with inflammation histologically. The indention was associated with sub-lethal cellular changes indicating that the changes probably occurred ante-mortem. The exact etiology of this skin lesion is not known; however, similar facial clefts due to constriction by amniotic bands have been described in human infants, and can be induced experimentally in lambs and mice (Rowsell, 1989). This indention was considered a separate entity from the fetal folds common in neonatal cetaceans which were also present in this young whale. There was no inflammation associated with the rake marks examined histologically, suggesting that at least some of the rake marks occurred after death.

There was a moderate drainage reaction in several of the lymph nodes examined and in the axillary and cervical lymph nodes there was sinusoidal neutrophilia and lymphadenitis. Again, these changes were very mild and, given the location of the lymph nodes, the inflammation may be related to the acute skin lesions. In several of the peripheral and thoracic lymph nodes examined there were small mineralized concretions in the capsule and fibrous tissue septa of the node. In some areas these concretions were associated with the capillary endothelial cell lining. The significance of this finding is not known. Similarly, the adrenal cortex was much thinner than expected and from what has been noted in other cetacean species. Again, the significance of this change is unknown, and it may be an anatomic variation of this species or related to age.

All of the inflammatory changes noted in the tissues examined were regarded to be mild, acute (6-12 hours old), and could have been secondary to injuries acquired during stranding or from being trapped in shallow water. There was no evidence of hemorrhage in the brain or in the cervical, cranial, or mandibular tissues and blubber. There was no evidence of viral or bacterial disease, including viral inclusions, lymphoid depletion, cytolytic changes, etc, in the tissues examined. Although cause of death could not be definitively determined, it is highly likely that maternal separation, dehydration, and poor nutritional condition contributed to this calf's death. The reasons for the maternal separation, dehydration and poor nutritional state of the calf are not known.

Disease and Other Biological Factors

Historically there have been many reasons for single or mass strandings, although most cases have unknown causes. In some cases pelagic animals are found near shore or in embayments when they are obviously chasing prey, being chased by predators, or are feeding. Once in shallow waters these pelagic species may strand. Many potential mass strandings have been prevented in the Cape Cod region of Massachusetts by herding the animals using small vessels and acoustic devices (Touhey, 2003). Unlike the recent North Carolina mass stranding of pilot whales, minke whale and dwarf sperm whales (Hohn *et al.*, 2006), observations of this group showed maintenance of the group cohesion under the adverse conditions in shallow unfamiliar waters and the rapid coalescence into a larger group once people left the water. It is likely that the group cohesion contributed to the circumstances under which these animals entered the Bay and remained there throughout the day.

Another factor which is reported to be responsible for mass strandings is disease or injury of one or more key individuals of a group who may lead animals into shallow waters, near shore or into embayments or lagoons (Robson, 1984). In some cases, once the injured or sick animal is removed from the area, the remaining members of the group have been successfully herded out to sea. In this case, no reports were received of freshly injured animals in the Bay, such as might have occurred with recent predation attacks. No animal was observed dead on the shallow areas of the Bay during the event or following the animals' return to the sea; although no survey for carcasses underwater was performed. It is unlikely that the poor condition of the young animal would contribute to the group's movement into the Bay. However, since no other animals were stranded or examined during this event it is impossible to discern whether any other animals were sick, potentially contributing to the stranding event.

Finally, based on interviews with fishermen, Hanalei Canoe Club members, NOAA biologists, life guards, and State of Hawaii Department of Land and Natural Resources biologists, no biological indicators such as predators or prey items that would explain the movement of the whales into the Bay or remaining there for over 28 hours were observed. However no real scientific effort was undertaken at the time of the event to perform the surveys and veterinary exams necessary to rigorously document the above mentioned factors.

Environmental Analysis

Several studies have determined positive correlations between environmental factors and the sites of cetacean strandings, particularly mass strandings. Coastal topography (Brabyn and McLean, 1992), large-scale climate events (Evans *et al.*, 2005), and wind effects on nearshore circulation (Walker *et al.*, 2005) have all been investigated in relation to cetacean strandings. In addition, harmful algal blooms and their associated biotoxins have been associated with unusual mortality events and strandings but have not been associated with unusual inshore congregations of pelagic animals (HARNESS, 2005).

Physical features

The bathymetry and coastal topography of Hanalei Bay was compared with the benthic features around Kaua‘i and the other main Hawaiian islands (Figure 20a). In their analysis utilizing data from New Zealand, Brabyn and McLean (1992) determined that mass strandings were more common in areas with gently sloping sandy beaches, an adjacent protruding section of coastline, and shallow bays where the coastline was less indented. These features are not found in Hanalei Bay. Hanalei Bay is the most distinct indented body of water along the northern coastline of Kaua‘i, and there are no adjacent protruding areas of coastline.

Both Brabyn and McLean (1992) and Walker *et al.* (2005) found that mass strandings of other species occured significantly more often on beaches that were in proximity to deep water. This particular bathymetric feature is similar to that of Hanalei Bay; only a few miles offshore

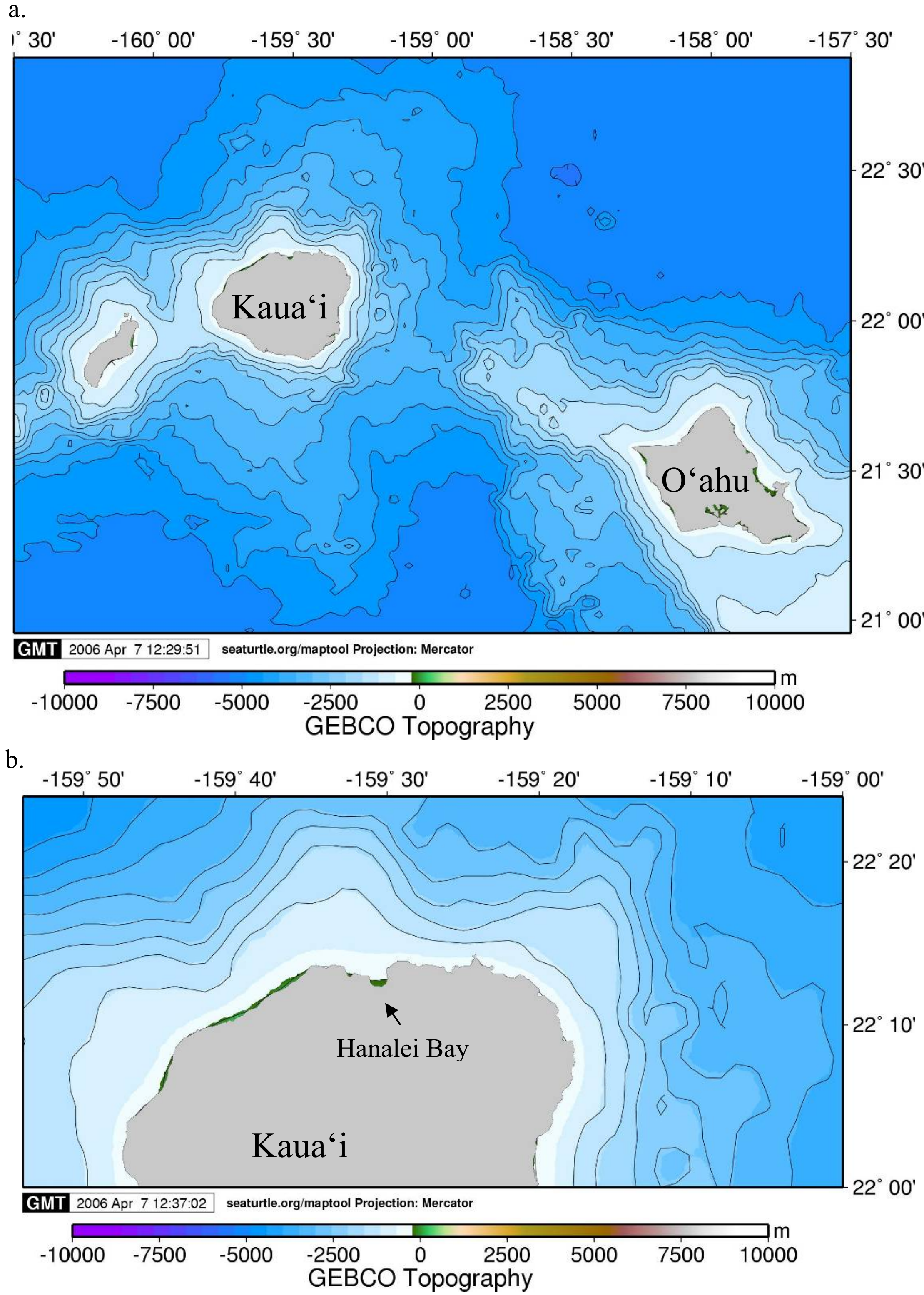

Figure 18. Bathymetry maps of a) Oahu and Kauai, and b) the north of Kauai. Contours are shown at 500-meter intervals. Bathymetry data from the GEBCO Digital Atlas, British Oceanographic Data Centre, plotted using the Maptool utility at seaturtle.org.

of Hanalei Bay, the bottom drops to over 2000 meters. However this is not a feature unique to the Bay. The volcanic islands of the Hawaiian chain rise sharply from the ocean floor; very deep waters can be found a short distance from the beach in most of the archipelago (Figure 20b). Thus, bathymetry does not help explain why this mass stranding occurred in Hanalei Bay at this time.

Wind and sea surface temperature features

Wind and sea surface temperature have also been examined in relation to cetacean stranding events (Evans *et al.*, 2005, Walker *et al.*, 2005). Walker *et al.* (2005) found that in all mass stranding events of cetaceans analyzed (n=15), a change in wind direction from upwelling-favorable to downwelling-favorable condition occurred in the week prior to the event. They hypothesized that the whales were tracking frontal convergences created by an upwelling front, either directly or indirectly, following prey migrations. We analyzed environmental data for the area for the time period preceding the stranding event, to examine factors that may have caused the animals to enter Hanalei Bay, and the days of the event, for factors that would cause the animals to remain in the Bay.

Sea surface temperature plots were created for the area around O‘ahu and Kaua‘i using data from the NOAA GOESS archive (Figure 19). An integrated map was also created for the 3 days surrounding the event (Figure 21; note different color scale). While some different temperature water masses can be seen with the exaggerated color scale in Figure 21, the maximum temperature difference in the map area was approximately 2 degrees. The waters around O‘ahu and Kaua‘i were almost uniformly warm (average 26.5°C) for the days preceding and during the stranding event. No major fronts were detectable.

Wind data from the National Weather Service were also analyzed for the four days preceding the event to assess variability (Figure 20). Along the north shore of Kaua‘i, the observed wind conditions are the prevailing trade winds from the east at approximately 12-14 knots, which is considered normal and expected for this late June-July time period (Andy Nash, NWS Honolulu, pers. comm). No changes in wind direction or strength which would contribute to front formation or dissolution were observed. July 3 and 4 were also studied to determine if any changes occurred that would cause the animals to remain in shallow waters, and again no anomalies or differences were detected.

In conclusion, the environmental factors of bathymetry, sea surface temperature and wind were analyzed for this stranding event. The bathymetry is similar to many other sites within the Hawaiian Island chain. The weather conditions appear to be normal for this time of year with no fronts or other significant features noted. The analysis of environmental features does not appear to provide an explanation for the cause of this event, or the reason the animals remained in Hanalei Bay.

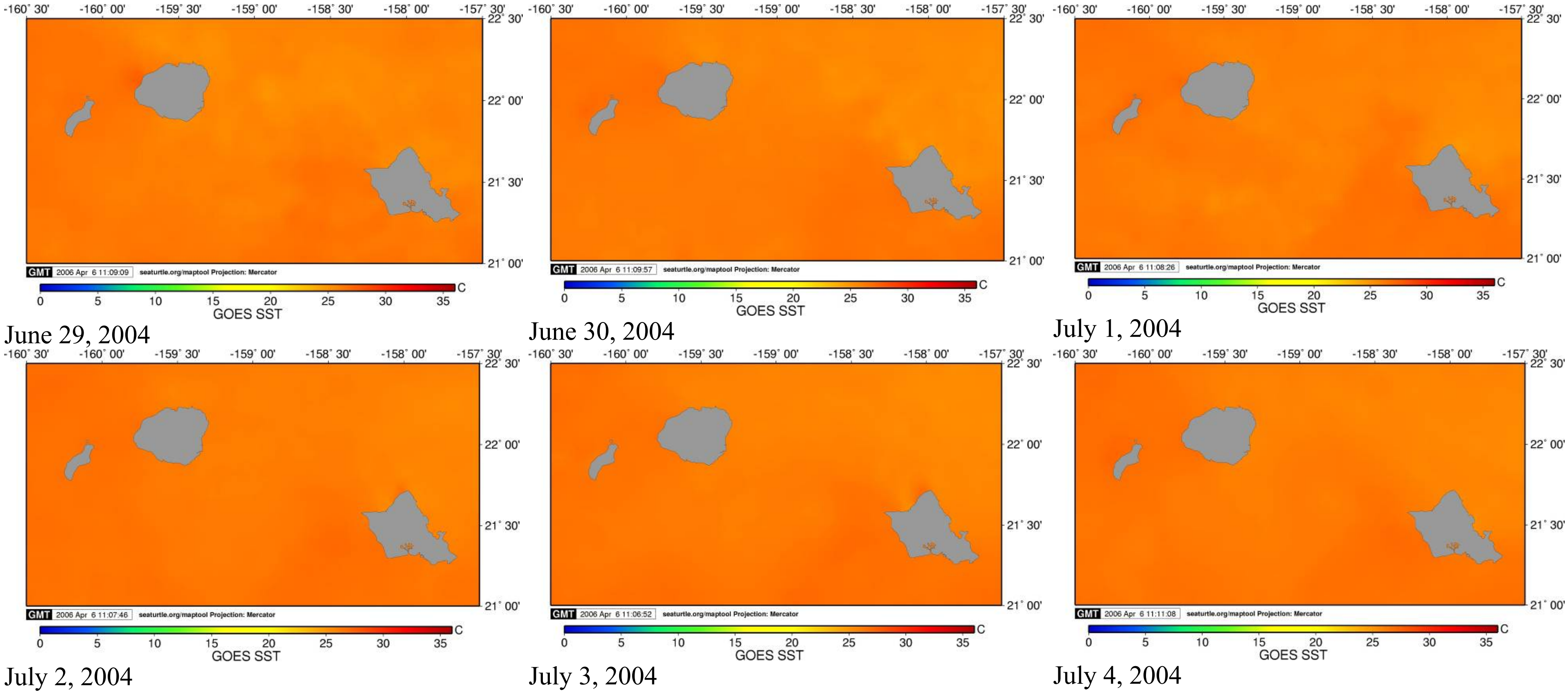

Figure 19. Sea surface temperature Jun 29 - Jul 4, 2004, the four days immediately preceding the stranding event and the days of the event. Sea surface temperature is represented in degrees Celsius. Sea surface temperature data are from NOAA's GOES daily sea surface temperature. The source data have a nominal spatial resolution of 6km and have been validated to be within 0.5C of actual SST. Plots were made using the Maptool program from seaturtle.org.

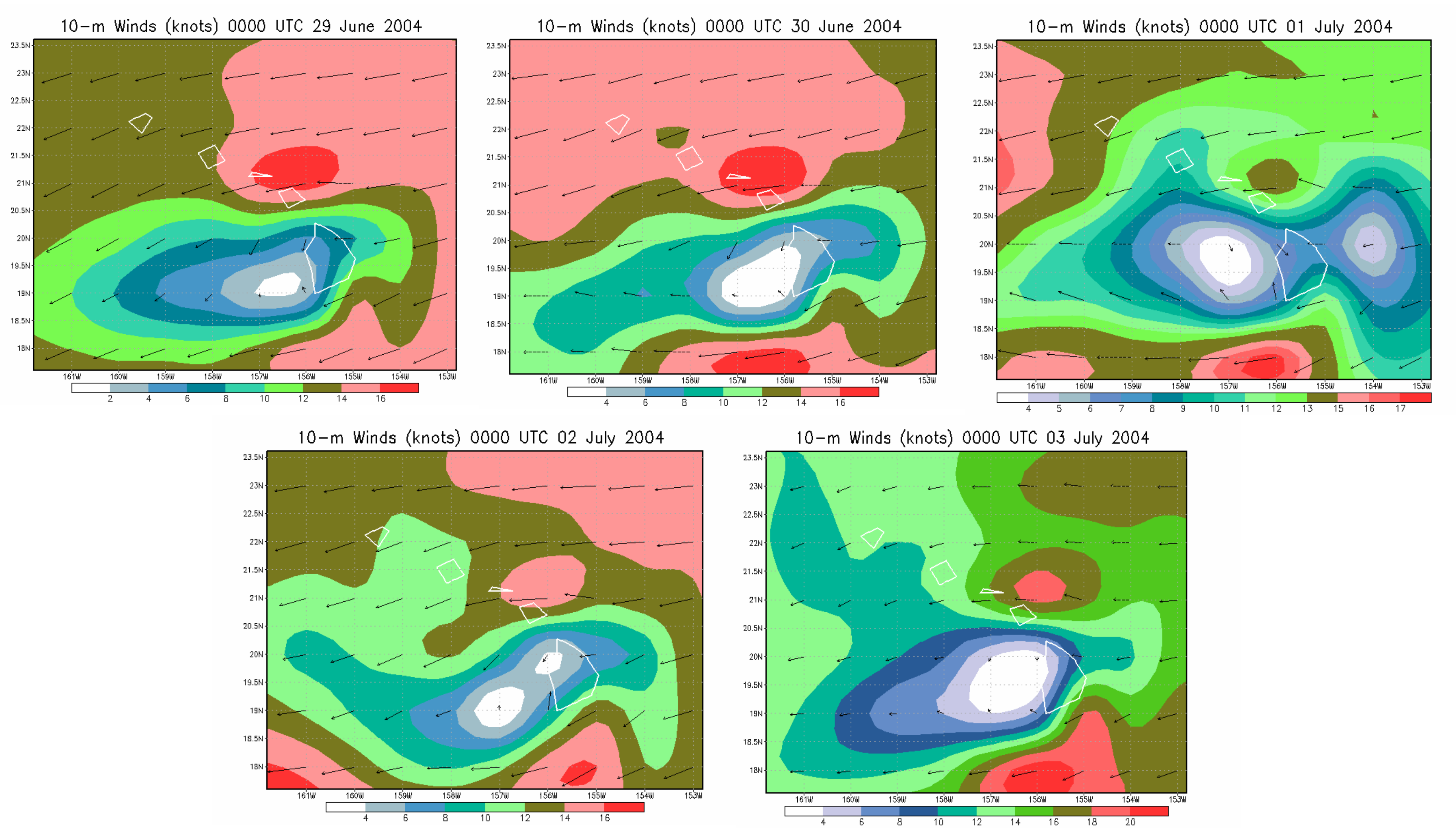

Figure 20. Wind speed and direction from Jun 29 - Jul 3, 2004, the four days immediately preceding the stranding event and the first day of the event. Wind speed is in knots. Note that the wind speed color scales are not identical among plots. Wind data are from the National Weather Service (NWS) NCDC NOMADS site and plots were made by the NWS Research Scientific Services Division, Eastern Regional Headquarters.

Harmful Algal Blooms

The on-site team evaluated potential biotic factors, including the presence of unusual chlorophyll signals from satellite imagery and phytoplankton in the water. There was no evidence of unusual chlorophyll imagery for this area and time frame (Seki, pers. comm.). Water samples were obtained by the US Coast Guard station near Lihue and sent to the University of Hawaii for identification. The water samples showed essentially a pure assemblage of the photosynthetic cyanobacteria, *Trichodesmium spp.* (Brown, email report). This colonial phytoplankton is large enough to be visible to the naked eye and is commonly found in tropical and subtropical waters of the world oceans. One species of *Trichodesmium* has been found to produce a biotoxin, but with the minimal sampling done during this event it is not known whether that species was present. Other species have been associated with deaths of marine organisms (generally, neurotoxins have impacted organisms tested --mostly zooplankton) (Sellner, 1997). *Trichodesmium* is generally not grazed well, but there is a harpacticoid copepod that feeds on some of this phytoplankton. *Trichodesmium* blooms are a common occurrence in Hawaii in July (Karl *et al.*, 1997), and most likely did not contribute to the unusual behavior of the melon-headed whales of entering or staying in the Bay.

Military Exercises

This event occurred during the 2004 Rim of the Pacific Exercises (RIMPAC) which is a biennial, sea control/power projection fleet exercise that has been conducted since 1968 and involves US forces and forces from various Rim-of-the-Pacific nations. Due to the presence and scope of military exercises being conducted during the Hanalei Bay marine mammal stranding event, contact with U. S. Navy officials was made during this event. Requests for stand down of active sonar use were made following initial discussions and the U. S. Navy responded very quickly to cease transmissions following this request (see Table 5).

An investigation of the possible relationship between military training exercises, active sonar transmissions, and movement of the animals into the Bay and remaining there was conducted focusing on active sonar use before and during the exercises on July 3, 2004. Initial investigation focused on the official training events of July 3, but was extended to consider the sonar transmissions of a group of six naval surface vessels (four U.S. and two Japanese ships) involved in training and tracking exercises while transiting toward the island of Kaua'i from the south on the afternoon and evening on July 2, 2004 as well (Fig. 21). Official active sonar exercises on or near PMRF did not commence until approximately 0800 hours (local time) on July 3 (Fig. 22). From what is known to the authors of this report regarding the scope and nature of previous RIMPAC exercises and other naval exercises in Hawai'i the active sonar transmissions on July 2-3 were not particularly unusual for the area and time of year in question.

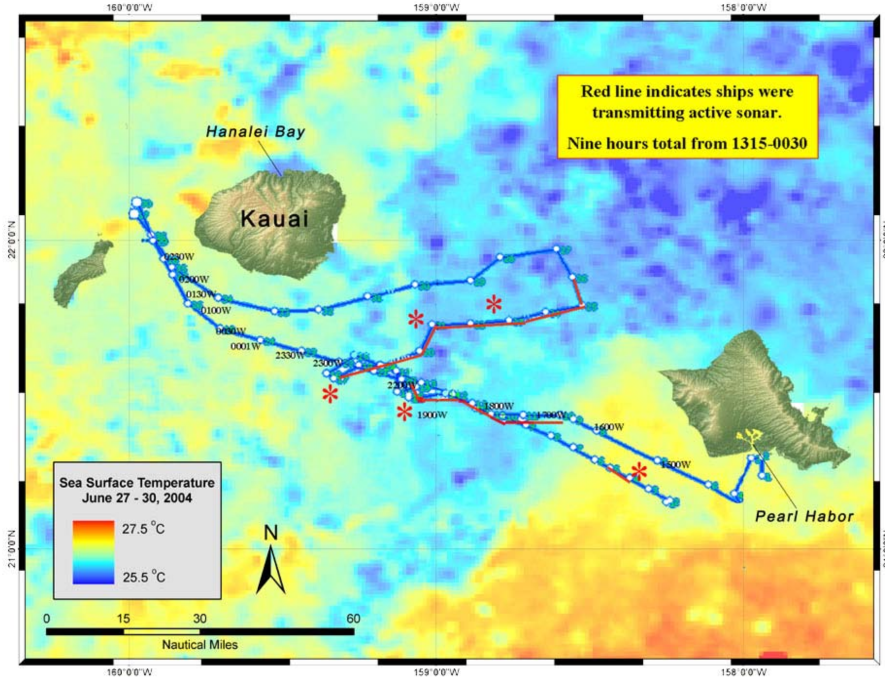

Figure 21. Vessel movement and sonar transmissions on July 2-3, 2004 prior to RIMPAC exercises. Red stars indicate transmission locations for which sound propagation analyses were conducted

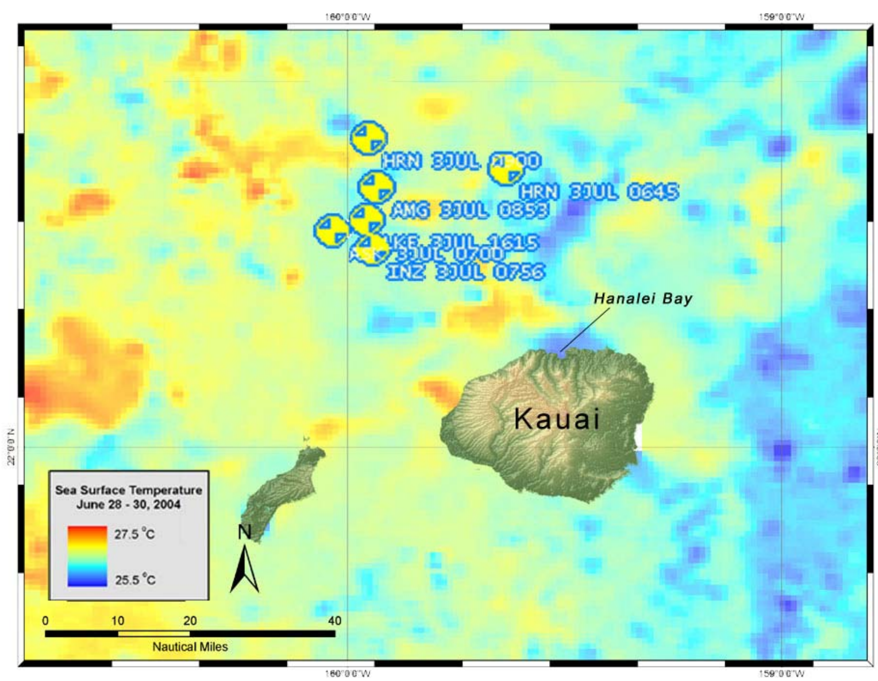

Figure 22. Vessel movement and sonar transmissions on July 3, 2004 during RIMPAC exercises.

For the past decade, the potential role of acoustic exposure, particularly to tactical mid-frequency, military active sonar, in marine mammal stranding events has been a subject of relatively intense consideration and debate (*e.g.*, Richardson *et al.*, 1995; NRC, 2000; 2003; 2005). Globally, four marine mammal mass stranding events, generally involving various species of beaked whales, have occurred in which active military sonar appears to have been the most likely causative factor. These include strandings in Greece in 1996 (Frantiz, 1998), Bahamas in 2000 (NOAA/US Navy Joint Interim Report, 2001), Madeira in 2000 (ICES AGISC 2005), and the Canary Islands in 2002 (Fernandez *et al.*, 2005). Although melon-headed whales were not involved in any of these previously reported events, they have similar habitat requirements and life history characteristics (*e.g.*, relatively deep diving) to most of the species involved in these four events. The beaked whale mass strandings noted above were relatively small numbers (<30) of animals per event as compared to the more typical mass stranding of melon-headed whales which may be a reflection of the difference in group size for melon-headed whales melon-headed whales (median group size 305 individuals) as compared to beaked whales (maximum group size observed 9 individuals; Huggins *et al.* 2005, Baird *et al.*, 2004).

Recent data suggest that under certain, though still unknown, conditions, at least one cetacean species (Cuvier's beaked whale: *Ziphius cavirostris*) exposed to active mid-frequency sonar may develop a pathological condition with lesions similar to decompression sickness in humans (NMFS, 2002; Jepson *et al.*, 2004; Fernandez *et al.*, 2005). These cases may be related to direct ensonification and/or changes in diving behavior, resulting in lesions associated with nitrogen bubble formation (Cox *et al.*, 2006). Similar lesions were observed in a Blainsville's beaked whale (*Mesoplodon densirostris*) studied following the Bahamas (2000) stranding event (Rotstein, unpublished). It is important to bear in mind that key questions regarding the conditions in which nitrogen bubble formation may occur in the presence of active sonar, and a number of other important issues bearing on the interpretation of observed lesions, remain unanswered (Piantadosi and Thalmann 2004). However, given the apparent occurrence of this phenomenon in certain deep-diving species (*e.g.*, beaked whales), it is appropriate to address whether it may occur in species with similar diving patterns and habitat requirements (*e.g.*, melon-headed whales) when they experience similar acoustic exposures. It must be noted that this event is dissimilar from those reported beaked whale events in that only one animal died and was examined, it did not have lesions consistent with the observed lesions in the Bahamas, and only one species stranded.

Behavioral responses to sound may play a role in marine mammal stranding events, whether they are related to physiological changes (*e.g.*, changes in diving inducing nitrogen bubble formation) or direct beaching behavior (Cox *et al.*, 2006). Extreme avoidance behaviors arising from acoustic exposure have been documented for some cetaceans other than melon-headed whales. For example, Geraci and Lounsbury (2005) report that coastal whalers have used certain species' tendency to flee in a straight line from a source of danger to successfully drive striped dolphins *(Stenella coeruleoalba)* and pilot whales *(Globicephla macrorhynchus)* ashore using impulsive sounds. Arguably, behavioral reactions of some cetaceans to active, mid-frequency military sonar have recently been observed. For instance, on May, 2003, *in situ* observations of altered behavior of killer whales *(Orcinus orca)*, and a minke whale *(Balaenoptera acutorostrata)* were reported in the area of tactical sonar use during a military exercise while transiting the eastern Strait of Juan de Fuca and Haro Strait (Bain, 2003; Balcomb, 2003; US Navy, PacFleet, 2004; NMFS, 2005). It is important to note here again that our knowledge of the effects of anthropogenic acoustic events on marine mammal health, behavior and mortality is still in its infancy. Relative to this event, virtually nothing is known about melon-headed whale reactions.

Table 5. Timeline of event, NMFS activities and naval activities relative to this event in Hanalei Bay.

Melon-headed whale Activities	NMFS and Network Activities	Navy Activities	Time	Date
		JMSDF P-3 dropped 6 active sonobuoys 30 nm SE of Kaua‘i	0730	July 2, 2004
		Active sonar used intermittently during transit approaching either side of the island	1015-2359	July 2, 2004
		2 RIMPAC units test active SONAR (Fig. 21) at PMRF Underwater Range	0645-0715	July 3, 2004
Group of whales enter SW part of Bay – 91 m from shore			0700	July 3, 2004
		RIMPAC exercise begins (Fig. 22)	0800	July 3, 2004
		RIMPAC units training on PMRF Underwater Range, Antisubmarine Warfare training	0800-1700	July 3, 2004
Group of whales moved cohesively from east side of Bay to center and then headed out of Bay but immediately turned around and returned to the east side of the Bay	Ocean Safety Board relay report from Lifeguards regarding whales and harassment by people		0930	July 3, 2004
Smaller subgroups (up to 4) spread out over 6-800 yards between the Pavilion and the Pine Trees to the south; public interacting with whales	10:30 Lifeguards, Police Dispatch trying to prevent human interactions in Bay; members of the public report calling PMRF regarding this event		Throughout day	July 3, 2004
Animals reformed into one cohesive group within 100 yards of shore near Pavilion beach Park	Kaua‘i police and DOCARE ordered public away from animals;		1600	July 3, 2004
	NMFS informs RIMPAC Battle Watch Captain (BWC) of stranding situation		1645	July 3, 2004
		BWC directs all ships to cease all active sonar transmissions	1647	July 3, 2004
		CPF BWC/CDO notified	1650	July 3, 2004
		CPF/CCTF RIMPAC decides to send OPREP-3 N/B	1730	July 3, 2004

Melon-headed whale Activities	**NMFS and Network Activities**	**Navy Activities**	**Time**	**Date**
	NMFS and HSRG personnel arrived in Kaua‘i, assessed situation, noted that no animals had stranded, and developed intervention plan		2030	July 3, 2004
	Volunteers hold beach watch near group		Throughout night	July 3-4, 2004
		RIMPAC units continue non-active sonar events operating on PMRF	0900	July 4, 2004
	Herding of group to open water begins (8 canoes and 30+ kayaks)		0930	July 4, 2004
Group of whales departed Bay and were no longer in sight			1030	July 4, 2004
	NMFS reports departure of whales to NAVY		1050	July 4, 2004
Lone young animal in Bay			1300	July 4, 2004
	NMFS reports sighting of one juvenile still in Bay to NAVY		1515	July 4, 2004
Animal stranded and pushed back out			Before 0900	July 5, 2004
Calf found dead			0900-1000	July 5, 2004
Calf packed on ice for shipment to California via Federal Express			Early afternoon	July 5, 2004
Calf necropsied			N/A	July 7, 2004

Acoustic Analysis

A detailed sound propagation analysis was conducted of sonar transmissions from both U.S. and Japanese naval vessels transiting from Pearl Harbor on O'ahu toward the island of Kaua'i on the afternoon and evening of July 2, 2004. Predicted sound fields were calculated for five positions along the ship's tracks coinciding with known transmissions of two types of mid-frequency sonar (indicated with red stars in Fig. 21). These positions were selected to approximate the range of possible conditions arising from the fact that the vessels were moving closer to Hanalei Bay.

For each of the five positions, transit speeds required for hypothetical animals to travel from the south and east of Kaua'i and reach Hanalei Bay by 0700 on July 3, 2004 were determined. These transit rates were then compared with the predicted sound fields to estimate whether animals exposed to military sonar transmissions could physically arrive in Hanalei Bay in the known time period. Detailed modeling analysis of the July 3 transmissions have been conducted by the U.S. Navy and are discussed below as well.

Propagation Analysis

A standard ray-tracing, sound propagation model (using the Bellhop Gaussian beam/finite element ray-tracing model available at: www.hlsresearch.com/oalib) was used to estimate acoustic conditions resulting from sonar transmissions at five specific times and locations of known transmissions of U.S. and Japanese vessels on the evening of July 2, 2004 to the south and southeast of Kaua'i:

1330: *USS Paul Hamilton* initial sonar transmissions (21° 15' N, 158° 20' W)
1900: *USS Lake Erie* sonar transmissions (21° 30' N, 159° 08' W) (Figure 21)
2000: *JDS Inazuma* and *Haruna* initial sonar transmissions (21° 35' N, 159° 20' W) (Figure 22)
2200: *JDS Inazuma* and *Haruna* sonar transmissions nearest Hanalei Bay (21° 45' N, 159° 0' W)
2300: *USS Paul Hamilton* sonar transmissions nearest Hanalei Bay (21° 45' N, 158° 40' W)

The propagation analysis models used average environmental features for July (bathymetry and nominal sound velocity profiles expected in that area for that time of year). The U.S. Navy provided NMFS specific measurements of these features (which can dramatically affect transmission ranges) from an area to the south and east of Kaua'i on July 2, 2004. These data indicate that sound propagation conditions were very similar to typical conditions for July, as indicated in the Generalized Digital Environmental Model (available at: https://128.160.23.42/gdemv/gdemv.html) database that underlies the propagation model used to conduct this investigation. In addition to bathymetric and environmental variables, information regarding variable operational characteristics of the various sonar systems was used in propagation analyses. According to technical data provided by U.S. Navy to NMFS following the stranding event, U.S. naval vessels were equipped with SQS-53C mid-frequency sonar systems (center transmission frequency: 3.5 kHz; nominal source level: 235 dB_{RMS} re: 1μPa) and Japanese naval vessel used OQS-5 and OQS-3 tactical systems (center transmission frequency: 5.0 kHz; nominal source level: 225 dB_{RMS} re: 1μPa).

Our calculations are believed to roughly approximate conditions present during military sonar transmissions on July 2, 2004. However, the propagation model used assumes that sound propagates omnidirectionally from the source. Tactical sonars can be focused to some extent in a particular direction. The fact that such information was not included in the analysis here is acknowledged to be a potentially significant limiting factor. Our analyses are thus appropriate for certain portions of zones surrounding the ships, depending on which operational mode the sonar was being used in and the exact orientation and targeting of the ship at each ping (information not currently available to NOAA). In the directional "beam" of the sonar (where it is pointed), received levels can, under certain conditions, exceed those predicted by an omnidirectional model. It is thus acknowledged that the current analysis is most accurate only for a sub-set of the area surrounding transmitting vessels.

For the purposes of visualizing sound fields resulting from active sonar transmissions for this analysis, 120, 140, and 160 dB_{RMS} re: 1µPa received level isopleths were arbitrarily selected. These received levels are <u>not presumed</u> to have any particular biological relevance for melon-headed whales or other cetaceans. These zones of similar estimated received level were determined by calculating maximum received levels in the 0-500m depth regime along eight directional radials (45º angular separation) relative to each transmission location at each bearing (N, NW, W, SW, S, SE, E, and NE). That is, the isopleths indicate the loudest estimated received level within the portion of the water column within which the animals would reasonably be expected to occur. It should be noted that this is a quite conservative

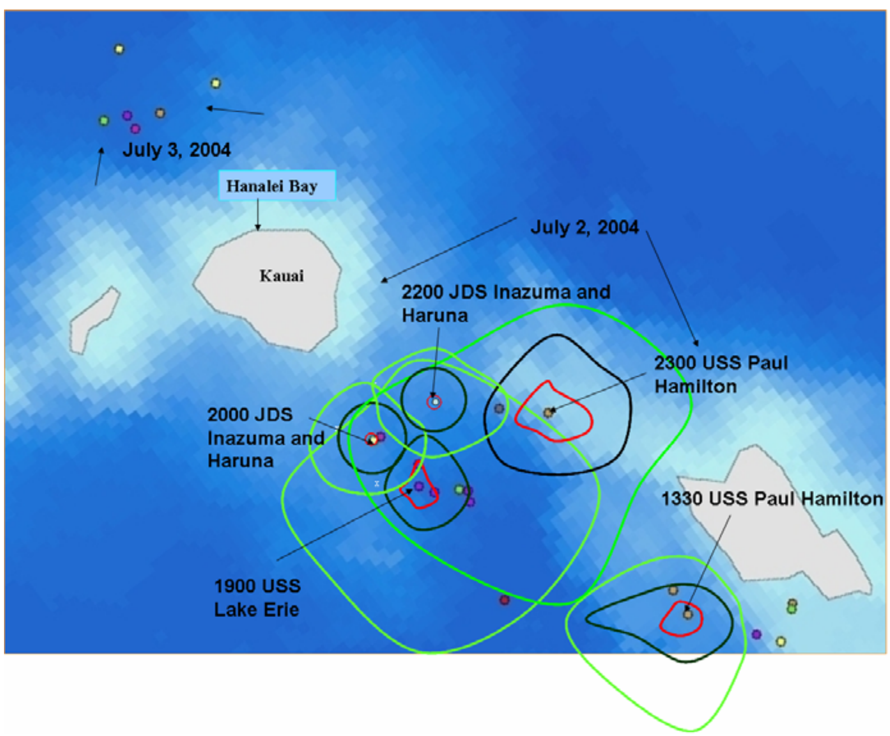

Figure 23. Representation of five active sonar transmissions on July 2, 2004 modeled in this analysis. Isopleths representing 120, 140, and 160 dBrms re: 1uPa are shown in green, black, and red respectively.

means of estimating received level isopleths; animals moving through the water column likely never experience the maximum received level in this depth band as calculated here. A composite representation of all five modeled transmissions with each of the three defined isopleths is shown in Fig. 23.

Determination of Ranges and Swim Speeds

Radial distances from Hanalei Bay to the south and east of Kauaʻi were estimated (Fig. 24). These spatial zones were then converted into average swimming speeds for each of the five transmissions analyzed to assess the feasibility of animals arriving in Hanalei Bay at 0700 on July 3 following active sonar exposure on the afternoon and evening of July 2. This approximation presumes that the pod was located to the south or east of Kauai'i on July 2, which may or may not have been the case. As noted earlier, this is one of the areas where melon-headed whales have previously been sighted with minimal effort in the Hawaiian Islands.

The spatial analysis was an admittedly simplistic approximation using nautical charts. Our calculations of distance from Kauaʻi at various transmission points agree closely, however, with those given in the charts provided in the Navy's analysis. It is also important to note that it is highly unlikely a more detailed mapping analysis would alter the conclusions reached in this report.

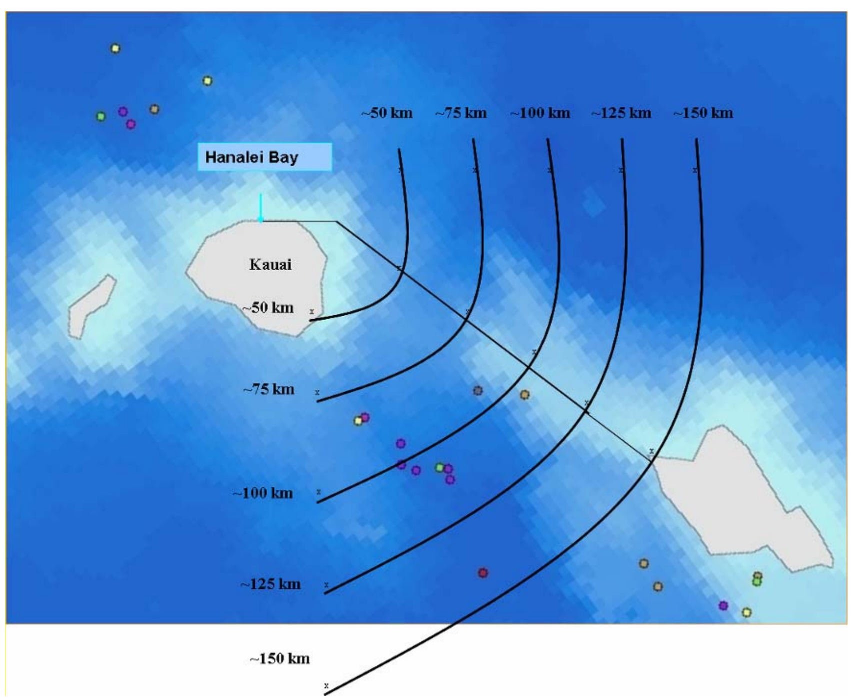

Figure 24. Map depicting estimated distance isopleths from Hanalei Bay at points to the south and east of Kauaʻi.

Assuming an 0700 arrival time (July 3) for the whale group in Hanalei Bay, necessary transit speeds coinciding with these transit ranges were determined for each of the five transmissions analyzed, accounting for transmission time and estimated sound fields. Two examples of these calculations are given in Figs. 25 and 26.

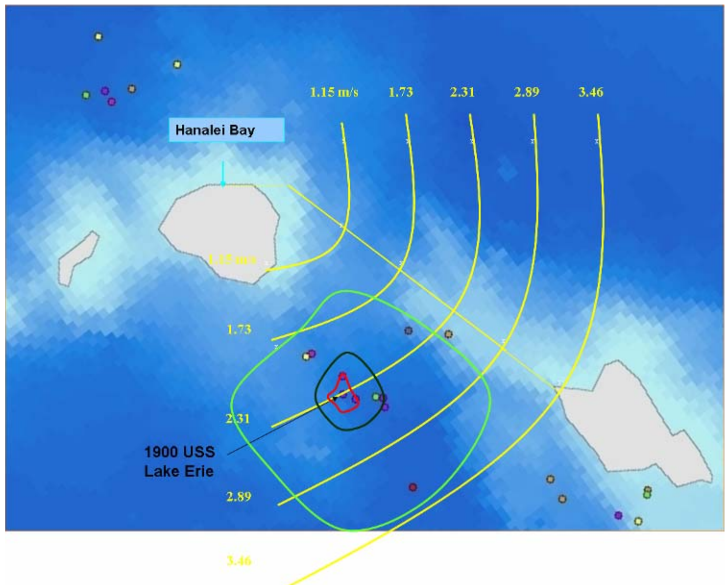

Figure 25. Approximate swim speeds necessary for the group of *Peponacephala electra* to reach Hanalei Bay following exposure to approximate sound fields from *USS Lake Erie* active sonar transmissions at 1900 on July 2, 2004.

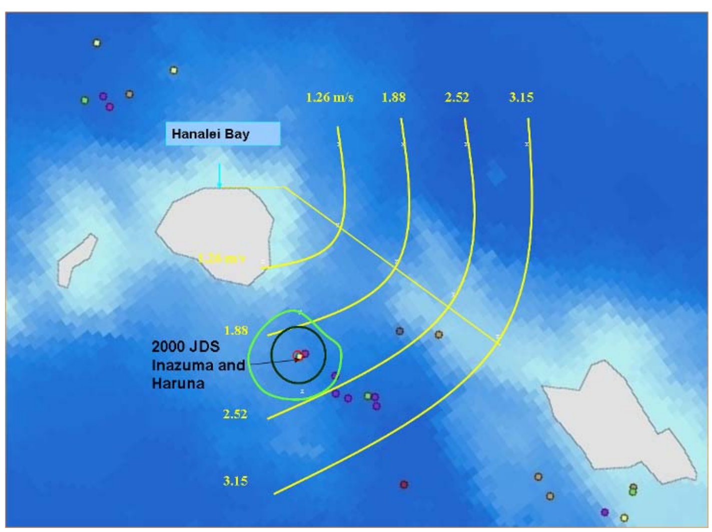

Figure 26. Approximate swim speeds necessary for group to reach Hanalei Bay following exposure to approximate sound fields from *JDS Inazuma* and *Haruna* at 2000 on July 2, 2004.

Relationship Between Estimated Sound Fields and Required Transit Speeds

Estimated sound fields were compared with transit speeds necessary to reach Hanalei Bay by the target arrival time for each of the five modeled active sonar transmissions. The combined results of these analyses indicate that the group would have had to travel approximately 1.4 to 4.0 m/s over 6.5 to 17.5 hours after receiving sonar sounds ranging from 120 to >160 dB_{RMS} re: 1μPa to reach the Bay at 0700 on July 3, 2004. It is important to note that in many cases, the position of the vessels themselves overlaps with required transit speeds on the order of 2.0 m/s from animals in the relatively near vicinity (again, the analysis considers exposure of animals in the vicinity of naval vessels to the south and east of Kaua'i only). Although no published data are available on cruising speeds in *Peponocephala,* cruising speeds in other cetaceans of approximately 1.8 to 3.1 m/s are sustainable over relatively long periods (Costa and Williams, 1999). Whether a mixed pod of melon-headed whales, including very young individuals would be capable of sustaining such a pace over a period of many hours is unknown but it is likely that the presence of young animals could limit transit speeds if the group remained together.

It should be noted that in some conditions, areas that include plausible transit speeds overlapped with the physical position of the military vessels. Thus, received sonar levels approaching the source level of the system could have been received by individuals to the south and east of Kaua'i, who would have reached Hanalei Bay by 0700 on July 3, 2004. Consequently, the precision of the acoustic analysis, as well as the precise level at which behavioral reactions occur, is arguably irrelevant. It is noteworthy that other cetaceans (beluga and narwhal) have been documented rapidly swimming away from other human noise sources at large distances (up to 80 km) in other areas (LGL and Greeneridge, 1986; NRC, 2005). This is thought to be a predator-fleeing response; humans hunt these species in the Arctic areas where the observations occurred. If a behavioral response in this situation was triggered at a received level just above the ambient noise level, the group could have moved much slower (< 1.0 m/s) and reached the Bay by 0700 on July 3, 2004. However, it is not known whether marine mammals may perceive tactical mid-frequency sonar signals as similar to those of potential predators (*e.g.*, social signals of killer whales) and react in a similar fleeing manner at low received levels (NRC, 2005). Further, it is arguably unlikely that such profound reactions at low levels would be expected in an area with relatively common military activity if animals were present at the same time and in the same vicinity or that if they were they would not have been previously detected.

Sonar Exposure on July 3, 2004 within Hanalei Bay

Acoustic propagation modeling was conducted by NMFS using nominal sound velocity profiles for the area to the north and west of Kaua'i for the month of July and the times and locations of July 3 operations at The Pacific Missile Range Facility (PMRF) provided by U. S. Navy. The results indicated generally that received levels near the mouth of Hanalei Bay were estimated to range from near or below likely ambient noise to perhaps 20-30 dB above it (~

125 dB_{RMS} re: 1µPa was the maximum estimated received level near the mouth of the Bay). Detailed modeling was conducted by U. S. Navy, 3rd Fleet (2006) using *in situ* sound velocity profiles (obtained in the July 6-21 timeframe) to estimate the received sound levels in Hanalei Bay on July 3 from active sonar operations. The presence of a "weak" surface propagation duct (described as similar to the nominal condition) was noted. The Navy analyses were in agreement with NMFS results in suggesting that under certain conditions, sounds from active sonar transmissions could be detected by cetaceans near or in Hanalei Bay. However, the Navy analyses estimate higher received levels, particularly in the top 25m of the water column where the surface duct apparently occurred (U. S. Navy, 3rd Fleet, 2006). Estimated mean received levels from transmissions of various vessels at various times ranged from approximately 138-149 dB_{RMS} re: 1µPa (U. S. Navy, 3rd Fleet, 2006) which would have been audible to people in the water at the time (Brandt and Hollien, 1969), despite the fact that the vessels were some tens of kilometers away from the Bay. Many people reported hearing sounds in the water but the majority of what was reported were vocalizations and whistles from the animals themselves. One person indicated to the stranding network that loud sonar sounds were detectable in the water for over an hour, but this was not reported by other individuals involved in the event.

These results strongly suggest that sounds associated with the operations of July 3, 2004 could have been audible to some or all of the animals as they were milling within the embayment. If the U. S. Navy propagation modeling is correct, the active sonar transmissions on July 3 from vessels located on PMRF were likely a dominant acoustic event in at least some of Hanalei Bay while the animals were milling over a period of many hours. The significance of the estimated level of sonar exposure, or the cumulative exposure dose, over the period of several hours while the operations at PMRF were ongoing and the whales were within Hanalei Bay is not clear.

Conclusion

Mass stranding events of melon-headed whales have not previously been reported in Hawai‘i except for the 1841 report of animals in Hilo Bay being driven to shore. It must be noted that the exact circumstances surrounding that event will never be known. The first confirmed single stranding of a melon-headed whale in Hawaii was in 1964 and since that time Hawaii has had more confirmed reports than any other state in the U.S. There has only been one confirmed mass stranding of melon-headed whales in the U.S., an event involving 5 whales which stranded in Florida in March 2006 following several days in which a larger group was observed close to shore and in shallow waters prior to the stranding. Melon-headed whales may occur in large group sizes in the wild, and therefore may strand in large numbers when such events occur (range is 4 to >250). Melon-headed whales are not normally considered an island-associated species, although there may be some exceptions to this, *e.g.*, Palmyra Atoll (Barlow, pers. comm.) and Marquesas Islands (Perrin 1976; Reeves *et al.*, 1999) which is approximately 2000 miles to the southeast. They may be more common around some of the Pacific Islands that have deep water areas close to shore; however, they are more typically seen far from any land and are so classified as a pelagic species.

Only three groups of melon-headed whales were detected within 25 nmi of the main Hawaiian Islands by Mobley *et al.* (2000), and a single group was detected over 500 miles from the main Hawaiian Islands by Barlow (2006) during a survey of the Hawaiian waters. The best estimate of abundance near the main Hawaiian Islands (within 25 nmi) is 154 based on the Mobley *et al.* (2000) analysis. Considering that Baird *et al.* (pers.com) determined, using boat-based observations involving 18 sightings, a mean group size of 147 for melon-headed whales in Hawai‘i, the entire abundance near the main Islands could be found in a single group. However, Mobley *et al.* (2000) found a much smaller mean group size (13.5), perhaps indicating that animals may also be more dispersed at times. The median group size determined during the surveys around the Hawaiian Islands and in the eastern tropical Pacific over the past 2 decades (24 sightings) is approximately 90 (Barlow, pers. comm. Baird *et al.* (pers. comm.) have sighted a group with sufficient frequency off the lee side of the Big Island to indicate that there may be island-associated individuals around Hawai‘i. However, that does not mean unequivocally that the individuals that entered Hanalei Bay were Hawai‘i residents. These whales could have been a pelagic group that just happened to be around the islands at the time of the event. It is uncommon for these deep dwelling animals to be found in such shallow waters in Hawai‘i, as these animals prefer water that is > 2000 meters. Also, despite records of melon –headed whale mass strandings elsewhere in large groups, mass strandings of melon-headed whales are rare in U.S. waters, including in those of Hawaii.

During the time the melon-headed whales were in Hanalei Bay, the animals were “milling about”—sometimes in tightly packed subgroups with individuals exhibiting spy hopping and tail slapping. Most investigators agree that tail slaps convey a threat or accompany frustration in addition to establishing contact with other school members (Dudzinski *et al.*, 2002). Unusually high frequencies of spy hopping and “milling behavior” may be abnormal behaviors possibly related to normally pelagic animals being in a shallow embayment. Mass stranding of beached whales are often preceded by “milling” events, where a group of normally pelagic dolphins enters shallow water and begins to circle continuously or move about haphazardly in a tightly packed group, with an occasional member breaking away and swimming toward the beach (Geraci and Lounsbury 1993). Milling behavior may last only a short time or up to several days before stranding occurs (or does not occur in some cases), so prompt and appropriate intervention by humans maximizes the changes of preventing beach strandings or rescuing animals that strand (Geraci and Lounsbury, 1993, 2005). It is well known from many acoustic drive fisheries targeting small cetaceans that boat operators can use sound produced by various means to provide an acoustic barrier that can be used to drive animals to shore until a mass stranding results (Brownell *et al.*, 2005). The combination of herding with small vessels and acoustic deterrents has been successful in preventing several milling events from becoming mass strandings of Atlantic white-sided dolphins (*Lagenorhynchus acutus*) in the Cape Cod region of Massachusetts (Touhey, 2003).

A single male calf was found dead after the stranding, but MRI and CT images as well as necropsy findings showed no signs of acoustic or blunt trauma. The combination of post mortem findings suggests that this was a calf that died in poor nutritional status with evidence of stranding-related stress common among cetaceans. There were several changes detected by imaging and histology (fluid in the right Eustachian tube, congestion of the right lung) that suggest this animal was lying on its right side for a significant period post mortem. The cause of this mortality is unknown but it is likely a result of lack of nutrition, dehydration, and maternal separation. The reason for the lack of nursing is unknown. The animal was known to be separated from the herd on afternoon of July 4, 2004 at which time it was seen alone. Although it is possible that the female and calf separated during the milling in the Bay or upon exit from it, we do not know whether the female was in the Bay, had previously died, or was separated prior to entrance into the Bay. We do know that the animal was obtaining marginal nutrition at best and had not nursed for longer than the 28 hours; however, lack of nursing is not always indicative of maternal separation.

Environmental analyses did not indicate any compelling reason that the animals entered the Bay on the morning of July 3, 2004 nor remained in the Bay through the morning of July 4, 2004. There were no obvious significant weather or oceanographic events, harmful algal blooms, or known unusual biological predator or prey events that could explain the animals' behavior moving into the Bay nor the groups continued presence in the Bay. However, we emphasize that there is a considerable dearth of information about these latter two variables before and during the event given our limited capacity to observe the surrounding environment. Strandings have been reported to occur due to other biological factors such as infectious diseases, toxic exposures, and others, but most commonly with unknown causes. Mass strandings more often involve highly social species where the strong cohesive social structure causes a group of animals to follow one lead animal into shallow waters or embayments and the animals maintain a highly cohesive group. In some cases in which the lead animal was sick or injured, once that animal is removed the rest of the group could be herded out to sea. We are unable to determine whether there was an ill or injured lead animal in this event; however no freshly injured or other stranded animals were observed during or following this event. Additionally, there may be other potential causative factors not considered in this report for which there is absolutely no information. Assessing causation of such an anomalous event involving a large group of apparently healthy animals thus remains limited by available information regarding potentially significant biological and other factors.

The only known, large-scale, anthropogenic activities occurring in the vicinity of this stranding event were the active sonar transmissions covering much of the area between the islands of Oahu and Kauaʻi on July 2 and those occurring at PMRF on July 3. This investigation considered the possibility that military, mid-frequency sonar transmissions on the afternoon and evening of July 2 caused the group of whales to move from areas to the south and east of Kauaʻi into Hanalei Bay on the morning of July 3 and that transmissions on July 3 played some role in their refusal to depart. The results of this analysis indicate that such an association was possible based on the estimated sound transmission conditions and reasonable animal movement speeds over the time period. The analysis is limited in that the location of the animals prior to their arrival in Hanalei Bay is unknown and omnidirectional (rather than focused) propagation of the sonar is presumed.

Sound propagation models of the RIMPAC sonar exercises conducted by NMFS on July 3, 2004 at Pacific Missile Range Facility (PMRF) off the NW coast of Kauaʻi suggest that sonar transmissions could have been detectable near or within Hanalei Bay; analyses by U. S. Navy, 3rd Fleet (2006) support and in fact considerably strengthen this conclusion. If sonar transmissions were audible at Hanalei Bay during the exercises, they could have contributed to the animals remaining there on July 3, 2004. The decision by the Navy to cease operations of active sonar as requested by NMFS may have provided an opportunity for the stranding network to herd the milling animals out of the Bay. Sonar transmissions were not present for ~18 hours prior to the animals being herded from the Bay and it is unclear why the animals failed to leave during this timeframe. The presence of large numbers of people in the Bay interacting with the milling animals on July 3 (prior to the concerted effort to move the animals on July 4) could have interfered with their ability to move cohesively out of the Bay. Since the most sustained effort to move the animals out of the Bay did not occur until after the sonar and chaotic human interaction was terminated, it is difficult to determine whether their positive response to the concerted herding effort was due to the absence of sonar exposure, the absence of intermittent and random human interactions, or a combination of these or other factors. Based on previous experience with small cetaceans in near shore stranding events, timely, coordinated, and appropriate intervention with the melon-headed whales on July 4 may have prevented this milling event from resulting in additional mortality.

While causation of this stranding event may never be unequivocally determined, we consider the active sonar transmissions of July 2-3, 2004, a plausible, if not likely, contributing factor in what may have been a confluence of events. This conclusion is based on: (1) the evidently anomalous nature of the stranding; (2) its close spatiotemporal correlation with wide-scale, sustained use of sonar systems previously associated with stranding of deep-diving marine mammals; (3) the directed movement of transmitting vessels toward the southwest and southeast coast of Kauaʻi; (4) the results of acoustic propagation modeling and an analysis of possible animal transit times to the Bay; and (5) the absence of any other compelling causative explanation. The initiation and persistence of this event may have resulted from an interaction of biological and physical factors. The biological factors may have included the presence of an apparently uncommon, deep-diving cetacean species (and possibly an offshore, non-resident group), social interactions among the animals before or after they entered the Bay, and/or unknown predator or prey conditions. The physical factors may have included the presence of nearby deep water, multiple vessels transiting in a directed manner while transmitting active sonar over a sustained period, the presence of surface sound ducting conditions, and/or intermittent and random human interactions while the animals were in the Bay.

The absence of information on a number of key points is significantly restrictive. The limitations of available information regarding where animals were prior to entering the Bay, their previous potential exposure history to tactical mid-frequency sonar or other human sound sources, and key biological information such as the presence of anomalous predator or prey distributions preclude a single unequivocal conclusion. Key questions regarding the possibility that sonar transmissions were responsible for the stranding event remain unanswered. For instance, why would a single cetacean species exclusively respond in such a dramatic and coherent manner when, based on the analyses conducted here and by U. S. Navy, 3rd Fleet (2006) and knowledge of Hawaiian cetacean abundance, many other marine mammals in the areas surrounding Kauaʻi were also exposed to sonar signals on July 2-3 2004? Another pressing question is why, given the apparent historical frequency of active, military sonar use in and around the Hawaiian Islands, such exposures have apparently not triggered similar events previously? There are hypothetical explanations for these and other lingering questions (*e.g.*, lack of previous concerted observational effort and the physical nature of the coastline and strong current patterns in the Hawaiian Islands that may limit the likelihood of detecting stranding events), but they too are strongly limited by the lack of information about both nominal behavior of this species and their reaction to natural and human sound sources. However, the limitations of the conclusions in this report demonstrates the need for concerted research on the distribution, life history, ecology, and behavior of deep-diving whales, including behavioral and physiological responses to both natural and anthropogenic acoustic stimuli. Complete and thorough response to and investigation of marine mammal stranding events are essential in understanding physical and biological contributing factors.

Acknowledgements

We are extremely grateful to the many people who assisted both on scene and off scene in this event, to the necropsy team, and to the reviewers of this document.

The on scene responders worked tirelessly to assess the situation, develop a plan to move the animals out of the Bay, and reduce the human interactions while the animals were in the Bay. They include: the Hanalei Canoe Club, particularly Hanalei Hermosura and Kainoa Forrest; the County of Kauai Water Safety Officers, particularly Chad Listman and Jody Simpson; the County of Kauai Police Department; NOAA Fisheries Service's Office for Law Enforcement special agents Paul Newman and Tommy Friel; the State of Hawaii's Department of Land and Natural Resources, Division of Conservation and Resources Enforcement, particularly Milton Ching; NOAA Fisheries Service's Pacific Islands Fishery Science Center, particularly Jennifer Bethel; NOAA Hawaiian Islands Humpback Whale National Marine Sanctuary, particularly Jean Souza; and the Hawaiian Islands Stranding Response Group, particularly Dr. Gregg Levine and Marlee Breese. U.S. Navy personnel with whom NOAA communicated during the event include LCDR Dan Dusek (3rd Fleet Battle Watch), LCDR Greg Geisen (Navy Public Affairs at PacFleet for RIMPAC ops), and CDR Dean Leach (PacFleet Environmental Counsel's Office).

In addition, we would like to thank those people who took the excellent photographs and provided copies to NOAA for documentation of the event, the animal behaviors, and the people involved. These include: Dennis Fujimoto, photographer for The Garden Island Newspaper; David Boynton; Brenda Zaun, wildlife biologist Kilauea Point National Wildlife Refuge; Jean Souza and Gretchen Johnson, NOAA Hawaiian Humpback Whale National Marine Sanctuary. Personal accounts of the events were provided by Gretchen Johnson and Dr. Bob Braun and these were invaluable in providing timelines and outlining events as they occurred. Joan Souza, Marlee Breese, and Dr. Bob Braun conducted additional interviews of eye witnesses for the report. Several NOAA Fisheries Service staff in Hawaii and at Headquarters provided additional support during and after the event including Brad Ryon, Tamra Farris, Dr. Janet Whaley, Trevor Spradlin and Connie Barclay.

There has been considerable input for the report from numerous colleagues. The environmental analyses would not have been possible without the use of data and maps from Joshua Watson, Techniques Development Meteorologist of the National Weather Service; Andrew Nash, Director of Operations, National Weather Service, Honolulu; Mike Peccini, I.M. Systems Group, Inc.; and Huaichen Yang, RS Information Systems. Angela Collins-Payne, Mary Jacobs-Spaulding and Trevor Spradlin from NOAA Fisheries Office of Protected Resources provided additional assistance with the report preparation.

Partial support for this stranding response came from the NOAA Fisheries John H. Prescott Marine Mammal Rescue Assistance Grant Program award to the Hawaiian Islands Stranding Response Group (NA03NMF4390037).

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Appendices

Appendix 1: Level A data sheet for the melon-headed whale calf stranded on July 5, 2004 and necropsied on July 7, 2004.

Appendix 2: Necropsy report for the melon-headed whale calf

Appendix 3: List of contributors to the report

Appendix 4: List of reviewers of the report

Appendix 1.
Level A Data sheet for the melon-headed whale calf

MARINE MAMMAL STRANDING REPORT – LEVEL A DATA

FIELD #: BCR-04-20-Ka NMFS REGIONAL #: NMFS-PE-04-20-SD (NMFS USE) NATIONAL DATABASE #: ______ (NMFS USE)

COMMON NAME: melon headed whale GENUS: Peponocephala SPECIES: electra

EXAMINER Letterholder: Robert C. Braun

Name: Robert C Braun Affiliation: HISRG

Address: 47-928 Kamakei Rd. Kaneohe, Hi 96744 Phone: 808-239-0440

LOCATION

State: Hi County: Kauai

City: Lihue

Locality Details: by the river in Hanalei Bay

Latitude: 22° 18' N

Longitude: 159° 30' W

OCCURRENCE DETAILS

MS#: ______ (NMFS USE)

Mass Stranding: ☑ YES ☐ NO # Animals: ______

Signs of Human Interaction: ☐ YES ☑ NO ☐ Could Not be Determined (CBD)

(Check one or more) ☐ 1. Boat Collision ☐ 3. Fishery Interaction ☐ 2. Shot ☐ 4. Other Human Interaction: ______

out of habitat for 150 P.E. in shallows, only 1 stranded

How determined: ☑ External Exam ☑ Internal Exam ☐ Not Examined

Other Causes: ☑ YES ☐ NO ☐ CBD Describe: starvation

DATE OF INITIAL OBSERVATION

Year: 04 Month: 07 Day: 05

STATUS *(Check ONE)*

- ☐ 1. Alive
- ☑ 2. Fresh Dead
- ☐ 3. Moderate Decomposition
- ☐ 4. Advanced Decomposition
- ☐ 5. Mummified/Skeletal
- ☐ 6. Dead – Condition Unknown

DATE OF EXAMINATION (LEVEL A) ☐ Not Able to Examine

Year: 04 Month: 07 Day: 08

CONDITION *(Check ONE)*

- ☐ 1. Alive
- ☑ 2. Fresh Dead
- ☐ 3. Moderate Decomposition
- ☐ 4. Advanced Decomposition
- ☐ 5. Mummified/Skeletal
- ☐ 6. Dead – Condition Unknown

INITIAL LIVE ANIMAL DISPOSITION *(Check one or more)*

- ☐ 1. Left at Site
- ☐ 2. Immediate Release at Site
- ☐ 3. Relocated
- ☐ 4. Disentangled
- ☐ 5. Euthanized at Site
- ☐ 6. Died at Site
- ☐ 7. Transferred to Rehabilitation
- ☐ 8. Died During Transport
- ☐ 9. Other

CONDITION *(Check ONE)*

- ☐ 1. Sick
- ☐ 2. Injured
- ☐ 3. Apparently Healthy
- ☐ 4. Out of Habitat
- ☐ 5. Other

Date: ______ Rehabilitation Facility: ______

Comments: ______

MORPHOLOGICAL DATA

SEX *(Check ONE)*

- ☐ 1. Male
- ☑ 2. Female
- ☐ 3. Unknown

AGE CLASS *(Check ONE)*

- ☐ 1. Adult
- ☐ 2. Subadult
- ☐ 3. Yearling
- ☑ 4. Pup/Calf
- ☐ 5. Unknown

Straight Length: 30 ☐ cm ☑ in ☐ actual ☑ estimate

Weight: 25 ☐ kg ☐ lb ☐ actual ☑ estimate

PHOTOS/VIDEOS TAKEN: ☑ YES ☐ NO

Disposition: the marine mammal center archives

TAG DATA

ID#	Color	Type	*Placement (Circle One)	Applied	Present
			D DF L LF LR RF RR	☐	☐
			D DF L LF LR RF RR	☐	☐
			D DF L LF LR RF RR	☐	☐

*D=Dorsal; DF=Dorsal Fin; L=Lateral Body
LF=Left Front; LR=Left Rear; RF=Right Front; RR=Right Rear

WHOLE CARCASS DISPOSAL *(Check one or more)*

- ☐ 1. Left at Site
- ☐ 2. Buried
- ☐ 3. Towed
- ☑ 4. Rendered
- ☐ 5. Sunk
- ☐ 6. Frozen for Later Examination
- ☐ 7. Unknown

SPECIMEN DISPOSITION *(Check one or more)*

- ☐ 1. Scientific Collection
- ☐ 2. Educational Collection
- ☑ 3. Other: Histopathology

Comments: ______

NECROPSIED ☑ YES ☐ NO Date: ______

NECROPSIED BY: Frances Gulland / Linda

NOAA Form 89-864 (rev. 6-01)
OMB No. 0648-0178, Expires May 31, 2004

PLEASE USE BACK SIDE OF THIS FORM FOR ADDITIONAL REMARKS

ADDITIONAL REMARKS

ADDITIONAL IDENTIFIER: ____________________

this calf was the only stranded of approximately 150 p.e. that entered Hanalei Bay on 07/02 or 07/03. they were encouraged out of the bay and the calf remained on 07/04. On 07/05 the calf was seen in next bay to east, stranded but pushed back out. Stranded 07/05/04 in Hanalei. Gretchen Johnson recovered the carcass. It was shipped to the marine mammal center in sausalito, CA. Drs Gullard, Haulena, Lowenstein did the necropsy & histo UC Davis & mri taken. Results to PIRO.

DISCLAIMER

These data should not be used out of context or without verification. This should be strictly enforced when reporting signs of human interaction data.

DATA ACCESS FOR LEVEL A DATA

Upon written request, certain fields of the Level A Data Sheet will be released to the requestor provided that the requestor credit the stranding network and the National Marine Fisheries Service. The National Marine Fisheries Service will notify the contributing stranding network members that these data have been requested and the intent of use. All other data will be released to the requestor provided that the requestor obtain permission from the contributing stranding network and the National Marine Fisheries Service.

PAPERWORK REDUCTION ACT INFORMATION

Appendix 2.
Necropsy Report for the melon-headed whale calf

Necropsy Report on Melon-headed Whale (*Peponocephala electra*)

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This carcass is a neonate, male, code 2 (fresh, organs intact, dead 48 hours minimum) whale calf that was collected in Hanalei Bay, Kauai, Hawaii, on 7/5/04. It was shipped Federal Express 7/6/04 on ice to The Marine Mammal Center (TMMC), Sausalito, California, from where it was taken to Raytel Imaging, San Francisco, for magnetic resonance imaging (MRI) and computer tomography (CT) scans prior to gross necropsy and collection of tissues for histopathology, bacteriology and banking at TMMC on 7/7/04.

Imaging

Magnetic resonance imaging prior to dissection was performed using a GE Genesis Signa 1.5T MRI using GE XL 9.0 software. T1-weighted scans of in the sagittal and axial planes were collected for the head. In addition, the following pulse sequences were performed: T2* gradient echo (GRE) in the coronal and axial planes, T2 fast spin echo (FSE) in the coronal plane, and T2 fluid attenuation inversion recovery (FLAIR) in the coronal and axial planes. T1-weighted axial and T2 FSE coronal scans were collected for the thoracic region. (Parameters for the scans can be found at the end of this section.)

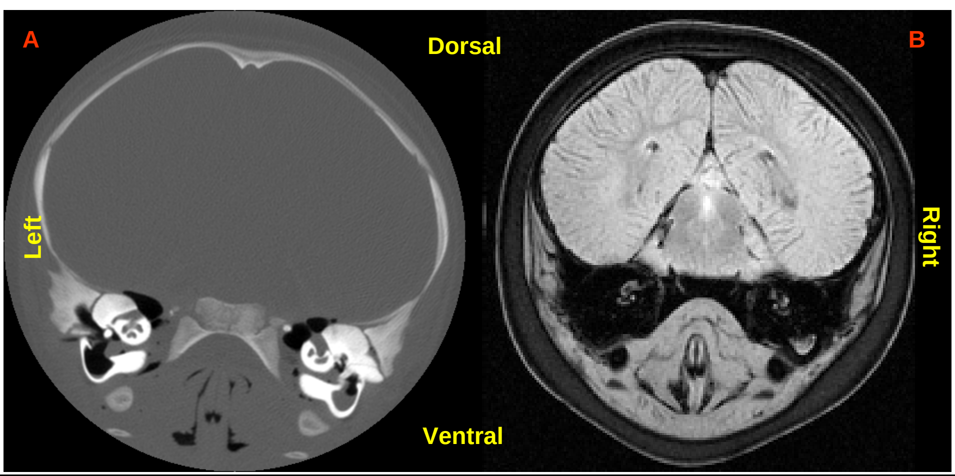


Figure 1. Images demonstrating normally developed brain without indication of hemorrhage, lesion or subdural hematomata. (A) CT scan through the brain, auditory bullae, and associated air spaces. (B) T2* GRE of the same region.

Computed tomography was performed with a GE Lightspeed CT. Images collected of the chest region (source of 140 kV at 120 mA) were contiguous and collimated to 5 mm. Images of the temporal bone (source of 120 kV at 100 mA) were also contiguous but collimated to 1 mm.

Incomplete cerebral myelination was consistent with neonatal developmental stage. No localized hemorrhages were observed within the parenchyma. No localized subarachnoid or intraventricular hemorrhages were observed and there was no indication of subdural hematomata (Fig. 1). No hemorrhage was apparent in any of the acoustic fats (i.e., melon and fats associated with the lower jaw).

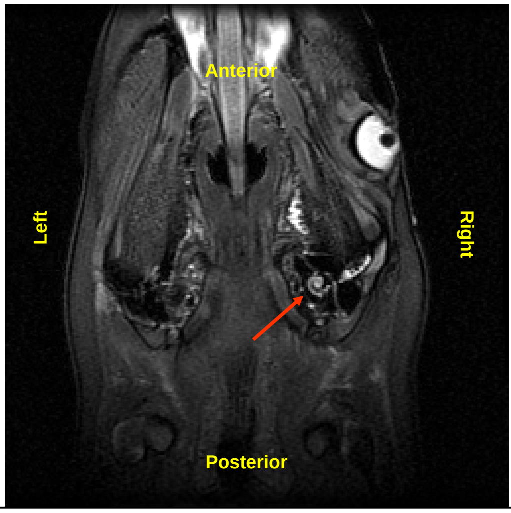


Figure 2. Coronal MRI image collected with the T2 FLAIR pulse sequence. The red arrow indicates the position of the cochlea. Some localized fluid accumulation appears in the Eustachian tube and associated sinus.

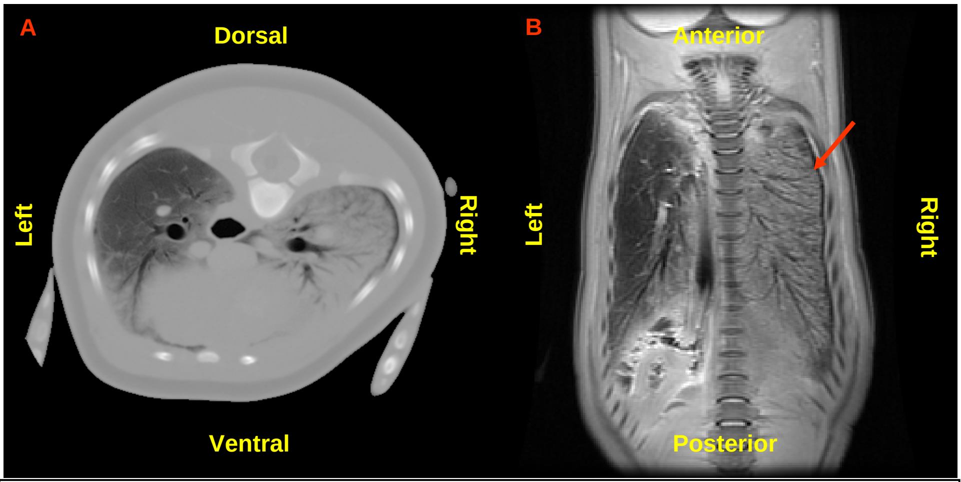


Figure 3. (A) CT demonstrating consolidative changes of the right lung, and to a lesser degree, in the left lung. (B) MRI collected with T2 FSE pulse sequence. The red arrow denotes the pronounced consolidative changes of the right lung.

The auditory bullae appeared grossly normal and the persistence of cochlear fluid permitted the cochlea to be visualized via the FLAIR pulse sequence (Fig.2). Associated sinuses and

Eustachian tubes appeared clear except for a localized region of hyperintensity involving the Eustachian tube and associated air spaces of the right auditory bulla, potentially corresponding to localized fluid accumulation. This collection measures approximately 7 x 9 x 10 mm. Although partially located within the pneumatized bone, it is not contiguous with the cochlea.

Airspace consolidative changes were observed in approximately 75% of the right lung (Fig. 3) and to a lesser extent in the ventral (caudal) portion of the left lung lobe. The main bronchi appeared clear and free of debris. The skeletal system was free of fractures and no structural or congenital deformities of either the soft tissue or skeletal system were detected.

MRI scan parameters – Head:

Plane and Scan Type	TR / TE	Slice Thickness / Skip	Matrix
Sagittal T1	500/17	4 mm / 1 mm	256 x 224
Axial T1	600/9	4 mm / 1 mm	320 x 224
Axial/Coronal GRE T2*	517/15 (20 degree flip)	5 mm / 1 mm	256 x 256
Axial/Coronal FLAIR	9000/133 (TI = 2200)	4 mm / 1 mm	256 x 224
Coronal FSE T2	4000/110	4 mm / 1 mm	384 x 224

MRI scan parameters – Chest:

Plane and Scan Type	TR / TE	Slice Thickness / Skip	Matrix
Axial T1	567/14	8 mm / 2 mm	256 x 192
Coronal FSE T2	3000/62	8 mm / 2 mm	256 x 192

Measurements taken at the time of necropsy

Weight: 17.5 kg

1. Total length: 115 cm
2. Snout to anus: 78 cm
3. Snout to genital slit: 67 cm
4. Snout to umbilicus: 56 cm
5. Snout to throat grooves: N/A
6. Snout to dorsal fin tip: 70 cm
7. Snout to anterior dorsal fin: 53 cm
8. Snout to flipper: 28 cm
9. Snout to ear: 23.5 cm
10. Snout to eye: 17.5 cm
11. Snout to gape: 15 cm
12. Snout to blowhole: 15 cm
13. Snout to melon apex: N/A (atrophied/non-developed melon)
14. Eye to ear: 6 cm
15. Eye to gape: 3 cm
16. Eye to blowhole edge, left: 11.3 cm

17: Eye to blowhole edge, right: 12.7 cm

18. Blowhole length: 1.3 cm Blowhole width: 3 cm
19. Diameter of ear opening: N/A (ear opening not distinguishable)
20. Head diameter at eyes: 15 cm
21: Length of eye opening: 3 cm
22. Rostral width, melon apex: N/A
23. Projection up/lower jaw: 0 cm
24. Number of throat grooves: N/A
25. Length of throat grooves: N/A
26. Flipper length, anterior: 23.8 cm
27. Flipper length, posterior: 17.4 cm
28: Flipper width, maximum: 6.5 cm
29: Length at mammary slits: N/A
30: Number of mammary slits: N/A
31: Length of genital slit: 9 cm; length of anal slit: 4.5 cm
32: Perineal length: 1.5 cm
33. Fluke width: 25 cm
34. Fluke depth: lobe = 9 cm, notch = 8.5 cm
35. Fluke notch depth: 1.9 cm
36. Dorsal fin height: 10 cm
37. Dorsal fin base length: 15 cm
38: Girth at eye: 57.5 cm
39. Girth at axilla: 56.5 cm
40. Girth, maximum: 57.5 cm
41. Girth at anus: 33.3 cm
42. Girth midway anus to notch: 23.6 cm
43. Height same place: 10.5 cm
44. Thickness same place: 4.4 cm
45. Blubber thickness, dorsal: 11 mm
46. Blubber thickness lateral: 11 mm
47. Blubber thickness ventral: 10 mm

<u>Post mortem findings</u>:

Figure 4. Left lateral view of whale carcass

Examined is the carcass of a 17. 5 kg, male melon headed whale (*Peponocephala electra*; Fig.4).

In several areas the skin is flaking off the underlying tissue (interpreted to be post mortem change). Approximately 6-8 circumferential fetal folds are present along the body (Fig. 5). The flukes are folded under at the tips (possible post mortem artifact). The umbilicus is absent (Fig. 6) and the umbilical slit is partially closed. Along the inner body wall the umbilical slit is surrounded by a small amount of fibrous tissue (Fig. 7). Several vibrissae are present along the rostrum. The melon is poorly developed and the body is thin, with concavity caudal to the skull.

Figure 5. Fetal folds on right side of carcass

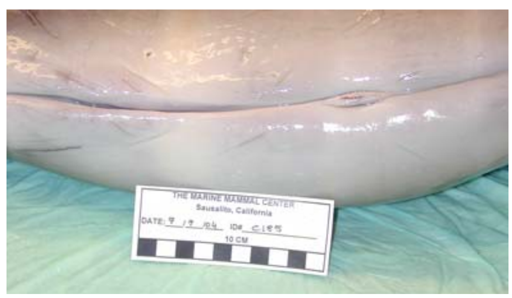


Figure 6. Umbilical scar on ventrum of carcass

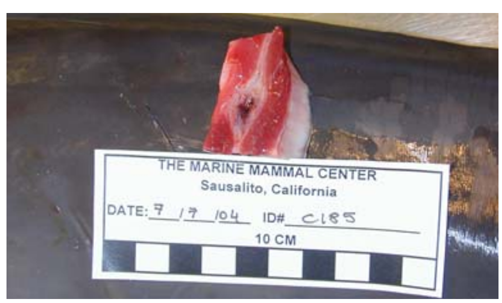
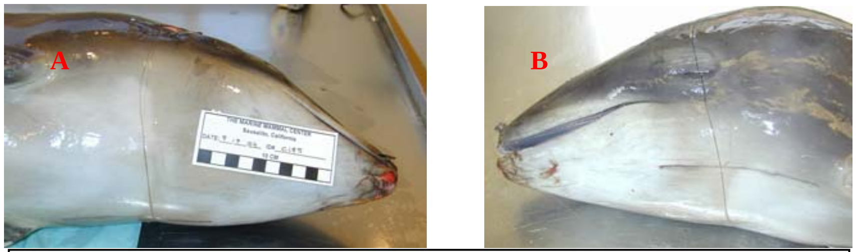


Figure 7. Internal view of healing umbilical scar.

There are several, 1.0 - 5.0 cm long, linear, depressed areas of skin along the chin and ventral mandible that have slightly raised, dark grey edges. Several, shallow, gray linear depressions are present along the ventrum, at midline and adjacent to the umbilicus and genital slits. Rake marks are present on the right side of the head lateral and anterior to the right eye and over the body. A single circumferential, 2.0 mm wide linear depression extends circumferentially around the head at the level of the eye (Figs. 8A and B). There is no evidence of hemorrhage associated with this linear depression.



Figures 8 (A and B). Circumferential linear lesion in skin.

There is scant adipose tissue in the abdominal cavity, around the kidneys, and in the coronary groove. The umbilical vein is partially patent. The urachus and umbilical arteries are partially patent.

There is a small amount of light tan, foamy fluid in the distal trachea and main stem bronchi. The right lung lobes are slightly collapsed, diffusely mottled dark red and purple, rubbery and exude foamy fluid and a large amount of blood on cut section (Fig. 9). The anterioventral, medial dorsal and margins of the left lung lobes are markedly collapsed, and approximately 50-60 % of the left lung is dark purple and rubbery. The remaining areas of left lung are dark pink and aerated. All sections of lung float in formalin. The heart weighs 141.2 g (0.8 % of body weight), the right ventricle is 0.8 cm thick, the left ventricle is 1.0 cm thick, and the interventricular septum is 1.0 cm thick. The ductus arteriosus is closed and the foramen ovale is slightly fenestrated. The thymus extends partially up the trachea and several lobes are present just distal to the larynx.

There is an approximately 4.0 cm diameter area of muscle over the distal left jaw that is pale pink to tan. There is no evidence of hemorrhage along the mandibular adipose tissue or skeletal muscle.

The esophagus and all chambers of stomach are empty. Minimal, light yellow to tan thick fluid is present throughout the small and large intestine. There is no evidence of meconium within the colon. Approximately 25 ml of golden urine is present in the bladder. The testes are immature.

The head was sectioned transversely at 1 to 2 cm increments using a band saw and the sections were examined grossly. Selected sections were fixed in formalin for preservation. No hemorrhages were detected in sinuses or inner ear cavities (Fig.10). The remainder of the head was refrozen.

Figure 9. Dorsal view of lungs removed from thorax.

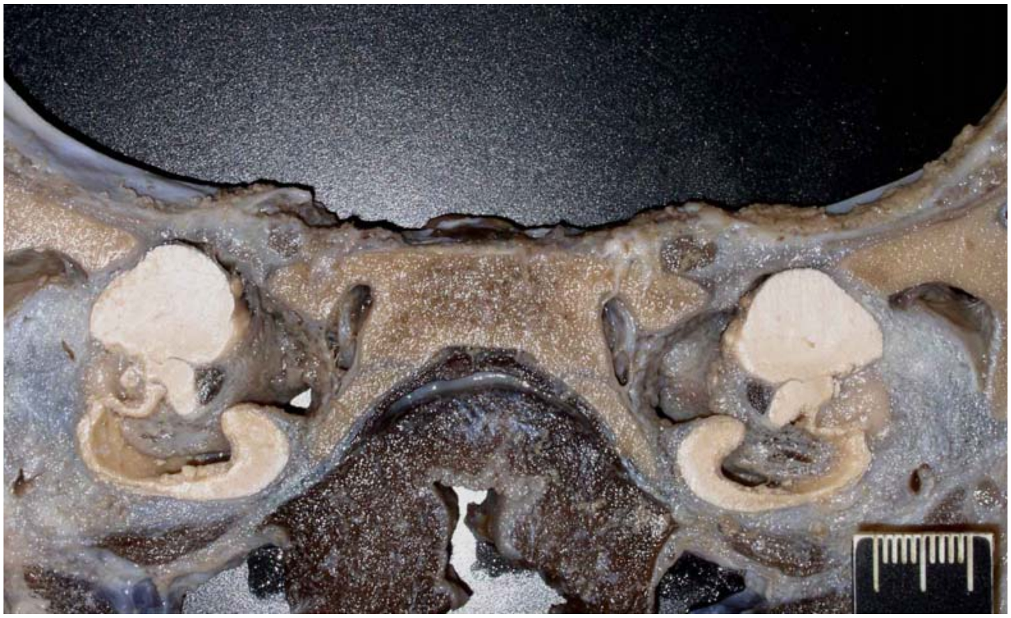


Figure 10. Sagital section of the frozen, formalin-fixed head at the level of the ears, showing absence of hemorrhage. The scale on the right side indicates 1 cm.

Microbiology: Aerobic and anaerobic bacterial culture of lung and liver grew *Enterococcus* sp., and two strains of *Photobacterium damsela* from each tissue.

Tissues banked for toxicology at –40^{0} C: Blubber (ventral midline and dorsum), liver, kidney, urine.

Tissues collected in DMSO for genetics: Skin (shipped to NOAA Southwest Fisheries Science Center, Chivers lab.)

Tissues frozen at –70^{0} C: lung, liver, spleen, kidney, serum (clotted blood from heart), urine, skeletal muscle, blubber.

Tissues sampled for histopathology: lungs, heart, trachea, aorta, thymus, salivary gland, thyroid glands, tongue, esophagus, stomach, duodenum, jejunum, ileum, colon, pancreas, spleen, liver, kidney, ureter, urinary bladder, blubber, adrenal glands, skin (multiple sites), eye, blubber, muscle (multiple sites), testes, brain, and the mediastinal, sternal, axillary, and mesenteric lymph nodes.

Histopathology

1) Lungs: Mild, multifocal, acute neutrophilic bronchopneumonia
2) Lungs: Moderate circulating leukocytosis and mild neutrophilic interstitial pneumonia
3) Lungs: Mild (right lung lobes) to moderate (left lung lobes) regional atelectasis, and moderate multifocal edema with aspirated squames and mild alveolar histiocytosis (Fig. 11)
4) Lungs: Acute passive congestion (moderate, right side and mild left)
5) Jejunum: Mild multifocal acute superficial neutrophilic enteritis
6) Skin, chin: Moderate multifocal, acute ulcerative and necrotizing dermatitis with epidermal hydropic degeneration
7) Cranial mediastinal, sternal, cervical and axillary lymph nodes: Moderate sinusoidal congestion, histiocytosis and erythrophagocytosis
8) Cervical and axillary lymph nodes: Mild sinusoidal neutrophila and minimal multifocal neutrophilic lymphadenitis
9) Cranial mediastinal, sternal, cervical, and axillary lymph nodes: Multiple mineralized concretions (see comment)
10) Spleen: Marked lymphoid depletion, circulating histiocytosis, and moderate extramedullary hematopoiesis (see comment)
11) Heart: Mild, multifocal, acute myofiber necrosis
12) Body as a whole: Emaciation
13) Liver: Moderate diffuse congestion, mild hepatic lipidosis, and mild hepatocellular anisokaryosis with intracytoplasmic protein droplets
14) Mesenteric lymph node: Moderate lymphoid hyperplasia and sinusoidal histiocytosis
15) Kidneys: Moderate segmental congestion
16) Pancreas: Mild zymogen depletion
17) Brain: Mild meningeal congestion
18) Tongue: Moderate segmental epithelial ballooning degeneration

19) Skin, head (circumferential depression): Thinning of stratum spinosum (intermediativum) and mild, multifocal, keratinocyte hydropic degeneration
20) Umbilicus: Superficial bacterial colonization and necrosis of distal umbilical vein and artery with fibroplasia (interpreted as normal regression)
21) Testes: Infantile

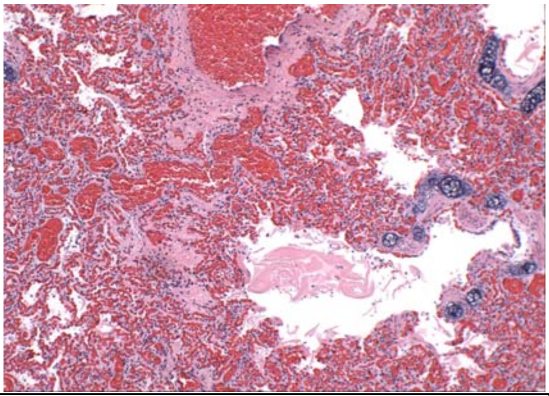


Figure 11. Hemotoxylin and Eosin stained section of right lung showing congestion and atelectasis.

Comments:

Based on the presence of fetal skin folds, degree of umbilical regression, standard length (reported normal birth length for *Peponocephala electra* is one meter), and histological appearance of the organs, this calf was most likely about a week old. All tissues examined were appropriately developed for a newborn cetacean and sections of lung were either fully or partially aerated. The meconium had been completely excreted, which occurs within the first few days of life in most species. The umbilicus had begun to regress and the ductus arteriosus was completely closed.

All of the inflammatory changes noted in the tissues examined were regarded to be mild, acute (6-12 hours old), and could have been secondary to injuries acquired during stranding or from being trapped in shallow water. There was no evidence of hemorrhage in the brain or in the cervical, cranial, or mandibular tissues and blubber. There was no evidence of viral disease in the tissues examined. Although cause of death could not be definitively determined, it is highly likely that maternal separation and poor nutritional condition were related to this calf's stranding.

This calf was emaciated and there was poor development of the melon. The stomach and intestines were empty. Therefore, this young whale likely had not nursed in sometime prior to stranding. Given the circumstances of the stranding, it is possible that this young animal was separated from the dam prior to stranding. It is not possible to determine whether this animal had ever nursed after being born. The thymus was well developed and there was no evidence of atrophy or depletion that can occur if there is poor nutrition or stress early in neonatal life. Hepatic lipidosis in young animals is often related to inanition or poor in utero nutrition.

Bronchopneumonia is a common finding in stranded cetaceans and in mild cases is often related to the act of stranding or being trapped in shallow water. There was a circulating leukocytosis in the lungs and in a few areas a very mild acute interstitial pneumonia. These interstitial changes were interpreted to be secondary to acute systemic inflammation. The left lung lobes were partially atelectic, which could be consistent with partial failure of alveolar expansion after birth (*atelectasis neonatorum*). The right lung lobes were diffusely congested and edematous consistent with stranding in right lateral recumbency. Small numbers of aspirated squames are normally found in the lungs of neonatal animals and can be present in the lungs weeks after birth. Acute myofiber degeneration and necrosis in the heart is thought to be related to stress induced endogenous catecholamine release. In this case the lesions were mild in the sections examined.

The skin lesions on the ventral mandible were acute and suggestive of external trauma. Interestingly, there was epithelial necrosis and adjacent intracellular edema in addition to the abrasions and ulcerations. These lesions can be associated with toxic injury to keratinocytes. Given the underwater topography of the area in which this animal stranded, we considered whether this change could have been related to contact or abrasions with coral. Similar lesions have been reported in humans following contact with coelenterates (*Letot, B., Pierard-Franchimond, C. & Pierard, G.E. Acute reactions to coelenterates, Dermatologica 1990, 180: 224-227*). There was a moderate drainage reaction in several of the lymph nodes examined and in the axillary and cervical lymph nodes there was sinusoidal neutrophilia and lymphadenitis. Again, these changes were very mild and, given the location of the lymph nodes, the inflammation may be related to the acute skin lesions. There was marked lymphoid depletion in the spleen. The lymphoid atrophy may be related to the mild inflammation in the skin, lungs, or small intestine, or could be reflective of the animal's poor nutritional condition and debilitation, though the thymus was not similarly depleted. Extramedullary hematopoiesis in the spleen is a normal finding in neonatal cetaceans.

The thin linear indention that extended circumferentially around the head was not associated with inflammation histologically. The indention was associated with sub-lethal cellular changes indicating that the changes probably occurred ante-mortem. The exact etiology of this skin lesion is not known, however, similar facial clefts due to constriction by amniotic bands have been described in humans infants, and can be induced experimentally in lambs and mice (*Rowsell, A.R. 1989. The amniotic band disruption complex. The pathogenesis of oblique facial clefts; an experimental study in the foetal rat. Br. J. Plast. Surg. 42:291-5; and Lockwood, C., Ghidini, A., Romero, R., Hobbins, J.C. 1989. Amniotic band syndrome: reevaluation of its pathogenesis. J. Obstet. Gynecol. 160:1030-3*). This indention was regarded to be a separate entity from the fetal folds common in neonatal cetaceans which were also present in this young whale. There was no inflammation associated with the rake marks examined histologically, suggesting that at least some of the rake marks occurred after death.

In several of the peripheral and thoracic lymph nodes examined there were small, mineralized concretions in the capsule and fibrous tissue septa of the node. In some areas these concretions were associated with the capillary endothelial cell lining. The significance of this finding is not known. Similarly, the adrenal cortex was much thinner than expected and from what has been noted in other cetacean species. Again, the significance of this change is unknown, and it may be an anatomic variation of this species or related to age.

Conclusions:

The combination of imaging, necropsy and histological findings suggest this calf was a neonate that died in poor nutritional status. There are several changes detected by imaging and histology (fluid in the right Eustachian tube, congestion of the right lung) that suggest this animal was lying on its right side for a significant period post-mortem. No evidence of trauma was detected.

Appendix 3.
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