Unusual cetacean stranding events of Taiwan in 2004 and 2005

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ABSTRACT

In early 2004 and in 2005, several unusual stranding events occurred in Taiwan during a period when large-scale naval exercises were conducted in and on nearby waters. Gross examination of the partial remains of two carcasses (a ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*) and a pygmy killer whale (*Feresa attenuata*)) and an intact Risso's dolphin (*Grampus griseus*) revealed that the former two had internal injuries to structures associated with or related to acoustics or diving. The several unusual stranding events and the findings of the gross *post mortem* examination of the only specimens that were available for study were suggestive that nearby naval exercises may have contributed to or caused the death of at least one cetacean in this region and that species other than beaked whales may also be susceptible to such activities. With an increasing number of military exercises in this region, more attention to the impacts of such activities on cetaceans is needed.

KEYWORDS: ASIA; STRANDINGS; GINKGO-TOOTHED BEAKED WHALE; SHORT-FINNED PILOT WHALE; PYGMY KILLER WHALE; DWARF SPERM WHALE; BLAINVILLE'S BEAKED WHALE; LONGMAN'S BEAKED WHALE; PANTROPICAL SPOTTED DOLPHIN; STRIPED DOLPHIN; RISSO'S DOLPHIN; DISTRIBUTION

INTRODUCTION

In recent years, concern about the impact of military activities (especially usage and testing of naval sonar) on cetaceans and other marine life has been increasing rapidly. A considerable amount of military activities occur in Taiwanese and adjacent waters due to decades of political instability and military tension in the region. Until recently, Taiwan's navy did not possess warships with the AN/SQS-53C mid-frequency active sonar (see *www.globalsecurity.org*) that has been implicated in the mass stranding of cetaceans in the Bahamas in 2000 (Balcomb and Claridge, 2001; England and Evans, 2001). At the end of 2005, Taiwan began acquiring US-made Kidd-Class destroyers (which do possess the above sonar). Furthermore, military exercises involving the US Navy occur in regions adjacent to Taiwanese waters (e.g. Balikatan exercises in the Luzon Strait of the Philippines). It has also been reported that Taiwan has plans to purchase two units of low frequency active sonar for land-based deployment.

With regards to cetacean welfare and conservation, the number of naval exercises in East Asian waters is of concern. Past records and more recent, but limited, ship-based cetacean survey data show that the waters of Taiwan (especially off the eastern and southern coasts) are inhabited by many deep-diving cetaceans (Chen, 2001; Wang *et al.*, 1995; Wang *et al.*, 2001; Wang *et al.*, 2002; Yang *et al.*, 1999; Yeh, 2001), of which at least some may be particularly vulnerable to naval activities (e.g. see Cox *et al.*, 2006). Furthermore, the potential deployment of new powerful anti-submarine warfare sonar by the US navy in the western North Pacific including waters near Taiwan raises more concerns about the potential impact of military activities on cetaceans in this region.

In this paper, we present the chronology of three series of unusual cetacean stranding cases that occurred on the shores of Taiwan (and nearby regions) in 2004 and 2005 and the results of *post mortem* gross examinations of three of the stranded animals.

MATERIALS AND METHODS

Information on cetacean stranding events were obtained from newspaper articles, direct observations, photographs, people who attended to stranding events and unpublished stranding records. Information about military exercises was obtained from newspaper, television news reports and from official internet sources.

Three carcasses were provided by local county governments for examination: ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*) – Pingtung County; pygmy killer whale (*Feresa attenuata*) – Tainan County; and Risso's dolphin (*Grampus griseus*) – Changhua County.

RESULTS

Chronology of the first series of events (see Fig. 1)

23 February 2004: Balikatan 2004 (large-scale US/Philippines joint military exercises) began; Taiwanese newspapers reported that naval exercises were conducted about 100km south of Taiwan on this day (also reported on the *US Marines in Japan* website: *http://www.okinawa.usmc.mil/*).

24 February 2004: Nine or ten short-finned pilot whales (*Globicephala macrorhynchus*) began stranding (alive) on a pebble beach south of Chengkung (Taitung County) in the morning. Other members of the group were seen swimming near the stranding site. Six carcasses were retrieved for display, education or research purposes by local institutions after rescue attempts failed.

29 February 2004: A female ginkgo-toothed beaked whale was found floating at sea near the town of Linbian (Pingtung County) by local coast guards at midday. It was uncertain if the animal was still alive when it was first discovered (reports were mixed). The specimen was sent to the National Museum of Marine Biology and Aquarium (NMMBA) where it was dissected by NMMBA staff but the intact head was frozen and later examined in detail by the authors (see below).

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1 March 2004: A fresh carcass of a striped dolphin (*Stenella coeruleoalba*) was found on a beach of Linbian (near the stranding location of the above ginkgo-toothed beaked whale). Photographs of the dolphin showed that it was not obviously emaciated and was bleeding from at least one (the left) eye. It was sent to the National Chengkung University for educational and research purposes.

7 March 2004: Balikatan 2004 military exercises ended (see *http://www.okinawa.usmc.mil/*).

7 March 2004: Although slightly beyond the geographical scope of this paper, an interesting event occurred in Zhejiang Province of the People's Republic of China. Seven short-finned pilot whales stranded alive on a beach. They were all assisted back to the sea by local residents but the cause of the stranding and the fate of the whales are unknown.

10 March 2004: One short-finned pilot whale stranded on the shores of Taishi (Yunlin County). The specimen was sent to the National Museum of Natural Sciences in Taichung City and examined by several researchers including staff of the Taiwan Cetacean Society.

These events are unusual because prior to 2004, there were only two other confirmed records of short-finned pilot whale strandings in Taiwan. Both events involved single individuals (females) and neither showed any obvious signs of internal injuries that could not be explained by natural causes such as pathogens, etc. (both specimens were dissected by the authors and the skeletons of these specimens are maintained at the NMMBA). The 24 February stranding was also the first mass stranding of short-finned pilot whales recorded in Taiwan. None of the animals examined by the authors at the stranding site exhibited typical signs of emaciation (such as the presence of a 'neck', loss of epaxial muscle mass, etc.). There is only one previously recorded stranding event of the striped dolphin in Taiwan (1, 2 and 5 dolphins stranded alive about 10-50km apart from each other over two consecutive days) and this species has only been observed in Taiwanese waters once (Yeh, 2001). Prior to 2004, there were at least 11 cases of stranded mesoplodonts (at least five were identified as ginkgo-toothed beaked whale and 1 as Blainville's beaked whale (*M. densirostris*). Unfortunately, for the previous stranded striped dolphins and mesoplodonts, there was no awareness of, or attention given to, injuries that may have been caused by acoustic or blast trauma or decompression sickness-like symptoms (e.g. see Fernández *et al.*, 2005; Jepson *et al.*, 2003).

Gross examination of the Linbian ginkgo-toothed beaked whale

General information

Only the intact head and partially cleaned post-cranial skeleton of the Linbian ginkgo-toothed beaked whale were available for the authors to dissect and examine. It was found floating at sea near Linbian (Pingtung County) on February 29. The specimen was female, at least 460cm long (measured from the flensed skeleton) and its mass was reported (in a newspaper) to be 870kg. The mammary glands were well-developed (but not lactating) and the epiphyses of all vertebrae were fused indicating sexual and physical maturity, respectively. The head was removed during initial necropsy by veterinarians and frozen for about one month before a detailed dissection was performed by the authors. Unfortunately, none of its visceral organs were available for examination of evidence of other lesions such as those described by Jepson *et al*. (2003).

The blubber weighed 201.7kg, which represented about 23% of the total reported mass of the whale. This was higher than the mean reported for mesoplodonts (Mead, 1989) and suggests that the Linbian ginkgo-toothed beaked whale was in good body condition before death. In addition, photographs of the whale did not reveal any obvious signs of emaciation. There was a substantial number of parasitic cysts (possibly *Phyllobothrium delphini*) in the blubber, particularly in the dorsal and ventral areas of the tailstock around the genital region. However, the level of infestation by this parasite in the blubber of the Linbian ginkgo-toothed beaked whale was not unusually heavy and similar levels have been observed in many presumably healthy cetaceans that were taken by local fisheries (J.Y. Wang, unpublished data).

The head

A circular area (about 20-25cm in diameter) of bruising in the left lower jaw region just ventral of the gape and some superficial damage to the skin were present. A longitudinal section of the melon along the midline revealed severe haemorrhaging in a pattern of several vertical stripes (or planes in three dimensions; Fig. 2a). The lower jaw fats also appeared to be discoloured by blood but this was not as striking as in the melon. Both tympanic bullae were shattered into many fragments (Fig. 2b) and a small amount of blood was observed in the tissues surrounding the bullae. Breakage of the tympanic bones occurred generally in the thinnest areas of the bones. Haemorrhage was found in the tissues lining the ventral regions of the pterygoid bones, the ventral margins of which were also severely fractured (and again breakage occurred generally in the thinnest portions of the bones; Fig. 2c). A considerable amount of dark blood was found under the skin lining the upper portion of both walls of the nasal septum of the external nares (Fig. 2d). The larynx appeared normal externally and no obvious signs of damage were found upon gross examination of this structure in longitudinal section. Haemorrhage in bone tissue was found in a wide band across the top of the anterior face of the cranial vertex and at the upper portions of the nasal septum. A fresh dark circular scar (about 1-1.5cm in diameter) that resembled knife damage to the bone was also observed on the right premaxilla on the anterior face of the cranial vertex and within the band of haemorrhage yet the tissue in this region was never removed by cutting (these injuries were discovered after the skull was cleaned of tissue using water maceration; Fig. 2e). The rest of the skull was undamaged with the exception of the fragile tip of the rostrum and the thin, brittle postero-ventral corner of both sides of the mandibles that were broken during skeleton preparation. A fully-healed fracture from a previous injury across the tip of the lower jaw was also found.

The body

On each side, there were 11 vertebral ribs (8 two-headed, 2 single-headed and 1 floating). The 10th vertebral rib on the right side was cut near the middle by veterinarians during necropsy. The vertebral formula was: C_e 7, T 11, L 10, C_a 20 = 48 (the last caudal vertebra was counted as one unit because its shape and size did not appear to be the union of two vertebrae). Some haemorrhage was found in the vertebral disk between the 9th and 10th lumbar vertebrae but the cause of the haemorrhage is unknown and may have been incurred during the stranding process, in the final moments prior to death.

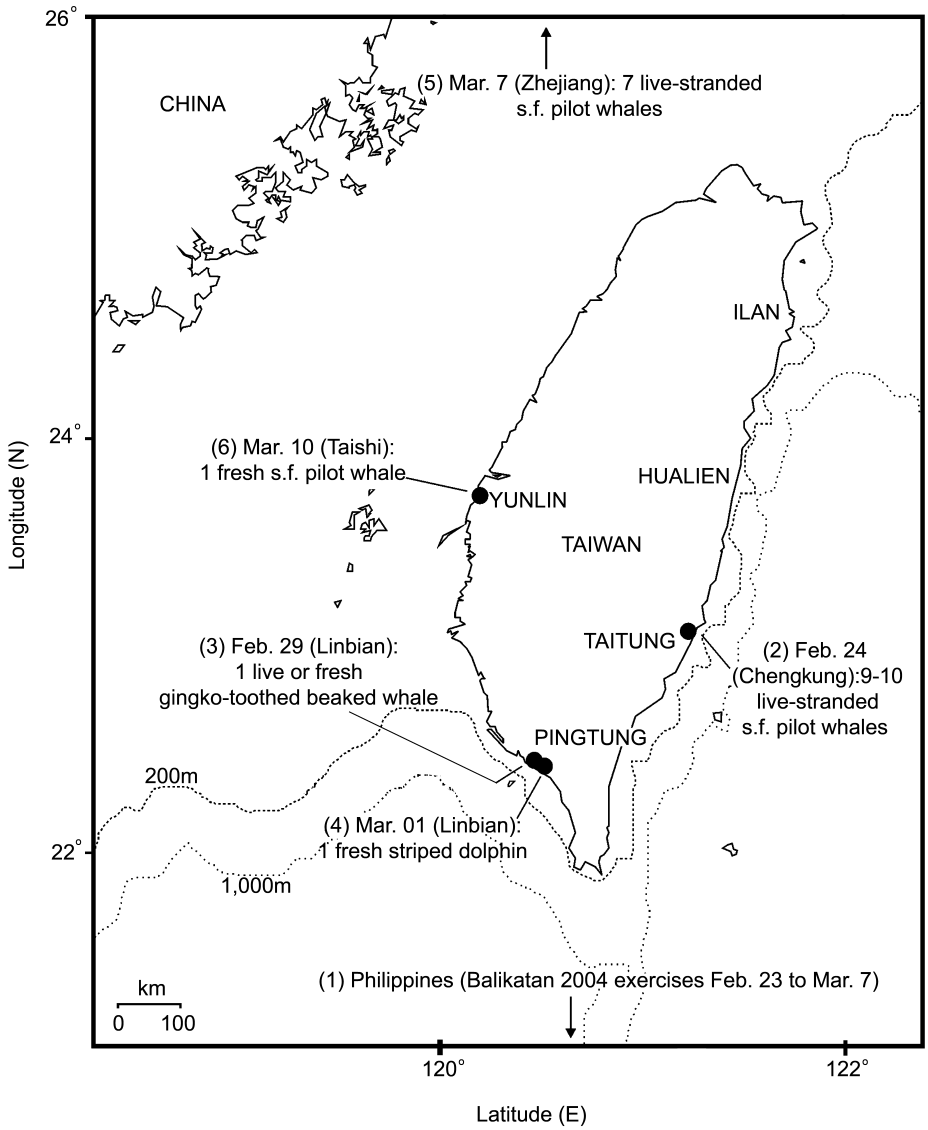

Fig. 1. Map showing a series of events that occurred on the island of Taiwan during the winter of 2004 (with one event being in Zhejiang Province, mainland China). Numbers represent the chronological order of the events.

Examination of the thoracic *rete* revealed extensive haemorrhage in the anterior approximately three-quarters of this structure. The vermiculate blood vessels in the anterior three-quarters of the thoracic *rete* were hardly, if at all, visible while the vessels in the posterior one-quarter were clear. The phalangeal formula of both flippers was: I 1, II 7, III 6, IV 5, V 4. Many metacarpal and phalangeal bones were broken at about the middle of the flippers but these injuries were likely incurred post-mortem, during the handling of the specimen.

The complete skeleton of this specimen was cleaned and is in the collection of the NMMBA (specimen code: JYW-04-02).

Chronology of the second series of events (see Fig. 3)

22 February 2005: Eight pygmy killer whales stranded alive on the shores near Jiangjun fishing port (Tainan County); three died, three were reportedly returned to sea and the other two were assumed to have been returned to sea. Initial reports misidentified these cetaceans as melon-headed whales (*Peponocephala electra*).

23 February 2005: 28 pygmy killer whales stranded alive on a beach near Chinshan fishing port, (Chiku village, Tainan County), which is about 5km south of the area above. Nine died, the remaining 19 were returned to sea.

23 February 2005: A Risso's dolphin stranded alive near Fangyuan village (Changhua County) and was sent to the NMMBA for rehabilitation, but died three days later.

26 February 2005: A school of 20-25 pygmy killer whales (species identification could not be confirmed from photos available) swam into the Nanxing industrial area of Hongmao port (Kaohsiung) around 10:00hrs.; coast guards herded them out at about 16:00hrs.

1 March 2005: A small Risso's dolphin was seen swimming in very shallow waters close to shore near Nanwan, Kenting National Park (Pingtung County). Attempts to catch it failed and it swam offshore.

Of all the stranded pygmy killer whales, two were kept for rehabilitation but died within a few days. All specimens were examined by local veterinarians and pathologists as commissioned by the Tainan County government.

Fig. 2. Internal injuries to the head of a ginkgo-toothed beaked whale that stranded on 29 February 2004. Arrows and ovals show the injuries: (a) vertical stripes of haemorrhage in the melon; (b) shattered tympanic bullae; (c) fractured pterygoid bones; (d) haemorrhage and blood clot under the skin lining the nasal septum; and (e) haemorrhage across the anterior face of the cranial vertex and nasal septum. (Photographs by John Y. Wang/*FormosaCetus*).

Only the Risso's dolphin of 23 February and one partially flensed, but completely eviscerated pygmy killer whale were available to the authors for *post mortem* examination (see below). Coincidentally, these events occurred during the same period (last week of February to first week of March) as the events of 2004.

Gross examination of the Tainan pygmy killer whale

General information

For the Tainan pygmy killer whale, only a partially intact head (area anterior of the blowhole and lower jaw were intact; the posterior part of the head was cut open and brain removed) and partially flensed and eviscerated body were available for examination. The accompanying information indicated this individual was involved in the 23 February mass stranding event. From the incomplete carcass, the body length was measured (piece meal) to be about 225cm and it was male. The thickness of the blubber of the animal was not unusually thin in any area of the body and appeared to be in good condition (note: photographs of most of the other dead specimens showed them to be fairly robust and none exhibited obvious signs of emaciation).

The head

There was a partially healed 'cookie-cutter' shark type wound on the right side of the anterior part of the head. The crater of missing flesh from the attack was about 3cm long, 2.5cm wide and 1.5cm deep. However, there were no other

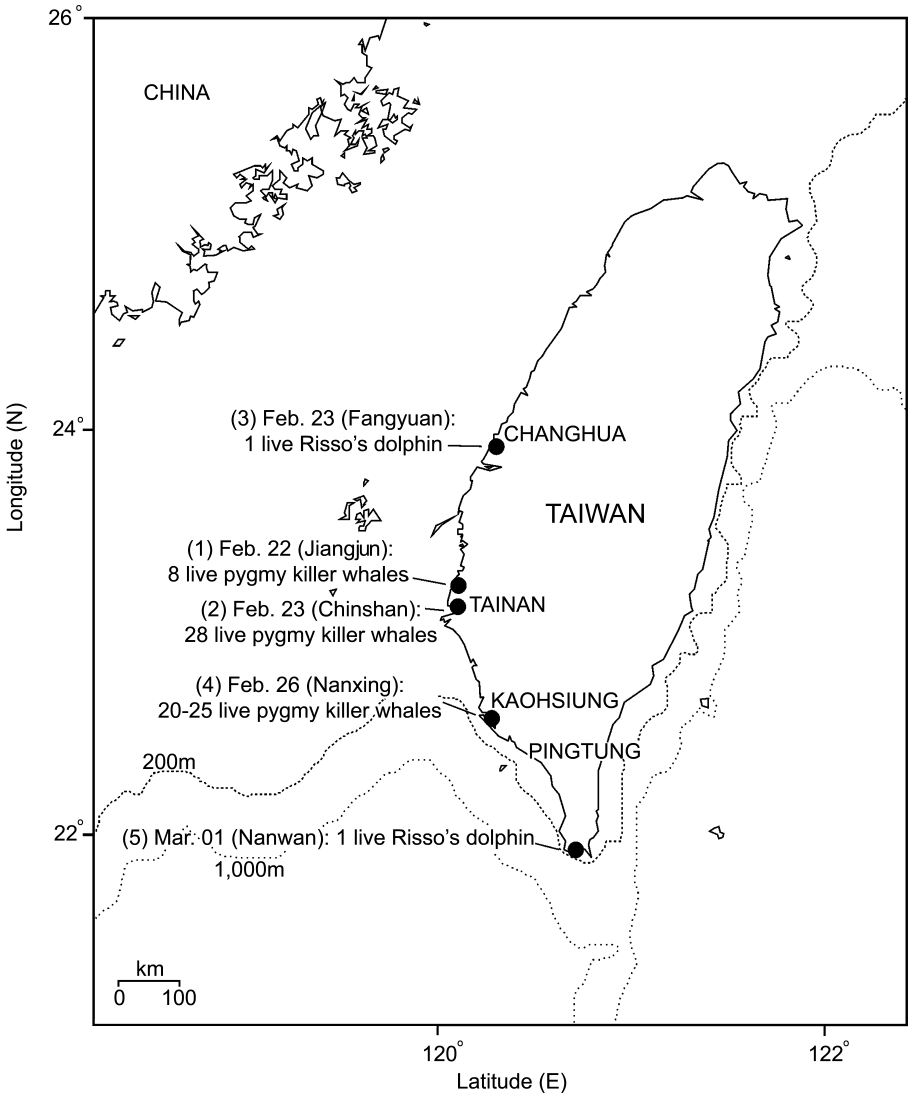

Fig. 3. Map showing a series of events that occurred on the island of Taiwan during the winter of 2005. Numbers represent the chronological order of the events.

obvious external injuries to the anterior part of the head and lower jaw regions. Fairly heavy loads of parasites were discovered in the auditory, pterygoids and orbital sinuses. In the melon, an unusual sheet of haemorrhage was found running parallel to and about 2cm above the plane of the rostrum and in a wedge shape. The wedge of haemorrhage was about 4-5cm wide, extended throughout almost the entire length of the melon and was thickest laterally on the right side and gradually became thinner medially and across to the left of the midline of the melon (Fig. 4). Given the incompleteness of the specimen, our examination was limited. The skull has not yet been prepared for examination or measurements and is being maintained in the freezers of the NMMBA (specimen code: JYW-05-09).

The body

Numerous completely healed 'cookie-cutter' shark type wounds were also found on the body, especially around the urogenital region. No obvious unusual internal or external injuries were noted but the material available was extremely limited. The skeleton has not been prepared and is being maintained in the freezers of the NMMBA (specimen code: JYW-05-09).

Gross examination of the Fangyuan Risso's dolphin

General information

The Fangyuan Risso's dolphin stranded on 23 February 2005, but died a few days later after unsuccessful rehabilitation efforts. It was a male measuring 262.0cm and 259.6kg (weighed after death). The entire carcass was frozen for 4.5 months before *post mortem* examination. There were no obvious gross signs of unusual injuries. The skeleton has not been prepared for examination or measurement and is maintained in the freezers of the NMMBA (specimen code: JYW-05-01).

Chronology of the third series of events (see Fig. 5)

It is important to note that the following list was compiled from local news sources and is only a subset of the many stranding events that occurred. A closed workshop aimed at examining the possible cause(s) of the large number of unusual stranding events in Taiwan was convened recently and included international cetacean pathologists, who examined the remains of some of the carcasses and histological preparations (see Anon., 2005a). During an open symposium on these unusual strandings in 2005, it was reported that from 19 July to 13 August, there were 22

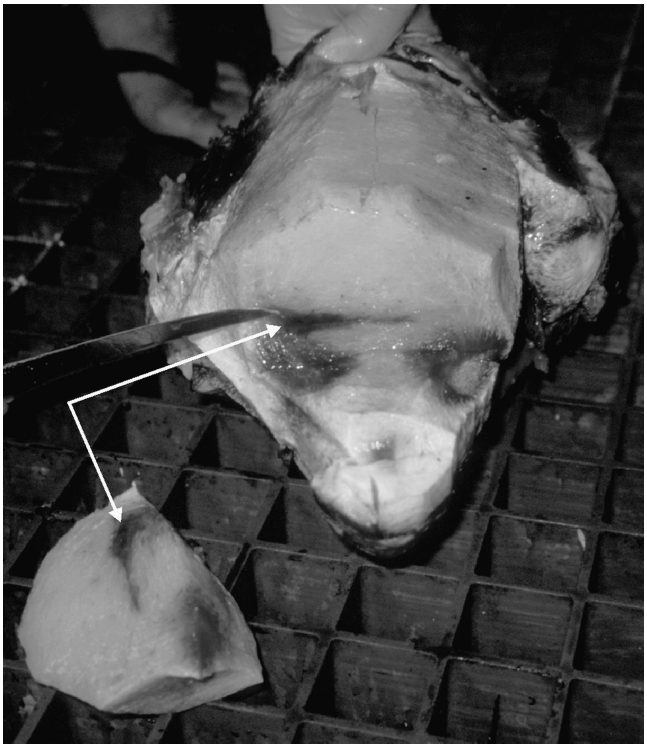

Fig. 4. A head-on view of a cross section of the melon at about mid-rostrum of a pygmy killer whale that stranded on 23 February 2005. Arrows point to the area of haemorrhage (Photograph by Shih-Chu Yang/*FormosaCetus*).

stranding events involving at least 7 species and 25 individuals (Yang, 2005). In five or six of the individuals examined, 'bubble-like' lesions were reported (Yang, 2005), but more detailed analyses of these lesions and other tissues were still being conducted by workshop participants.

19 July 2005: A single pantropical spotted dolphin (*Stenella attenuata*) was found dead on a beach of Chijin (Kaohsiung County). News reported the animal was discovered at about 16:30hrs and appeared to have been dead for about a day.

20 July 2005: A dwarf sperm whale (*Kogia sima*) was found dead on a beach near Aodi/Gongliao (Taipei County) in the evening.

21 July 2005: Two striped dolphins stranded alive on the shores of Toucheng (Ilan County) in the morning (one died, the other was returned to the sea on July 22).

21 July 2005: One *Kogia* sp. (species identification could not be confirmed by the authors) stranded alive on the shore near Aodi/Gongliao (Taipei County) and was discovered at about 15:00hrs; it was later returned to the sea.

22 July 2005: Two beaked whales were seen swimming close to shore in shallow waters off Ilan County in the afternoon.

22 July 2005: One cetacean of unknown species stranded alive near Suao (Ilan County) in the afternoon but was returned to the sea.

22 July 2005: One live or freshly dead dwarf sperm whale was found on a beach of Xiamen, Fujian province of mainland China (the news article reported it as a minke whale but the accompanying photograph clearly showed a dwarf sperm whale).

23 July 2005: Two (possibly mother and calf pair) Longmans's beaked whales (*Indopacetus pacificus*) stranded alive on a beach near Suao (Ilan County) in the afternoon and died. These animals were originally misidentified as ginkgo-toothed beaked whales.

24 July 2005: A Blainville's beaked whale was found alive on a beach at Wujie (Ilan County) at 12:30hrs but died shortly afterwards. This animal was also misidentified initially as a ginkgo-toothed beaked whale.

26 July 2005: The East China Sea (Donghai) Fleet of the People's Republic of China was reported to have held exercises in July[1] but no details (including dates) of the exercises were disclosed in the report.

29 July 2005: A dead *Kogia* (species identity could not be confirmed by the authors) washed into the port of Keelung City. However, there are mixed reports that claimed this was a dwarf sperm whale that was alive when discovered.

30 July 2005: One dwarf sperm whale was found swimming in Taichung Harbour (Taichung County).

30 July 2005: One dwarf sperm whale (species identity could not be confirmed by the authors) stranded alive on a beach of Hsinchu County and was returned to the sea.

3-4 August 2005: Taiwan's navy held exercises (Han-Kuang No. 21) off southwest Taiwan that involved depth charges (see *www.taipeitimes.com*, 04 August 2005).

7 August 2005: US/Japan joint exercises (JASEX) in and around the waters of Guam and Okinawa began (see US Pacific Command's official website[2]).

10 August 2005: A young Blainville's beaked whale stranded alive on a beach of Zhunan (Miaoli County) and kept for rehabilitation before dying about three days later.

13 August 2005: JASEX ended (see US Pacific Command's official website[2]).

This series of events was composed mainly of deep-diving and oceanic species. In Taiwan, striped dolphin records are relatively rare as stated earlier. The large number of *Kogia* spp. and beaked whale strandings over such a short period is highly unusual. This stranding rate is by far the highest ever recorded in Taiwan, where an active reporting network for cetacean strandings has operated since the mid 1990s. Because the first stranding (19 July, pantropical spotted dolphin) was located at a distance from all other earlier stranding events, the former case is unlikely to be related to the others. The strandings in July were not related to the naval exercises of Taiwan or the US and Japan listed above. However, it is unclear if military exercises were being conducted by the People's Republic of China. Investigations into potential causes of these unusual stranding events, including military activities and detailed pathological examinations of some of the carcasses, are being conducted presently (Anon., 2005a).

DISCUSSION

Many of the severe internal injuries sustained by the Linbian ginkgo-toothed beaked whale were extraordinary because there were no obvious signs of external injuries with the exception of bruising to the left lower jaw region ventral to the gape and superficial damage to the skin (the latter damage was almost certainly caused during post-mortem handling of the specimen). In addition, the well-protected (by soft tissue and bone) tympanic bones were shattered, yet there was no damage to the lower jaw bones or calvarium adjacent to this area. The pterygoid bones were also fractured even though this region of the head is also well protected from physical trauma by soft tissue and the lower jaw. Furthermore, all obvious injuries (except the vertebral disk haemorrhage) were to, or adjacent to, anatomical

[1] *www2.chinesenewsnet.com/NewsPics/Reuters/Tue_Jul_26_19_42_29_2005.html*

[2] *http://www.pacom.mil/exercises/jasex05/index.shtml*

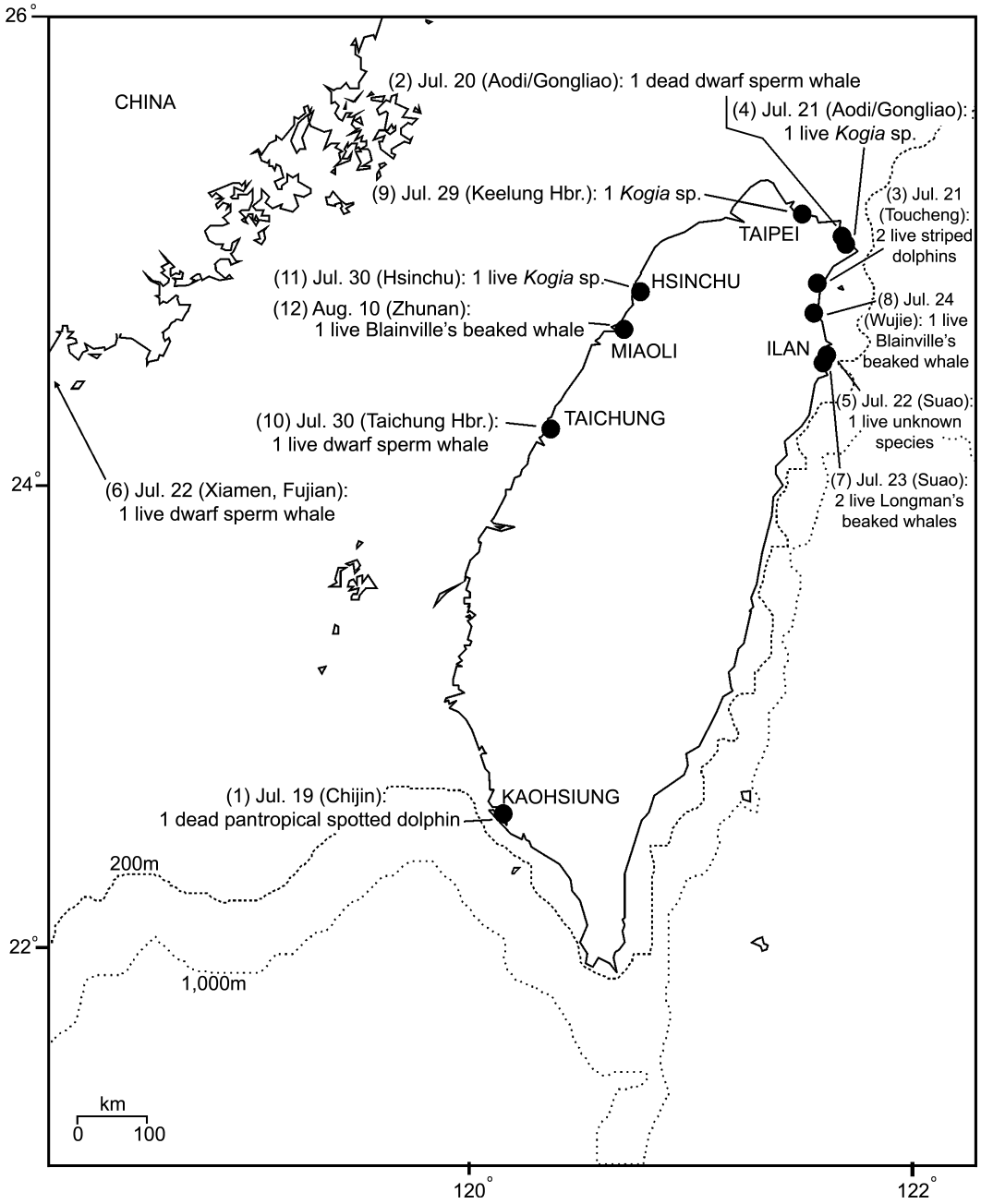

Fig. 5. Map showing a subset of a series of stranding events that occurred on the island of Taiwan during the summer of 2005 (with one event being in Fujian province, mainland China). Numbers represent the chronological order of the events.

structures associated with the animal's acoustic sense (i.e. melon, lower jaw fats, nasal septum, tympanic bones, anterior face of the cranial vertex) or likely involved in or related to diving (i.e. thoracic *rete*, pterygoid bones). Unfortunately, none of the visceral organs were available for examination. The freshness of the carcass, its discovery location and the coincidence of the event with nearby large-scale military exercises are suggestive that the energy source may have originated from these exercises.

The haemorrhage in the melon of the pygmy killer whale somewhat resembled the melon injuries observed in the Linbian ginkgo-toothed beaked whale but the haemorrhage was not as extensive or severe and in a different orientation than the latter case and no other soft tissue injuries were found during gross examination of the limited material available. We suspect that at least some of the other more than 30 individuals involved in the mass stranding events at Tainan on 22 and 23 February 2005 would also exhibit similar, and possibly more, injuries. It would be too coincidental that the only and incomplete specimen that we examined be the only one with such injuries. However, we can only await the findings of those who performed the *post mortem* examinations on the other specimens. Although the 2005 event involved the largest number of individuals, there have been prior cases of mass stranding events of pygmy killer whale in Taiwan such as in 1996, 1997 and 2002 (unpublished data). The causes of pygmy killer whale strandings in Taiwan are unknown and require more attention.

Live single stranding events involving Risso's dolphin are fairly common and it is one of the most commonly encountered species in Taiwanese waters (see Chen, 2001; Huang, 1996; Wang *et al.*, 2001; Yang *et al.*, 1999; Yeh, 2001) so the occurrence of the Fangyuan stranding event

was not unusual, probably unrelated to the pygmy killer whale stranding events and maybe a 'natural' background event.

The number of unusual cetacean stranding events during and shortly after the end of nearby naval exercises suggests that stranding events involving cetacean species other than beaked whales (particularly, *Kogia* spp. and short-finned pilot whale) should also be examined in the context of military activities. However, unlike the Bahamas stranding events in 2000 (Balcomb and Claridge, 2001), a full suite of information is unlikely to be available for these Taiwanese cases. However, the following factors may be rejected for some of these cases.

Earthquakes

Most of the unusual strandings did not appear to be related to earthquakes. Earthquakes occur often and tectonic movements exceeding magnitude 5.0 (Richter scale) are fairly frequent in and around Taiwan, yet large numbers of strandings are not so common. On 29 February 2004, two earthquakes measuring magnitude >4.0 (at the epicentres) were recorded in the morning off Ilan County (northeast Taiwan) and off Hualien County (central eastern Taiwan) before the discovery of the Linbian ginkgo-toothed beaked whale (see Anon., 2004 for earthquake information). However, it is unlikely that these activities caused or contributed to the death of this animal because the earthquakes were relatively minor (for Taiwan) and the epicentres were situated about 200-275km (point-to-point distance across land) away from the town of Linbian in southwest Taiwan. Similarly, it is also unlikely that the Linbian striped dolphin stranding of 1 March 2004 was related to earthquakes (>4.0) that occurred off Hualien County in the evening of 29 February 2004 and the early morning of 1 March. The other stranding events on 7 and 10 March were distant, temporally and spatially, from sizeable seismic movements that occurred in March prior to the stranding events (Anon., 2004).

Two earthquakes measuring almost magnitude 5.0 (at the epicentres) were recorded on 23 and 24 February 2004 just north of the location of the 24 February 2004 mass stranding of short-finned pilot whales (see Anon., 2004 for earthquake information). Presently, with minimal information from the carcasses of the short-finned pilot whales, natural seismic activity cannot be eliminated completely as the cause of, or a contributing factor, to this mass stranding event.

From 20 February to 1 March 2005, five sizable earthquakes measuring over magnitude 4.0 were recorded (Anon., 2005b). In the early morning of 23 February, a 4.19 earthquake was recorded near Orchid Island, which is fairly distant from the stranding locations in Tainan County. Also, it is likely that the 23 February stranding of pygmy killer whales were related to the stranding event of the previous day so it seems unlikely this earthquake was the cause of the stranding of these pygmy killer whales. The other four large earthquakes occurred on 28 February off and along eastern Taiwan (Ilan and Hualien counties), quite distant (about 200-330km) from the location where a small Risso's dolphin nearly stranded on 1 March. We conclude that earthquakes are unlikely to be the reason for any of the cetacean strandings during this series of unusual events.

There were 15 recorded earthquakes between 18 July and 10 August, 2005 that were at least magnitude 4.0 (of these two were >5.0) at their epicentres (Anon., 2006a). However, due to either the distance of the stranding locations from the epicentres of the earthquakes and time of the movements, only for the following six events would earthquakes be a potential factor: 21 July – two striped dolphins in Ilan County; 21 July – one *Kogia* sp. in Taipei County; 22 July – two beaked whales reported near the shore of Ilan County; 22 July – one stranded cetacean that was sent back to sea; 23 July – two Longman's beaked whales in Ilan County; and 24 July – one Blainville's beaked whale. There were five earthquakes that could be related to these stranding or near-stranding events. On 19 July, there was an earthquake off Hualien County (4.28). On 20 July, there were two earthquakes, one inland in Pingtung County at 18:48hrs (4.29) and one along the coast of Ilan County at 21:06hrs (5.22). On 22 July, there was an earthquake also along the east coast at Taitung County at 19:52hrs (4.17). Finally, on 23 July, there was a magnitude 4.41 earthquake at 01:18hrs (Hualien County). As there is little information available presently on these stranding victims, earthquakes can not be eliminated as at least a contributing factor to their stranding.

More research is needed to understand the effects, if any, of earthquakes on cetaceans. However, it is clear that earthquakes were not the main factor in causing most of the stranding events presented in this paper. It is also noteworthy that Taiwan is an area where natural seismic activities are common (Anon., 2004; 2005b; 2006a) but the recent numbers of stranding events have not been equally as common. For example, from 4 January to 29 June 2005, there were more than 50 earthquakes that were magnitude 4.0 or greater and more than ten that were greater than or equal to 5.0 (mostly off eastern Taiwan), but there were fewer stranded cetaceans during this period than between 19 July and 13 August 2005. If earthquakes do affect cetaceans, there does not appear to be any obvious temporal or spatial pattern between stranding events and the magnitude (as measured on the Richter scale) of the seismic activities.

Typhoons

For the first (February/March 2004) and second (February/March 2005) series of stranding events, typhoons were not a factor. Even though two typhoons (*Matsa* and *Haitang*, the latter being a super typhoon) battered Taiwan during the period of the third series of strandings (Anon., 2006b), severe weather was unlikely to have been the primary cause of all the strandings because typhoons are common in Taiwan from June to September but such large numbers of stranded cetaceans have not been recorded in previous years. Furthermore, there was an overwhelmingly high number of infrequently encountered species (e.g. kogiids and ziphiids) and almost none of the more common species in Taiwanese waters such as spinner dolphins (*Stenella longirostris*), Risso's dolphins, pantropical spotted dolphins and bottlenosed dolphins (*Tursiops* spp.). However, it is possible that the typhoons led to the beaching of compromised individuals and although it may be possible that deep-diving cetaceans were more susceptible to these recent storms, it is difficult to explain why previous and subsequent powerful storms did not have a similar impact on local cetaceans.

Seismic research

The main research ship for seismic surveys in Taiwan is the *Ocean Researcher No. 1* and vessel equipment and activities are well documented (e.g. National Center for Ocean Research of Taiwan, *www.ncor.ntu.edu.tww* and *www.ntuio.oc.ntu.edu.tw*). The *Ocean Researcher No. 1* has seismic equipment and CHIRP sonar. Prior to the period of the first series of strandings, there were two student training (of physical oceanography) trips that were made by *Ocean Researcher No. 1* from 10-21 February 2004 and 25-27

February 2004 (in the coastal waters off SW Taiwan). These trips did not appear to involve seismic surveys using air guns or sonar.

During and just prior to the second series of stranding events (late February/early March 2005), *Ocean Researcher No. 1* did not conduct any research trips so could not have caused these strandings.

Around the period of the third series of stranding events, there were several research trips by *Ocean Researcher No. 1*: 16-20 July (OR1 759 – ODP surveys); 24-31 July (OR1 – 760 VANS surveys); 2-3 August (student training trip from Kaohsiung to Keelung); 4-5 August (student training trip from Keelung to Kaohsiung); and 6-17 August (South China Sea research). On July 16 and 17 and from 24-31, ocean floor surveys of the northern part of the South China Sea (off the continental shelf) were conducted using the CHIRP sonar. This sonar has a frequency range of 3-11kHz and a beam width of 25-50°. It seems highly unlikely this sonar system could have caused most, if any, of the strandings in the northern parts of Taiwan in the latter half of July. Furthermore, air guns were never used during or prior to any of the three series of unusual strandings. However, seismic research cannot be ruled out completely because smaller vessels are capable of conducting seismic surveys and seismic research vessels from mainland China may also be conducting surveys in adjacent waters. Oil/gas and mineral exploratory activities are increasing in the region and the impact of such surveys on cetaceans needs to be examined. Much more detailed information about seismic research equipment and activities in and around Taiwanese waters is required (see IWC, in press).

CONCLUSIONS

Although, some factors can be eliminated as the cause of some strandings, it is difficult to make solid conclusions about the causes of most of these events or the serious internal injuries that were found during gross examination of two of the animals involved. However, at least one, the Linbian ginkgo-toothed beaked whale, coincided with large-scale military exercises south of Taiwan and the internal injuries that were sustained by this whale were remarkable. Naval sonar and live ammunition exercises are two of many plausible causes that need to be investigated. However, given the paucity of *post mortem* results from other cetaceans that stranded and other supporting information (e.g. recordings of ocean sounds, details about the military exercises, etc.), it is impossible to determine the reason for the unusual stranding events. For the most recent series of events, more detailed *post mortem* results are expected, but information about human and natural activities in this region is also needed urgently.

Recommendations

It was unfortunate that the *post mortem* results of only one complete and two partial carcasses from the first two series of stranding events were available. To increase our knowledge and understanding of the impact of human and natural activities on cetaceans, all specimens need to be examined properly by experienced researchers. Given the large and increasing military presence of several nations in Chinese and adjacent waters, including the newly acquired Kidd Class destroyers (which possess the 53C mid-frequency sonar that has been implicated in the deaths of some cetaceans – see England and Evans (2001)) of the Taiwanese navy, it would not be surprising if more unusual cetacean stranding events occurred in the future. One of the aims of this paper is to bring attention to the possibility of an, as yet undocumented, impact of naval and seismic research activities on populations of cetaceans inhabiting Taiwanese and adjacent waters, which needs to be investigated with the help of international expertise. Below are several recommendations that can help to increase our understanding of anthropogenic and natural activities on cetaceans in this region.

(1) Local researchers and government authorities need to acknowledge that military activities may seriously injure or kill cetaceans and lead to stranding events.

(2) All efforts should be made to preserve entire carcasses of all stranded cetaceans (especially deep-diving or oceanic species) for examination by experienced researchers and to collaborate with international experts on cetacean pathology.

(3) All unusual stranding events should be examined with considerations of recent military or other activities emitting intense amounts of energy (e.g. live fire target practice, seismic research, etc.) in local and neighbouring waters.

(4) Information about military exercises needs to be obtained or made available if presently unavailable to improve the understanding of the issue(s).

(5) Taiwanese waters should be monitored acoustically on a continuous basis.

(6) Live stranded cetaceans (especially of deep-diving or oceanic species) should not be returned to the sea immediately because they are unlikely to survive. Release of an animal should only be conducted if the animal can be demonstrated to be healthy and can be tracked remotely (e.g. with satellite telemetry), as well as monitored visually after release for a minimum of one to two months as recommended by St. Aubin *et al.* (1996). Unless a released animal can be monitored, success of the release (and any rehabilitation efforts) cannot be determined.

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