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**WORLDWIDE REVIEW OF PYGMY KILLER WHALES, *Feresa attenuata*,
MASS STRANDINGS REVEALS TAIWAN HOT SPOT**

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ABSTRACT

Pygmy killer whales, *Feresa attenuata*, are known worldwide from tropical to warm-temperate waters. The first recorded mass stranding event (MSE) of this species occurred in January 1968 in South Africa. We documented 16 MSEs to April 2006 in Bali, Indonesia. The number of animals involved in these MSEs ranged from 3 to 28, but most MSEs were less than eight animals. Taiwan was identified as a major hot spot for these MSEs with 25% of the events occurring since 1995 in a relatively small section of coastline in the south-west. Three additional near MSEs were documented from Taiwan between 1995 and 2005. We found no relationship between date of the MSEs or near MSEs and the moon phase. We propose that the most plausible explanation for these MSEs and near MSEs at least around Taiwan is anthropogenic sound.

INTRODUCTION

Today pygmy killer whales, *Feresa attenuata*, are known worldwide in tropical and warm temperate waters, but fifty year go they were known from just four specimens and two of these were from unknown locations and the other two were from Japan and Senegal . The species was first described as *Delphinus intermedius* from a skull obtained by the British Museum of Natural History from an unknown location (Gray 1827). He later established the genus *Feresa* for this species (Gray 1871). A second specimen, also from an unknown locality, was described as *F. attenuata* (Gray 1874). Eighty years passed with no new examples of *Feresa* until it was rediscovered over 55 years ago in Taiji, Japan (Yamada 1954). The fourth specimen was from Yenn, Senegal (Cadenat 1958, Fraser 1960). Although numerous new specimens have been reported since its

rediscovery over fifty years ago, this species remains the least known of the world's delphinids, (Ross and Leatherwood 1994, McSweeney *et al.* 2009). This small cetacean is generally considered to be an offshore species it has been widely recorded from sightings and single strandings throughout much of the tropical and subtropical parts of the Indian, Pacific and Atlantic Oceans. The English common name pygmy killer whale was first proposed by M. Yamada in 1954 and has since been generally used worldwide.

Worldwide records for *F. attenuata* include: Japan, Yamada 1954; Senegal, Cadenat 1958; Japan, Nishiwaki *et al.* 1965; Hawaii, Pryor *et al.* 1965; South Africa, Bass 1969; eastern Tropical Pacific, Perrin and Hubbs 1969; Texas, Gulf of Mexico, James *et al.* 1970; St. Vincent, Lesser Antilles, Caldwell and Caldwell 1971, eastern Australia, Bryden 1976; Arabian Sea, Harwood 1980; Sri Lanka, Alling 1983; Peru, Van Waerebeek and Reyes 1988; Argentina, Lichter *et al.* 1990; Brazil, Zerbini and de Oliveira Santos 1997; Vietnam, Smith *et al.* 1997. Most of these records are based on either at-sea sightings or single stranding event but rarely they have been reported to mass strand (Mignucci-Giannoni *et al.* 1999). Mass strandings, usually in small numbers, are known from South Africa, Hawaii, Florida, Texas, and British Virgin Islands (Bass 1969, Odell and Asper 1986, Mazzuca *et al.* 1999, Wursig *et al.* 2000, Mignucci-Giannoni *et al.* 1999).

Detailed records of six pygmy killer whale mass strandings for Taiwan, three near mass strandings (milling events) are reported here along with a summary of other worldwide mass strandings for this species.

METHODS

A mass stranding event (MSE) is when three or more animals strand together. MSEs are frequently preceded by “milling” events, where a pod or school of pelagic dolphins or small whales enter shallow water and begin to circle continually or move about haphazardly in a tightly packed group, with occasional members breaking away and swimming towards the beach (Geraci and Lounsbury 1993, Brownell *et al.* 2009). A near mass stranding event (NMSE) is a “milling event” that does not result in a MSE.

The potential for confusion exists over the use of the term “milling” to describe the behavior of the MHWs because this word has been used to describe two different forms of cetacean behavior. While some authors, such as Geraci and Lounsbury (1993), use the term to describe typical pre-stranding behavior, others use it to describe the frequent changes in heading sometimes observed in schools of small cetaceans during their normal daily activities (Shane *et al.* 1986). This type of “milling” can be “associated with feeding, socializing or play, if rapid, or with resting or idling, if leisurely” (Shane *et al.* 1986) and is not a warning that stranding may be imminent. The “milling” behavior seen in Hanalei Bay, Hawaii was the type described by Geraci and Lounsbury (1993).

All Taiwan information used in this review are from the cetacean stranding data bank housed in Chou’s laboratory at the National Taiwan University. We also confirmed details on all mass strandings as well as milling events of pygmy killer whales using reports from newspapers, TV news reports and interview with people who were at the strandings sites.

RESULTS

We collected data on a total of 22 MSEs or near MSEs for the pygmy killer whales between January 1968 to April 2006. In 14 of the 1 MSEs researchers found the whales stranded live. In the other three MSEs, the animals had recently died in two cases and in the other case they were found mummified well after the stranding event. The 17 MSEs had from three to 28 individuals with a mean was 6.3 animals, but in 14 MSEs the group size was 3 to 5 animals. The most common area for these MSEs was Taiwan and Florida/Georgia, USA regions were 32% and 26.3% respectively. Seven (41.2%) of these 17 MSEs have occurred since 1996 and 57.% of these were from Taiwan.

Mass stranding events—Table 1 lists all Feresa MSEs before the first one in Taiwan in 1996. A total of four mass strandings were recorded from Taiwan (Table 1) since 1996. The first MSE was 18 live animals stranded at the mouth of the Tzeng-Wen River, Tainan Co. on 23 February 1996. Three of these whales stranded live and then died and the other 15 were returned to the sea. The second event was five whales that stranded on 17 January 1997 at Piemen, Tainan Co. One died and four were returned to the water. The next day three animals also at also stranded at Piemen on 18 January 1997. One died and two animals were returned to the water. We assumed that the whales on the second day in the Piemen strandings were from the same school as the first stranding on 17 January. The third MSE was four animals that stranded live on 4 July 2002 in Chang Hhua, Tainan Co. All of these whales were transported by boat about 3 nm offshore and released. The fourth record was 8 whales stranded live at approximately 11:00 on 22 February 2005 at Chian-Chun village, Tainan Co. Three whales died on the beach, two were taken for rehabilitation and three were returned to the sea. The next day MSE was

28 whales that stranded live at approximately 10:30 on 23 February at Ching-Shan fishing port in Chian-Chun. Additional whales were observed milling offshore. Nine whales died on the beach and the other 19 were returned to the sea and chased away by the Coast Guard. These last two groups stranded less than 24 hours apart and the distance between two stranding locations was approximately 13 km.

Milling Events— A total of three additional milling events were recorded around Taiwan, but did not result in MSEs. The first event occurred in early February 1995 when an estimated 20-40 individuals enter the Tzuo Ying Naval Harbor near Kaohsiung City and were reported to moved in and out of the harbor for about a week. After this time, the whales were not seen again. The species identification was confirmed from photographs provided by [Mr. Ming-Yuan Le]. The second event occurred on 11 February 2003 when about 20 animals entered the 2nd port of Kao-Hsung Harbor, Kaohsiung Co. The species identification was confirmed from a photograph that appeared in the southern edition United Daily News [southern edition] Kaohsiung City on 12 February 2003, page 5. At least nine PKWs can be seen in photograph and two of the whales were spy-hopping. The whales were not present in the harbor on the morning of 12 February. The third event occurred on 26 February 2005 with an estimated 20 whales occurred near Da-Lin-Pu, Chi-Chin village, Kaohsiung City. Jack Yang confirmed species identification based on video shown of this event on television. The event was just three days after the double MSEs on 22 and 23 February 2005 approximately 100 km to the north of the MSEs (see Table 1). These whales were not reported again after the first observed on 26 February. It is likely that some of all of the whales in this third milling event (26 February 2005) were from the 24 whales that were refloated from the MSEs on 22 and 23 February 2005.

Worldwide MSEs –Twelve other mass strandings of pygmy killer whales have been previously reported worldwide (Table 1). The first known MSE for this species was in South Africa in 1968 (Bass 1969) and the second was from Florida, USA in 1976 (Schmidly 1981). Six additional MSE occurred during the 1980s in Florida, Hawaii, Texas and Georgia (Forrester *et al.* 1980, Mazzuca *et al.* 1999, Texas and Georgia). During the 1990s, three more MSE were reported from Florida, the British Virgin Islands and Venezuela (FL, Mignucci-Giannoni *et al.* 1999, Bolanos and Villarroel 2003). One additional MSE was from New Caledonia (Borsa 2006).

In our list of 20 MSEs or near MSEs, 18 had information on the exact date of stranding or milling and were live or fresh dead, and from these we were able to determine the phase of the moon during which the stranding or milling event occurred. The number of MSEs or near MSEs was unrelated to the phase of the lunar cycle.

DISCUSSION

About 35% of the worldwide MSEs or near MSEs of PKWs have occurred on the southwestern coast of Taiwan since 1995 and another 20% of these MSEs have occurred along the coast of the southeast United States, mainly in Florida. The remaining 45% of the MSEs occurred in Hawaii, British Virgin Islands, Venezuela and South Africa.

School size for this species in subtropical regions (South Africa, Japan and Florida) is usually less than 15 animals. In tropical waters like the eastern Tropical Pacific, the group size is larger and up to 70 whales (mean = 25). Around Hawaii, group can contain up to 50 animals and occasionally a few hundred (Leatherwood *et al.* 1988). Off the north-eastern coast of Sri Lanka one school was estimated at 120 animals (Leatherwood *et al.*

1984). However, the identification of the dolphins in this large school was not made by researchers and therefore the species id is not certain.

Before the Taiwan MSE of *Feresa*, all previous MSEs of this species were of only small pods that varied in size between 3 and 5 animals. The group of 28 and 18 *Feresa* that stranded on 23 Feb. 2005 23 February 1996, respectively in Taiwan are the largest and second largest schools to mass strand for this species.

Single strandings of pygmy killer whales are known from all of the locations with MSEs (Maldini *et al.* 2005, Odell and Asper 1986, Ross 1984, Chou unpublished Taiwan data) with the exception of Venezuela. Additional single strandings of pygmy killer whales are known from numerous tropical locations worldwide. Mignucci-Giannoni *et al.* (1999) summarized all Atlantic Ocean stranding records for this species. Indian Ocean records of *Feresa* specimens are summarized in Leatherwood *et al.* (1991).

Single strandings of *Feresa* are rare around Taiwan (Yang 1976, Chou, unpublished stranding data since 1990). Two single strandings are known from the east coast of Taiwan.

In the case of the PGWs examined in the Taiwan mass stranding the body condition of all animals was good. There were no traumatic external or internal lesions consistent with by-catch and all of them stranded live. From the available data from the other *Feresa* MSEs, most stranded live.

Various factors have been proposed to explain mass strandings of cetaceans in the past:

Weather

Errors in navigation, areas with broad tidal flats, strong or unusual currents may be related to some MSEs. In the case of the MSE in Venezuela, the whales were first observed “swimming parallel and close to the shore and docks” (Mignucci-Giannoni *et al.* 1999) and these authors noted that this “event occurred the day after Hurricane Marilyn devastated the Virgin Islands”. Typhoons are common around Taiwan but the season for these events is mainly June to October and all of the MSEs and milling events occurred in either January or February except one in July. One MSE occurred on 4 July 2002 but no typhoon occurred in this region before this stranding. However, The July 2002 MSE was on the central western coast of Taiwan. A medium sized typhoon “Rammasun” passed offshore of the northeastern tip of Taiwan between 2 to 4 July but we do not believe this had any influence of the July 2002 MSE.

Magnetic field anomalies

Most important common factor is the strong social cohesion that is single animals attract other animals

Viral or infectious diseases

Viral contaminants outbreaks may be suppress the host’s immune system and thus increasing the frequency of MSEs. No obvious disease was found in any of the animals from the Taiwan MSEs.

HABs

No accounts of harmful algal biotoxin bloom were found that matches with any of the *Feresa* MSEs in Taiwan.

Sound

MSE must be increasing in frequency due to anthropogenic causes. This is a worldwide problem in the oceans.

General Discussion

As milling events often turn into a MSE, it is important to experiment with ways to prevent these events from becoming fatal. Geraci and Lounsbury (1993) recommended the use of “noise, nets, people, and boats to herd the animals offshore”. When possible we recommend testing of acoustic deterrent devices (ADD), such as the pingers used to prevent bycatch of marine mammals (Barlow and Cameron 2003) when milling events occur. The combination of herding with small vessels and ADDs has been used with some success in preventing several milling events from possibly becoming mass strandings of Atlantic white-sided dolphins (*Lagenorhynchus acutus*) in the Cape Cod region of Massachusetts, USA (Touhey 2003).

Based on the available data our investigations appear to rule out diseases, weather/climatic (phase of the moon), fisheries interactions, acute physical trauma (e.g. boat impact), and starvation, HABs. However, sound can not be ruled out.

Previous to the first 1996 MSE of pygmy killer whales in Taiwan, only two MSEs of small cetaceans are known from Taiwan. Yang (1976) reviewed the state of knowledge from Taiwan cetaceans and reported a mass stranding of 109 live harbor porpoise, *Phocoena phocoena* on 11 October 1957 at Hengchun. However, these animals were re-identified as Melon-headed whales, *Peponocephala electra* (Wang *et al.* 2001). One of us (RLB) also examined one of the animals in 1967 from this MSE and confirmed that they were *P. electra*. Wang *et al.* (2001) reached the same conclusion on the species identification of this MSE. Another ten MSEs or near MSEs (with three or more animals)

of small cetaceans, excluding pygmy killer whales, have occurred in Taiwanese waters since 1990. The species involved in these other Taiwan MSEs included: 7 short-finned pilot whales, *Globicephala macrohynchus*; on 24 February 2004 (Wang and Yang 2006), 15 pantropical spotted dolphins, *Stenella attenuata*, on April 1996 (Chou *et al.* 1996), 20+ dolphins on 19 June 2000, five dolphins on 5 November 2003, 10 dolphins on xxxx 2008 (Chou, unpublished stranding data); five striped dolphins, *S. coeruleoabla*, on 14 March 1998 (Chou, unpublished stranding data); 12 rough -toothed dolphins, *Steno bredanensis*, on 2 September 1995 (Chou *et al.* 1996), four dolphins on 28 April 2002, three dolphins on 11 Feb 2004 (Chou, unpublished stranding data); and three ginko-tooth beaked whales, *Mesoplodon ginkgodens* on 29 February 2004 (Wang and Yang 2006).

Based on the large number of PKW MSE, PKW milling events, and other small cetacean MSEs that have been recorded in Taiwan since 1990, we suggest that these events (both MSEs and milling events) must be the result of some very unusual unknown environmental or anthropogenic events that causes these events.

Spatially all of the PKW MSEs and PKW milling events occurred on the southwestern along approximately only xx km of the coast while most of the single strandings of this species occurred along the eastern coast of Taiwan.

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Table 1. Worldwide mass stranding records for Pygmy Killer Whale, *Feresa attenuata*, (with 3 of more animals).

5	Jan. 1968	Luderitz Lagoon South west Africa	Live	Bass 1969 Best 1970
5	15 Feb. 1976	Dog I., Franklin Co., Florida, USA	Mummies	Schmidly 1981 Forrester <i>et al.</i> 1988
3	8 Jan. 1981	Panama City, Bay, Co., Florida, USA	Fresh dead	Odell & Asper 1986
4	13 June 1981	Ma'alaea, Maui, Hawaii^ USA	Live	Mazzuca <i>et al.</i> 1999, Maldini <i>et al.</i> 2005
3	10 July 1983	Whale Harbor, Monroe Co., Florida, USA	Fresh dead	Odell & Asper 1986
3	1 Dec. 1983	Port Aransas, Nueces Co., Texas, USA	Live	Ray Tarpley +
4	7 May 1988	Jekyll I., Glynn Co., Georgia, USA	Live	Stevens Kagey
3	16 July 1988	Kihei, Maui, Hawaii [total3+?]	Live	Mazzuca <i>et al.</i> 1999]# Jenner <i>et al.</i> 1989
3	4 Sept. 1992	Port of Saint Joe, Florida, USA 29°48'N, 85°18'W	Live	Gulf Marine aquarium examined
5	16 Sept. 1995	Trellis Bay, Beef Island, (Tortola) British Virgin Islands 18°26.8' N, 64°32.2'W	Live	Mignucci-Giannoni <i>et al.</i> 1999
18	23 Feb. 1996	Mouth of Tzeng-Wen River, Kaoshiung City, Taiwan	Live	3 died others returned NTU
5	7 Jan. 1997	Peimen, Tainan Co., Taiwan	Live	NTU
3	18 Jan. 1997	Peimen, Tainan Co., Taiwan	Live	NTU

3	17 Feb. 1998	Playa Tucacas, Falcon, Venezuela	Live	Bolanos & Villarroel 2003
4	4 July 2002	Jo-Tzong Chiao, Hsien-His village, Chang-Hua, Co., Taiwan	Live	all returned NTU
8	22 Feb. 2005	Chiang-Chun Harbor Tainan Co., Taiwan	Live	3 died & others returned NTU
28	23 Feb. 2005	Chiang-Chun Harbor, Tainan Co., Taiwan	Live	9 died & others returned NTU
3	30 January 2006	near La Coulee (2215'S., 16633'E) New Caledonia	Live	2 returned by locals Locals Borsa (2006) #92
Plus additional single specimen on 3 Feb. 2006 dead at Baie de Toro (22°09'S, 166°17'E) which may be one of the two that were refloated on 30 January (Borsa 2006)				
8	19 April 2006	Padanggalak Beach, Bali (near Denpasar)	Live	8 returned by locals – Mustika <i>et al.</i> 2009

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Table 2. Worldwide near mass stranding events for Pygmy Killer Whale, *Feresa attenuata*, (with 3 of more animals).

Number	Date	Location	Remarks	References
20-40	February 1995	Taiwan	milling	This paper
20	11 February 2003	Taiwan	milling	This paper
20	26 February 2005	Taiwan	milling	This paper`