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Short Note

First Record of a Right Whale Fossil Radius from the Pre-Historic Period of Japan

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The family Balaenidae, including the right and bowhead whales, are passive skim feeders who swim slower and have larger flippers compared with most other baleen whales (Jefferson et al., 2008). Ten species of balaenids have become extinct in geological time (de Lavigerie et al., 2020).

Based on molecular phylogenetic studies, a modern genus *Eubalaena* includes three species: (1) *E. glacialis*, (2) *E. australis*, and (3) *E. japonica* (Rosenbaum et al., 2000; Gaines et al., 2005). These are the southern, North Atlantic, and North Pacific right whales, respectively, based on their allopatric distributions.

A substantial number of right whales are affected by human activities, including whaling, vessel collisions, entanglement in fishing gear, climate change, pollution, noise, and habitat loss (Kenney, 2018). The North Pacific right whale (*Eubalaena japonica*) has been recognized as an endangered species, and their current population trend is unknown (Cooke & Clapham, 2018). We know that the number of right whales is very low based on stranding and bycatch records in Japan utilizing the Marine Mammal Stranding Database of the National Museum of Nature and Science (Tokyo) (www.kahaku.go.jp/research/db/zoology/marmam/drift/index.php). The database shows only 19 *E. japonica* records in the genus *Eubalaena* since 1902, which is much smaller than those of other baleen whale species such as, for instance, the humpback whale (*Megaptera novaeangliae*; Tanaka & Taruno, 2021). In a book published in 1897, the right whale was noted as the most frequently observed whale in the seas around Japan (von Siebold, 1897).

In Japan, some earlier records of right whales were stored and reported. Some products that were stored at a temple, the Shosoin in Nara Prefecture, Japan, for 1,200 years, were made from the baleen plates of the right whale (Shindo, 1978; Omura, 1986). A draft written in 1808 recognized the morphology of the right whale and its behavior (Otsuki, 1808/1976). However, the population size of *E. japonica* prior to the 19th century is almost unknown (Cooke & Clapham, 2018).

Historical fishery records are a powerful source to estimate species distribution, especially of species which were exploited before records of modern scientific study (Josephson et al., 2008). On the other hand, fossils can also be powerful sources, which are direct evidence that an animal existed in the past. They are especially useful for pre-historic periods.

Herein, we report a right whale fossil (specimen number OMNH-QV 4813, collected in the Osaka Museum of Natural History, Japan) from a sediment deposited about 8500 to 5000 years before present (BP) in Osaka, Japan (see below). The specimen was collected about 17 m under the surface at Minamihommachi 3 Choume, Osaka City (34° 40' 56.97" N, 135° 30' 3.55" E; Figure 1A & B) on 7 February 1966 during building construction. The depth of the locality is about 15 m below sea level because a map shows that altitude of the area is about 2 m (Osaka City Toshikeikaku-Kyoku, 1974). An alluvium, the Namba Formation, forms the Osaka Plain and includes a marine soft clay layer called Ma 13 (Marine Clay 13). The Ma 13 is continuous and thicker to the western side of Osaka City and Osaka Bay (Kansai Geo-Informatics Research Committee, 2007). The thickness of the Ma 13 becomes thinner to the western side of the Uemachi Upland. Then, the Ma 13 becomes very thin and disappears east to the Mido-suji (Figure 1C). The horizon of the specimen is about 100 m west and 9 m lower than the thin-out point of Ma 13 (Figure 1). It is certain that the original horizon of the specimen is a marine sediment because autochthonous marine molluscs, *Ostrea* sp., were preserved on the surface of the specimen. Thus, the specimen was deposited after the sea level reached -15 m.

A sea level curve, presented by Masuda et al. (2000), allows us to estimate that the age of sea level reaches that level at about 8500 BP. The thin-out point of the marine clay layer suggests that the widest distribution of the marine clay sedimentation was during the highest sea level period (Masuda, 1992). The age of the highest sea level at the Osaka Bay was about 5000 BP (Masuda, 1992). Thus, the estimated age of the specimen is about 8500 to 5000 years BP.

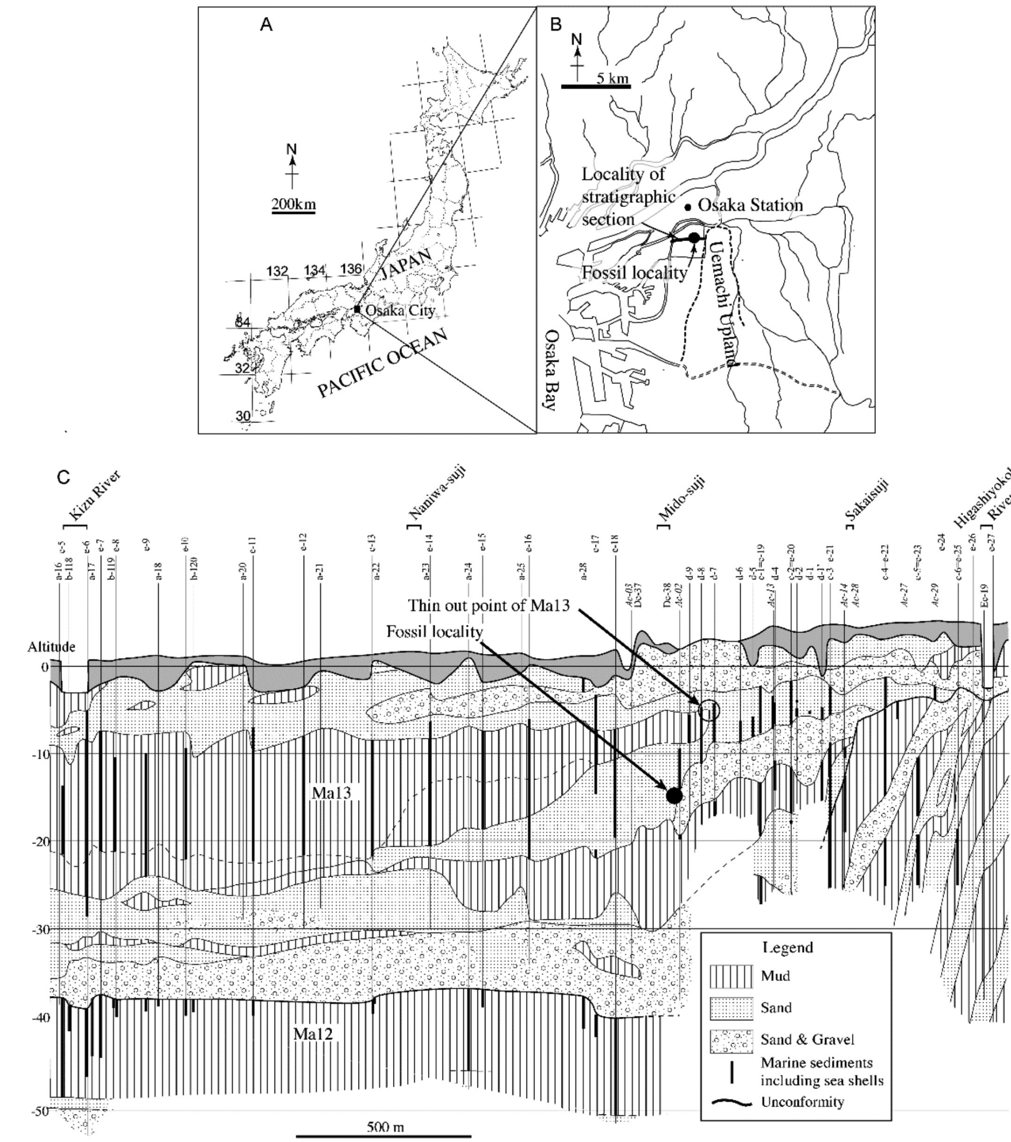

Figure 1. Maps (A) and (B) showing the locality of OMNH-QV 4813, *Eubalaena* sp.; and (C) stratigraphic sections using previous publications and reports deposited in OMNH. In (C), boring data, such as [a-xx], [b-xx], and [c-xx], are taken from geological survey reports of the 4th line (Cyuo line) of the Osaka City subway; [Dc-xx] are taken from the Kinki Branch of the Architectural Institute of Japan & Kansai Branch of the Japanese Geotechnical Society (1966); and [Ac-xx] are taken from the Kansai Branch of the Japanese Geotechnical Society & Kansai Geotechnical Consultants Association (1987).

The specimen was identified as the left radius of a balaenid whale (Figure 2; Table 1), which is a narrow fan-shaped bone (Figure 2). The radius shows a proximodistally short shaft and an anteroposteriorly elongated distal end. The length of the proximal end is smaller than that of the distal end. A preserved small area on the proximal end shows a rugose surface, which implies that the epiphysis was removed. The shaft has a convex lateral surface and flat medial surface. On the posterior surface of the shaft, there is a large circular nutrient foramen (8 mm in diameter). On the lateral surface, a circular huge hole with a smooth lip (67 mm in diameter) opens at the distal end of the radius and runs into the shaft, which might have been used as a nest for invertebrates (there are no remains of animals in it). The distal end of the radius preserves a flat articular area for the intermedium facing posterodistally. Its surface is also rugose and implies that the part is not ossified yet. The ontogenetic stage of the specimen is physically immature based on bone epiphyses conditions and its comparison with other individuals.

The specimen is identified as a member of the Balaenidae, which has a more robust radius than those of the other mysticetes such as the Balaenopteridae, *Eschrichtius robustus* (gray whale), and *Caperea marginata* (pygmy right whale; Figure 3; Benke, 1993). The specimen belongs to the genus *Eubalaena* because the radius displays an anteroposteriorly long distal end, and it is fan shaped in mediolateral view. On the other hand, among the Balaenidae, another extant genus, *Balaena,* shows a shorter distal end (see below).

Previously, some diagnoses of the genus *Eubalaena* have been reported on the cranium (Bisconti, 2002; Kimura et al., 2007; Churchill et al., 2012) and tympanic bulla (Tsai & Chang, 2019). Some synapomorphies of *E. australis* and *E. japonica* clade were introduced (Churchill et al., 2012). However, there are no previously introduced synapomorphies for the genus *Eubalaena* on the radius.

Herein, we propose a diagnosis of the genus *Eubalaena* on the radius. The genus *Eubalaena* can

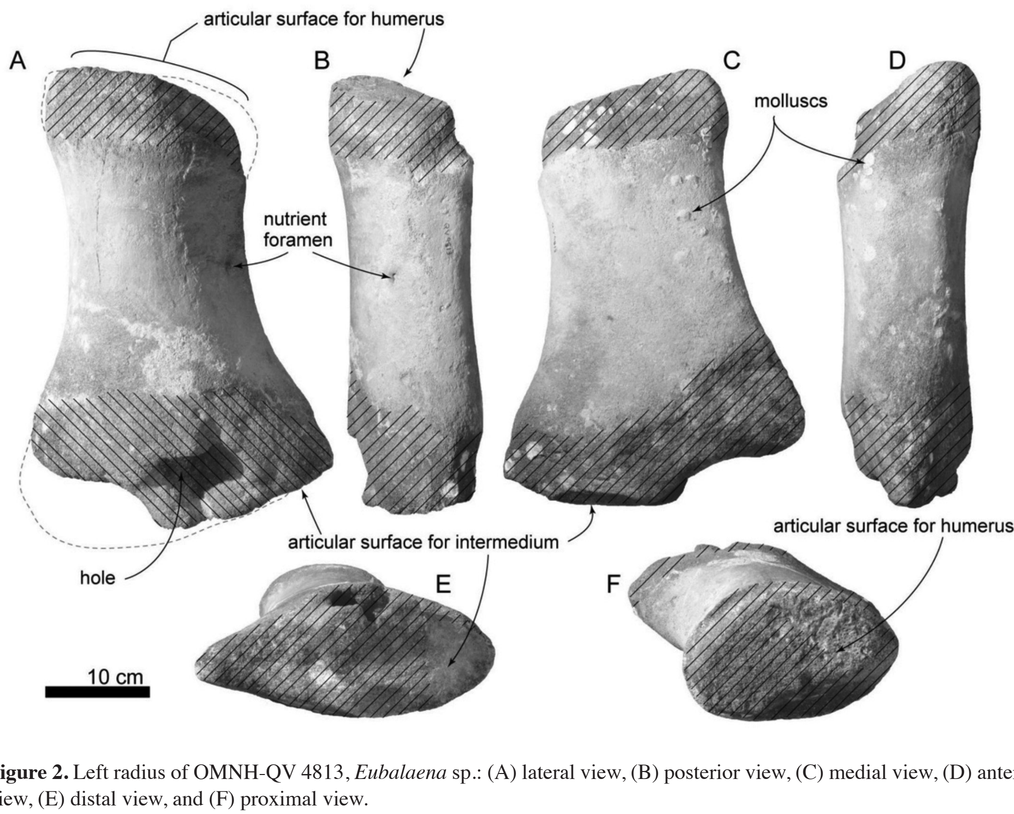

Figure 2. Left radius of OMNH-QV 4813, *Eubalaena* sp.: (A) lateral view, (B) posterior view, (C) medial view, (D) anterior view, (E) distal view, and (F) proximal view.

Table 1. Radius proportion among the Balaenidae. Ratios were calculated from measurements based on photos from previous publications. Institutional abbreviations in specimen numbers are MNHNP – Museum National d'Histoire Naturelle, Centre National d'Etude des Mammiferes Marins, Paris, France; NMNZ – Museum of New Zealand Te Papa Tongarewa, Wellington, New Zealand; OMNH – Osaka Museum of Natural History, Osaka, Japan; and ZMUC – Zoological Museum of the University of Copenhagen, Denmark.

Scientific names	Anteroposterior length at proximal end/ anteroposterior length at distal end	Anteroposterior length at distal end/narrowest length at shaft	Specimen numbers	Reference
Balaena mysticetus	0.94	1.26	--	Nishiwaki & Kasuya, 1970
Balaena mysticetus	0.79	1.54	--	Van Beneden, 1880
Balaena mysticetus	0.80	1.54	ZMUC 1596	de Lavigerie et al., 2020
Eubalaena australis	0.60	1.80	--	Van Beneden, 1880
Eubalaena australis	0.62	1.71	--	Van Beneden, 1880
Eubalaena australis	0.65	1.53	MNHNP A2929	Benke, 1993
Eubalaena australis	0.69	1.53	NMNZ MM002239	de Lavigerie et al., 2020
Eubalaena glacialis	0.68	1.81	--	Allen, 1908
Eubalaena glacialis	0.62	1.83	61A	Omura et al., 1969
Eubalaena glacialis	0.68	1.96	61B	Omura et al., 1969
Eubalaena japonica	0.65	1.82	Kritittapu specimen	Omura, 1958
Eubalaena sp.	0.67	1.69	OMNH-QV 4813	This study
Megaptera novaeangliae	0.79	1.86		Van Beneden, 1880
Balaenoptera acutorostrata	1.07	1.36		Van Beneden, 1880
Balaenoptera musculus	1.01	1.45		Van Beneden, 1880
Eschrichtius robustus	0.60	1.77		Andrews, 1914
Caperea marginata	1.12	1.00		Bisconti, 2002

be differentiated from the *Balaena* by having a dramatically anteroposteriorly longer distal end of the radius (distally wider radius in lateral view). There are differences in the ratio of the anteroposterior length at the proximal end vs the anteroposterior length at the distal end in *Eubalaena* spp. (0.60 to 0.69) and *Balaena mysticetus* (0.79 to 0.94), and the ratio of the anteroposterior length at the distal end vs the narrowest length at the shaft in *Eubalaena* spp. (1.53 to 1.96) and *B. mysticetus* (1.26 to 1.54) (Figure 4 & Table 1).

Even the specimen displays a partially broken distal end, which preserves enough length to identify it as a member of the genus *Eubalaena*. However, it is difficult to identify it at species level based on the radius shape because ontogenetic variation of the balaenid radii may be large, especially the anteroposterior length. Considering the distribution, *E. japonica* is the most likely identification for the specimen. However, we could identify the specimen as *Eubalaena* sp. based on the morphologic diagnostic as shown above.

The specimen is a rare fossil record of the *Eubalaena*. There are only two fossil records of the *Eubalaena* from Japan (Kimura et al., 2007; Kimura, 2009). One specimen of *Eubalaena shinshuensis* was documented from the Miocene/Pliocene (about 6 million years BP) in Nagano Prefecture (Kimura et al., 2007), and a cranium of *E. glacialis* was reported from the Yayoi or younger period (about 2500 to 200 years BP) in Akita Prefecture (Nishiwaki & Hasegawa, 1969; Ozawa et al., 1982; Mitsutani, 2001).

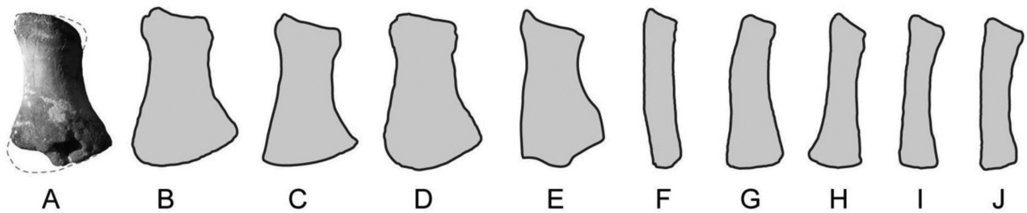

Figure 3. Left radii of OMNH-QV 4813, *Eubalaena* sp., and extant Mysticeti in left lateral view: (A) OMNH-QV 4813, (B) *Eubalaena japonica*, (C) *Eubalaena glacialis*, (D) *Eubalaena australis*, (E) *Balaena mysticetus*, (F) *Caperea marginata*, (G) *Eschrichtius robustus*, (H) *Megaptera novaeangliae*, (I) *Balaenoptera musculus*, and (J) *Balaenoptera acutorostrata*. Illustrations are modified from cited previous publications in Table 1 and are not to scale.

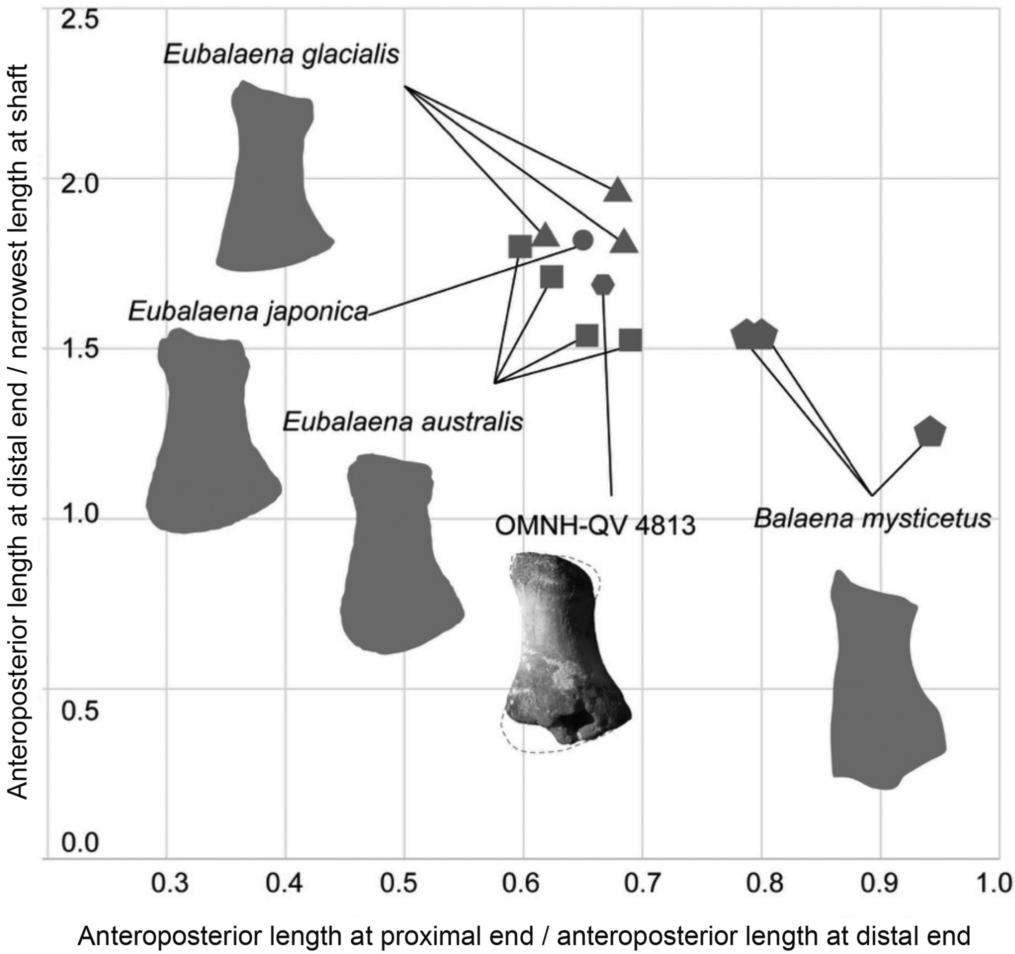

Figure 4. Radius proportion divides the *Eubalaena* and *Balaena*. The two axes are ratios, which were calculated from measurements based on photos from previous publications (see also Table 1). Illustrations of the radius are not to scale and are modified from previous studies (from top left to bottom right): *E. glacialis* from Allen (1908), *E. japonica* from Omura (1958), *E. australis* from de Lavigerie et al. (2020) (this image is mirrored—right side becomes left one), OMNH-QV 4813, and *B. mysticetus* from Van Beneden (1880).

The specimen is the first certain record of a *Eubalaena* from the pre-historic Jomon Period (8500 to 5000 years BP) in Japan. The Marine Mammal Stranding Database of the National Museum of Nature and Science shows no *Eubalaena* records around the locality of the specimen (in Osaka Bay and connected Seto Inland Sea). The population size or density most likely was larger several thousand years ago prior to increasing human activities such as whaling. The specimen is direct evidence of the existence of the whale, which starts to reveal the past distribution of the right whale.

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