Bulletin of Earth Sciences of Thailand

A Review of Cetacean Fossils from the Holocene Gulf of Ayutthaya

*Saranpat Ouilapan[1], Parisa Nimnate[2], Cholawit Thongcharoenchaikit[3], Kantanat Trakunweerayut[4]

[1] Heathfield International School, Bangkok, Thailand
[2] Division of Geoscience, Mahidol University Kanchanaburi Campus, Kanchanaburi, Thailand
[3] Office of Natural Research, National Science Museum, Pathum Thani, Thailand
[4] Excellence Center in Evolution of Life, Basin Studies and Applied Paleontology, Palaeontological Research and Education Center, Mahasarakham University, Maha Sarakham, Thailand

*Correspondence: saranpat.ouilapan@gmail.com

Received: 03 Mar 2025
Revised: 10 May 2025
Accepted: 13 May 2025

Abstract

Cetacean fossils from the Thai Lower Central Plains, or what was once the paleo-Gulf of Ayutthaya during the Holocene maximum transgression, despite their potential in the study of sea-level oscillations and their vast discoveries in the past centuries, have only been infrequently reported and lacked compilations. This prevents insights into these past cetacean faunas from being studied in the scientific field. Accordingly, this research aims to review the records of Cetacean fossils from the Holocene Gulf of Ayutthaya, to experimentally retrace historical sea level transgressions using these fossils, and lastly, due to the diverse cetacean records, compare Holocene cetacean faunas with present-day faunas of the Gulf of Thailand. Results showed that 17 cetacean fossil sites has been identified from the Thai Lower Central Plains, all being found in the Bangkok Clay Formation and dating from 1,000 – 6,000 YBP. The most abundant species found was *Balaenoptera edeni* (n = 7), out of the seven taxa discovered, and a specimen from Bang Khun Thian District, Bangkok is preliminarily reidentified as *Ziphius* cf. *cavirostris*, posing a new record of the genus in the Gulf of Thailand. Moreover, these cetacean fossil localities also allow for an interpretation of the paleo-shoreline, aligning with previous research using different indicators, further solidifying the vast extent of the Holocene Gulf of Ayutthaya. Lastly, almost all the cetacean faunas identified are still present in the present-day Gulf of Thailand.

Keywords: Cetacea, Marine vertebrate fossils, Holocene, paleo-Gulf of Ayutthaya, sea-level regressions

1. Introduction

Since the first recorded discovery of Thai cetacean fossils from the late 19th to early 20th century (Thanarak, 1921), cetacean fossils have been continuously discovered throughout the Thai Lower Central Plain, a wide, flat area of approximately 10,400 square kilometers, gradually descending towards the Gulf of Thailand between mountain ranges in the west and east and isolated hills in the north (Songtham *et al*., 2015). These cetacean fossils and other remnants, buried among Thailand's paddy fields and agricultural landscapes, are testaments of a shallow gulf that once submerged the Lower Central Plain during the Holocene maximum transgression, starting from 8,000 ─ 6,000 YBP, namely the paleo-Gulf of Ayutthaya, as sea level rises to approximately 4 meters above present (Sinsakul, 2000; Tanabe *et al*., 2003). Subsequently, the paleo-Gulf resulted in the southwards progression of the Chao Phraya delta and the deposition of the marine Bangkok Clay Formation, characterized by

its grey and greenish-grey clay and silt with no mottle (Teerachaikulpanich & Phupat, 2003) which composes of a diverse range of fossilized faunas and floras including mollusks, bivalves, pollens, and vertebrate fossils (Negri, 2009; Puchała, 2014; Kaweera & Saetian, 2021; Ketwetsuriya & Dumrongrojwattana, 2021; Jirapatrasilp *et al*., 2024). The paleo-Gulf eventually regresses to its present levels along with the Chao Phraya delta at approximately 1,500 YBP (Sinsakul, 2000).

To this date, studies of the nature and extent of the Holocene paleo-Gulf mostly rely on geomorphological, sedimentological, paleontological, palynological, archaeological, and stratigraphical research, placing the maximum extent of the paleo-Gulf near Phra Nakhon Si Ayutthaya and Ang Thong Province (Somboon & Thiramongkol, 1998; Tanabe *et al*., 2003). However, using vertebrate fossils, especially cetacean as an indicator in the area, has been underexplored. Globally, the dispersal of cetacean and marine mammal fossils has been used to indicate paleo-shoreline positions and the closure/opening of seaways dating back as far as the Paleogene (Gingerich, 1992; Peredo & Uhen, 2016). Cetacean species also serve as biostratigraphic indicators of paleo-shoreline when found in well-dated and undisturbed stratigraphic contexts and indicate the paleo-environment and depositional stages. With indicators of an undisturbed depositional environment consisting of but not limited to ichnofossils, bioerosional marks, and abrasion marks (Esperante, Guinea & Nick, 2009; Esperante *et al*., 2014; Bosio *et al*., 2024). Therefore, this research aims to compile cetacean fossil records from the paleo-Gulf, use them to experimentally reconstruct the Holocene maximum transgression shorelines, and compare past cetacean faunas with those of the present-day Gulf of Thailand to understand the ecological changes over time better.

2. Methodology

2.1. Compilation of cetacean fossil records

The records of cetacean fossils found in the Thai Lower Central Plain were investigated by reviewing previous and historical reports and research.

2.2. Retracing Holocene maximum shoreline

In the past, many studies have utilized marine vertebrate fossils to retrace paleo-shorelines and glacier margins around the world (Dyke, Hooper & Savelle, 1996; Dyke *et al*., 1999; Jirapatrasilp *et al*., 2024). Likewise, since cetacean fossils are abundant in the Lower Central Plain, this paleo-shoreline interpretation, therefore, used cetacean fossil sites as indicators to the maximum extent of the paleo-Gulf of Ayutthaya.

2.3. Comparison of paleo and present cetacean faunas

As the Holocene Gulf of Ayutthaya was connected to the present-day Gulf of Thailand, the relations between the faunas of the two gulfs should be explored. Therefore, the paleo cetacean faunas were compared with the present faunas of the Gulf of Thailand in the Department of Marine and Coastal resources (DMCR)'s report and other research.

3. Results and Discussions

3.1. Cetacean fossil sites

A total of 17 cetacean fossil sites had been discovered in the Thai Lower Central Plain, consisting of five sites in Samut Prakan Province; three sites in Chon Buri Province; three sites in Bangkok; two sites in Samut Sakhon Province; one site in Chachoengsao Province; one site in Samut Songkhram Province; one site in Phra Nakhon Sri Ayutthaya Province; and one site in Ang Thong Province (Figure 1). Here, all known

details regarding each site are reported in order of distances from the present-day shoreline, which is either measured from the actual site location or the local district/sub-district office of the site's locality (for sites with unclear/unreported locality). Site names follow the district/sub-district of discovery with the exceptions of previously named sites.

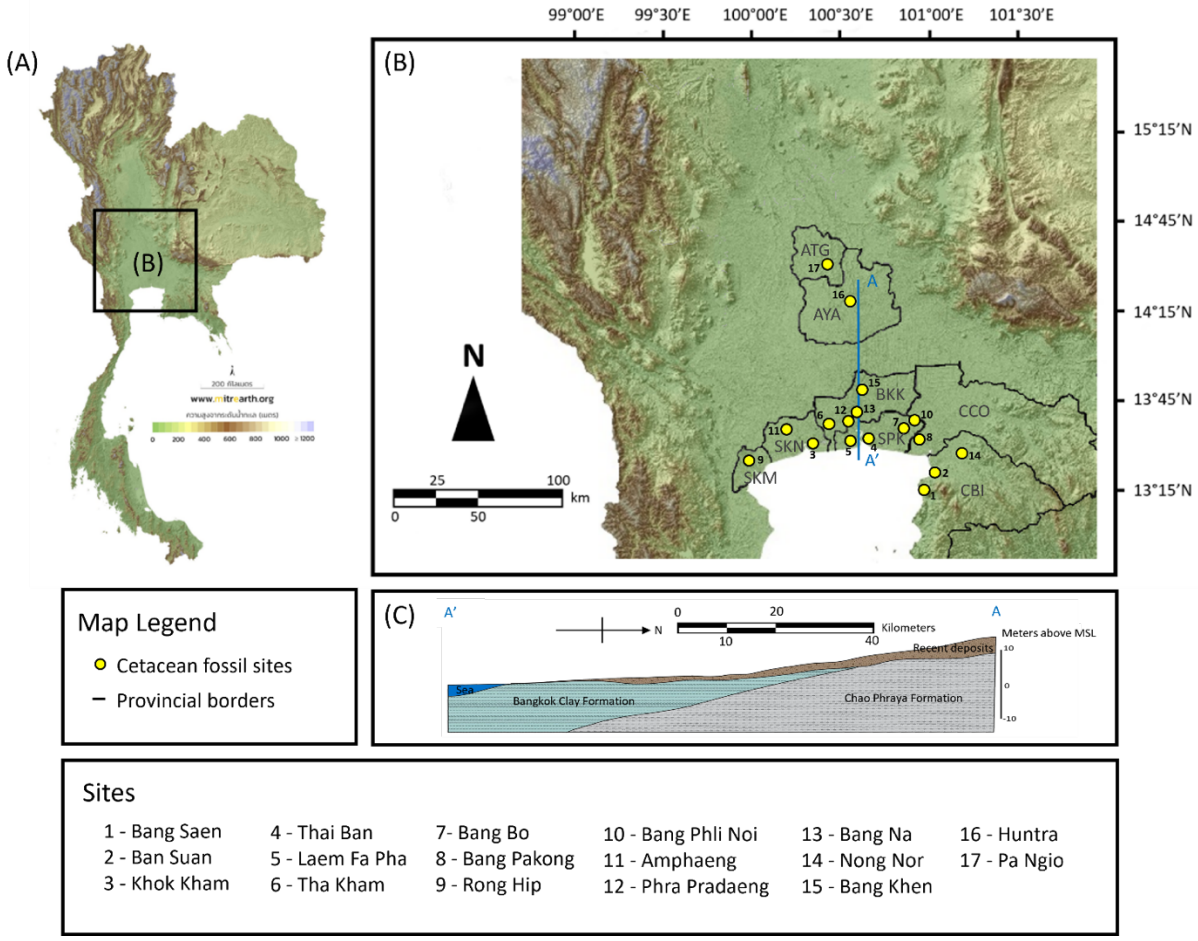

Figure 1 (A) General topographic map of Thailand. (B) topographic map of the Lower Central Plain with cetacean fossil sites an the provincial borders of those with cetacean fossils (image courtesy of Professor Dr. Santi Pailoplee). (C) schematic geological cross-section of the area (ATG, Ang Thong; AYA, Phra Nakhon Sri Ayutthaya; BKK, Bangkok; CCO, Chachoengsao; CBI, Chon Buri; SPK, Samut Prakan; SKN, Samut Sakhon; SKM, Samut Songkhram) (modified from Somboon & Thiramongkol, 1992; Fossil Protection Division, 2021; Intui, Inazumi & Soralump, 2022)

3.1.1. Bang Saen site

In 1999, a sub-fossil of *Balaenoptera edeni* was reported from Bang Saen District, Chon Buri Province, located less than 1 kilometer from the present shoreline. The fossils consist of an incomplete skeleton and one mandible and were reported to have been kept at the Bang Saen Institute of Marine Science (Andersen & Kinze, 1999). As of the present, the fossil cannot be accurately located

3.1.2. Ban Suan site

Around 1962, a 15-meter-long sub-fossil skeleton of a cetacean was unearthed in a soil pit

in Ban Suan District, Chon Buri Province (Figure 2) approximately 1 kilometer from the present shoreline. The skeleton was first identified as *Balaenoptera borealis* due to its

similarities to another skeleton in Nakhon Sri Thammarat Province, which was then identified as *B. borealis,* and due to the abundance of *B. borealis* in the Gulf of Thailand (Lekagul, 2002). Presently, the skeleton from Nakhon Sri Thammarat has been reidentified as *B. edeni*, and so have all previous records of Thai *B. borealis* (Chantrapornsyl, Adulyanukosol, & Kittiwathanawong, 1996; Andersen & Kinze, 1999). Therefore, the skeleton from Ban Suan is best identified as *B. edeni*. The skeleton was kept in the private collection of Boonsong Lekagul, but at present, the skeleton could not be accurately located.

Figure 2 Present-day location of the Ban Suan site, now deprived of its original conditions and covered with concrete

3.1.3. Khok Kham site

In 2005, a cetacean skeleton (Figure 3) was uncovered in Khok Kham Sub-District, Mueang District of Samut Sakhon Province. The skeleton was unearthed from a local shrimp farm, approximately 2 kilometers from the present shoreline. It is now kept in a now-closed mangrove forest nature trail in Phanthai Norasing Witthaya School and labeled as *B. edeni*. The skeleton is reported to date back more than 1,000 YBP (Kaweera & Saetian, 2021).

Figure 3 Khok Kham *Balaenoptera edeni* skeleton at Phanthai Norasing Witthaya School

3.1.4. Thai Ban site

One mandible of an unidentified baleen whale is on display at the Dinosaur Museum, Samut Prakan Crocodile Farm & Zoo, Thai Ban Sub-District, Mueang Samut Prakan District, Samut Prakan Province (Figure 4). An interview with Mr. Charoon Youngprapakorn, the farm's CEO, reveals that the mandible was found in 1957, during the farm's construction, at a depth of more than 2 meters, approximately 2 kilometers from the present shorelines.

Figure 4 Unidentified baleen whale mandible on display at the Dinosaur Museum, Samut Prakan Crocodile Farm

3.1.5. Laem Fa Pha site

Four separate vertebrae of an unidentified whale are on display at the Ban Khun Samut Chin Museum, Laem Fa Pha Sub-District, Phra Samut Chedi District,

Samut Prakan Province (Figure 5). An interview with Mr. Wisanu Khengsamut, headman of the Ban Khun Samut Chin village reveals that the vertebrae were discovered separately in 2004 in a shrimp farm near the museum at a depth of 1 to 2 meters. The area where the vertebrae was discovered is approximately 3 kilometers from the present shoreline.

Figure 5 Four cetacean vertebrae on display at the Ban Khun Samut Chin Museum (Specimen 1-4)

3.1.6. Tha Kham site

At the Local Museum of Bangkok - Bang Khun Thian District, an incomplete cetacean skull (Figure 6) found in Tha Kham Sub-District, Bang Khun Thian District, Bangkok, approximately 8 kilometers from the present shoreline, is on display and labeled as *Tursiops* spp. The specimen is unnumbered and is 69 centimeters long and possesses a synvertex cranii structure (Figure 7), a structure which is not present in *Tursiops* spp. but instead in the family Ziphiidae, of which two genera are present in Thailand: *Mesoplodon* and *Ziphius* (Adulyanukosol *et al*., 2014). This specific specimen is preliminarily identified as *Ziphius* by being in total agreement with Moore's (1986) diagnostic characteristics of the skull of *Ziphius*:

1. Where the premaxillary bones ascend posteriorly on either side of the superior nares and terminate, their anterior faces are oriented mesially a small but obvious amount from directly forward.

2. The combined breadth of the nasal bones is greatest anteriorly and where the right nasal is out on contact with the right premaxillary bone

3. When the skull is upright and the long axis of the beak is horizontal, in lateral view the nasal bones both project somewhat farther anteriorly from the synvertex of the skull than do the up-curled posterior ends of the premaxillary bones.

Lastly, only one species of *Ziphius* is recognized, *Ziphius cavirostris* (Mead, 2009). Therefore, the preliminary identifications of the Tha Kham specimen are best placed as *Ziphius* cf. *cavirostris*. A reconstruction of the Tha Kham specimen is presented in Figure 8, showing possible barnacle scars (Figure 9).

Systematics:

Order Cetacea Brisson, 1762
Suborder Odontoceti Flower, 1867
Family Ziphiidae Gray, 1865
Genus Ziphius Cuvier, 1823
Ziphius* cf. *cavirostris Cuvier, 1823

Figure 6 Ventral view of the incomplete cranii from the Local Museum of Bangkok - Bang Khun Thian District

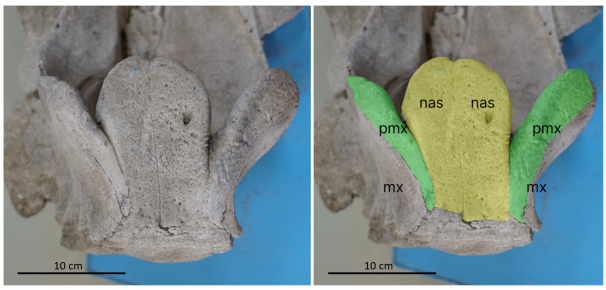

Figure 7 Synvertex structure of the Tha Kham specimen (nas, nasal; pmx, premaxilla; mx, maxilla)

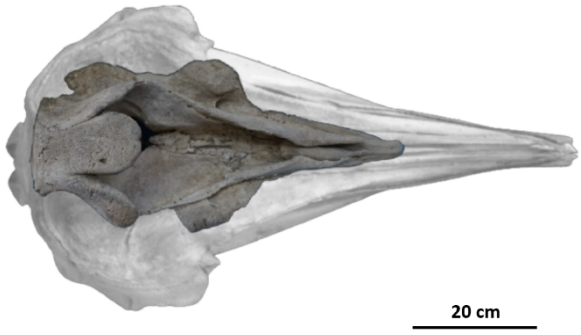

Figure 8 Reconstruction of the skull of the Tha Kham specimen (modified from Karaa *et al*., 2021)

Figure 9 Barnacle scars on the Tha Kham specimen

3.1.7. Bang Bo site

In 1976, a skull and vertebrae were discovered in a fishpond in Bang Bo District, Samut Prakan Province, approximately 9.5 kilometers from the present shorelines. The specimens are kept at the Chulalongkorn University Museum of Natural History (CUMNH) and labeled as *B. edeni* (Figure 10).

Figure 10 Bang Bo *Balaenoptera edeni* skull at the CUMNH

3.1.8. Bang Pakong site

In 1996, a skeleton was discovered (Figure 11) during the construction of a lake in the Wichittra Thani village, Bang Pakong Sub-District, Bang Pakong District, Chachoengsao Province, approximately 10 kilometers from the present-day shorelines. The specimens were identified as belonging to *Baleanoptera physalus* and were dated as >5,730 YBP due to the lack of radioactive isotopes in the specimens. Presently, the skeleton is kept and is on display at the Wichittra Thani village next to the excavation site, which is now a lake (Figure 12) (Chantrapornsyl, Adulyanukosol, & Kittiwathanawong, 1996).

Figure 11 1996 excavation of the Bang Pakong site (Thairath Newspaper, 15 August 1996)

Figure 12 Bang Pakong *Balaenoptera physalus* skeleton on display at the Wichittra Thani village

3.1.9. Rong Hip site

Four complete unidentified cetacean vertebrae were reported from Rong Hip Sub-District, Bang Khonthi District, Samut Songkhram Province, approximately 14 kilometers from the present shorelines, in a plantation at a depth of 1 - 1.5 meters. The fossils were reported to be 1000 - 6000 YBP, though the skeleton could not be accurately located (Kaweera & Saetian, 2021).

3.1.10. Bang Phli Noi site

In 2020, the Marine and Coastal Resources Research and Development Institute published the excavation report of a baleen whale skeleton, composed of a skull and 10 vertebrae in Bang Phli Noi Sub-District, Bang Bo District, Samut Prakan Province, approximately 15 kilometers from the present shorelines in a fishpond. The excavated specimens have presently been moved to and stored at the Marine and Coastal Resources Research Center of the Upper Gulf of Thailand (East) (Marine and Coastal Resources Research and Development Institute, 2020).

3.1.11. Amphaeng site

In 2020, the Department of Mineral Resources excavated a cetacean skeleton from Amphaeng Sub-District, Ban Phaeo District, Samut Sakhon Province, approximately 15 kilometers from the present shorelines at a depth of 6.5 meters (Figure 13). This site is Thailand's first systematically excavated cetacean fossil site, and perhaps the most thoroughly reported. The skeleton comprises 141 individual articulated, semi-fossilized bones discovered in the prone position with an estimated body length of 14 meters. Due to its spectacular preservation, osteological identifications had been made from its bifurcated first ribs and nasal bones, identifying it as *B. edeni* and radiocarbon dating of the bones had yielded the age of 3,380 ± 30 YBP. Once fully excavated, the skeleton was moved to the Golden Jubilee National Geological Museum and is on display (Figure 14) (Kaweera & Saetian, 2021). This discovery is one of Thailand's most important fossil excavations, with high publicity in the media and among Thai citizens and initiated much Holocene research on various fossils and sediments from this specific site, including the publication of new species (Chitnarin, 2021; Fossil Protection Division, 2021; Ketwetsuriya & Dumrongrojwattana, 2021; Khamha, 2021; Rugmai, 2021).

Figure 13 2020 excavation of the Amphaeng site (Image courtesy of veterinarian Rachawadee Chantra)

Figure 14 Amphaeng *Balaenoptera edeni* skeleton on display at the Golden Jubilee National Geological Museum

3.1.12. Phra Pradaeng site

A *B. edeni* skeleton was reported to have been excavated from Phra Pradaeng District, Samut Prakarn Province, approximately 16 kilometers from the present shoreline (Chantrapornsyl, Adulyanukosol, & Kittiwathanawong, 1996). Presently, the location of the skeleton cannot be accurately determined.

3.1.13. Bang Na site

A *B. edeni* skeleton was reported from Bang Na District, Bangkok, at a depth of 1 meter, approximately 18 kilometers from the present shorelines. The skeleton was dated to 1500 – 2500 YBP and was reported to have been stored at CUMNH as specimen CET_NHMCU-01 but presently, the skeleton could not be accurately located (Andersen & Kinze, 1999).

3.1.14. Nong Nor site

During the 1991 – 1993 archeological excavation of the prehistoric site of Nong Nor in Phanat Nikhom District, Chon Buri Province, 25 kilometers from the present shorelines. Multiple cetacean remains hunted by prehistoric inhabitants of the site (Higham, 2017) were discovered among the artifacts of the first human occupation phase. Giving the pooled mean uncalibrated radiocarbon date of 3908 ± 58 YBP and the calibrated age ranges of 4511–4477 and 4449–4147 cal YBP (2σ). These remains mainly consist of vertebrae, composed of *Neophocaena phocaenoides*, *Steno* sp., and *Delphinus*/*Stenella* sp. (Fordyce, 1997); these specimens are all kept in the storage of the Prachinburi National Museum.

3.1.15. Bang Khen site

During the reign of Rama V (1868-1910), a cetacean skeleton was discovered in Bang Khen, Bangkok, close to Rama VI bridge (Thanarak, 1921; Wonghtes, 2005). The discovery area most likely refers to the Bang Khen community along Khlong (canal) Bang Khen, approximately 34 kilometers from the present shorelines, rather than the present-day Bang Khen district (Bualek, 2022). The present location and identification of the cetacean discovered are unknown.

3.1.16. Huntra site

An unidentified cetacean fossil was reported from Huntra Sub-District, Mueang District, Phra Nakhon Si Ayutthaya Province, 93 kilometers from the present shorelines (Kaweera & Saetian, 2021). As of the present, the fossil cannot be accurately located.

3.1.17. Pa Ngio site

A cetacean fossil of unknown species was discovered in Pa Ngio Sub-District, Mueang District, Ang Thong Province, approximately 121 kilometers from the current shoreline (Kaweera & Saetian, 2021). However, its exact location remains unidentified.

3.2. Retracing Holocene shorelines

These discoveries of articulated cetacean skeletons in the Lower Central Plain presents that most cetacean fossils were deposited as whale falls in the abyssal zone (Smith *et al*., 2015), due to the articulated

placement of their skeleton (for example the Amphaeng, Bang Pakong, and Khok Kham specimen), creating a unique whale fall ecosystem, which lures in other marine faunas to feast and thrive on the carcass then deposited as fossils along with the cetaceans. Fossils from the Lower Central Plain also show this through toothmarks, mollusks, and barnacles present on the fossils of the Amphaeng specimen (Kaweera & Saetian, 2021), and the barnacle scars on the Tha Kham specimen's skull, justifying that the cetaceans were deposited underwater, simultaneously as the marine clay was being deposited. This implies that the cetacean carcasses must have passed through an intense and rapid removal of abdominal tissue, likely by scavenging faunas, which limits gaseous production and allows the carcass to remain on the sea floor during deposition (Danise & Dominici, 2014). Furthermore, as the carcass settles on the sea floor, it would have undergone depositional stages where the carcass was rapidly but incompletely covered with marine clay, allowing scavenging faunas to feast on the exposed parts, then completely covered with sediments, where fossilization processes begin (Kaweera & Saetian, 2021).

Additionally, the fact that the cetacean fossils were deposited in marine clay is also supported as only four out of 17 cetacean sites with reported depths (except Nong Nor as the cetacean fossils had been tampered with by prehistoric humans) places the fossils in the Bangkok Clay Formation, a layer of marine grey and greenish-grey, fossiliferous clay and silt (Teerachaikulpanich & Phupat, 2003) which overlies the olive grey or medium-to-dark green Pleistocene fluvial stiff clays of the Chao Phraya Formation. Sand lenses and silt are also often interlaminated within the stiff clay formation with beds of peat, shells, decayed plants, and organic materials commonly shared in some areas. The stiff clays are also eroded into broad and shallow valleys by streams, which predates the marine intrusion (Eide, 1968; Eide, 1977; Rau & Nutalaya, 1983). On the other hand, the Bangkok Clay Formation also underlies the recent fluvial deposit of the area, which composed of floodplain sediments of the Chao Phraya River and its tributaries. The contact between the Bangkok Clay and the recent fluvial deposits also shows weathering and erosion as the depositional environment transitions from a marine environment to a fluvial environment (Dheeradilok, 1995; Hutangkura, 2014; Fossil Protection Division, 2021; Kaweera & Saetian, 2021) (Figure 15).

Lastly, after confirmation that the fossils are deposited among marine clay, the maximum extent of the paleo-Gulf can be interpreted based on the fossil depositions, as all the sites are between 2 to 5 meters above mean sea level (MSL), a contour interval of 5 meters can be used to estimate the maximum transgression, placing it as far deep as Ang Thong and Phra Nakhon Si Ayutthaya Provinces. These results are in line with previous interpretations of the maximum transgression using different indicators (Sinsakul, 2000; Tanabe *et al*., 2003; Negri, 2009), reinstating that the majority of the Lower Central Plains were unmistakably submerged as part of the paleo-Gulf of Ayutthaya during the Holocene maximum transgressions (Figure 16), demonstrating the utilization of cetacean fossils as an indicator of sea level transgression and introduces a new set of information of the mid-Holocene highstand and a new method to studying prehistoric sea-level regressions.

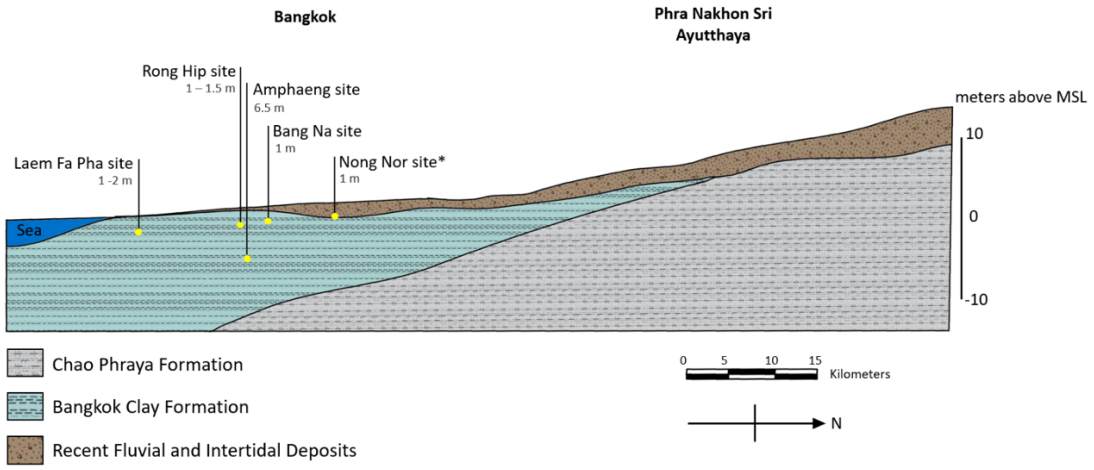

Figure 15 Geological profile of the Lower Central Plain with cetacean fossil sites with known depths indicated (modified from Somboon & Thiramongkol, 1992; Fossil Protection Division, 2021; Intui, Inazumi & Soralump, 2022)

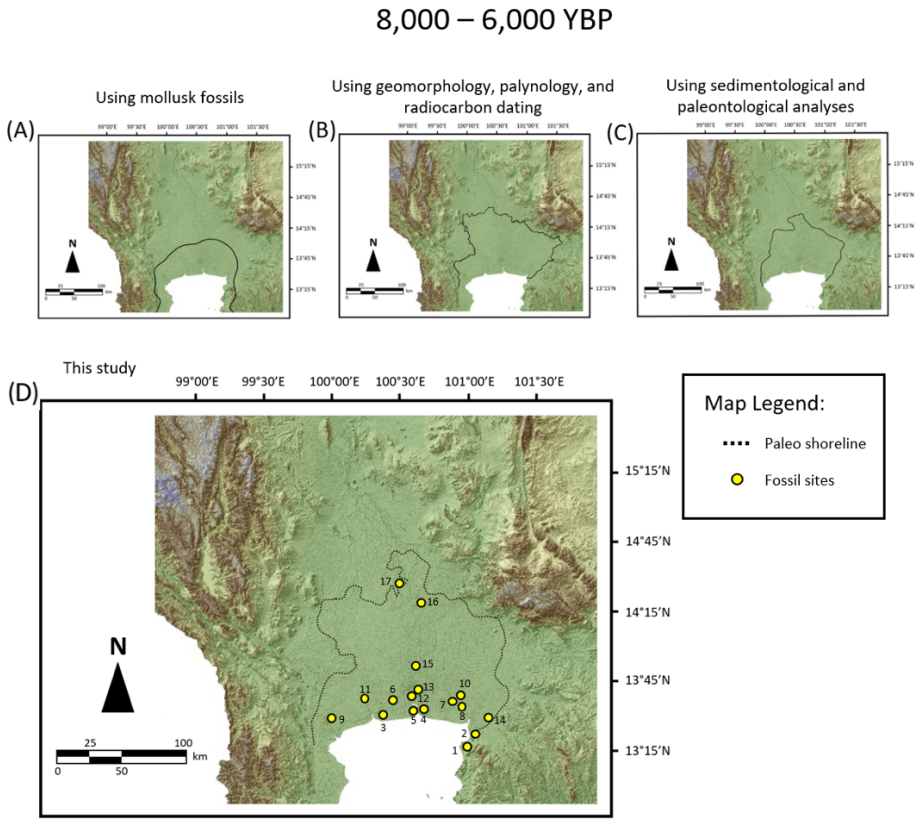

Figure 16 Reconstructions of the maximum extent of the paleo-Gulf of Ayutthaya (8,000 – 6,000 YBP) (Image courtesy of Professor Dr. Santi Pailoplee). (A) paleo-shoreline reconstruction using mollusk fossils (modified from Negri, 2009). (B) paleo-shoreline reconstruction using geomorphology, palynology, and radiocarbon dating (modified from Hutangkura, 2014). (C) paleo-shoreline reconstruction from sedimentological and paleontological analyses (modified from Tanabe et al., 2003). (D) paleo-shoreline reconstruction from cetacean fossil sites (this study) using the contour interval of 5 meters above MSL (modified from Takaya, 1969)

Table 1 Cetacean fossil taxa discovered from the Thai Lower Central Plains

Family	Scientific Name	Common Name	Occurrence
Balaenopteridae	*Balaenoptera edeni*	Bryde's whale	7
	Balaenoptera physalus	Fin whale	1
Delphinidae	*Delphinus/Stenella* sp.	-	1
	Steno sp.	-	1
Phocoenidae	*Neophocaena phocaenoides*	Finless porpoise	1
Ziphiidae	*Ziphius* cf. *cavirostris*	Cuvier's beaked whale	1

Table 2 Comparison between the cetacean faunas of the paleo-Gulf of Ayutthaya and the present-day Gulf of Thailand (Adulyanukosol *et al*., 2014; Chantra *et al*., 2023; Department of Marine and Coastal Resources, 2023). Superscripted corresponding numbers refer to identical cetacean taxa between the two gulfs

paleo-Gulf of Ayutthaya		Gulf of Thailand (present day)	
Family	**Scientific Name**	**Family**	**Scientific Name**
Balaenopteridae	*Balaenoptera edeni* [1]	Balaenopteridae	*Balaenoptera acutorostrata*
	Balaenoptera physalus [2]		*Balaenoptera edeni* [1]
Delphinidae	*Delphinus* [3]/*Stenella* sp. [4]		*Balaenoptera omurai*
	Steno sp. [5]		*Balaenoptera physalus* [2]
Phocoenidae	*Neophocaena phocaenoides* [6]	Delphinidae	*Delphinus capensis* [3]
Ziphiidae	*Ziphius* cf. *cavirostris*		*Feresa attenuate*
			Globicephala macrorhynchus
			Orcaella brevirostris
			Orcinus orca
			Peponocephala electra
			Pseudorca crassidens
			Sousa chinensis
			Stenella attenuate [4]
			Stenella coeruleoalba [4]
			Stenella longirostris [4]
			Steno bredanensis [5]
			Tursiops aduncus
		Kogiidae	*Kogia breviceps*
		Phocoenidae	*Neophocaena phocaenoides* [6]
		Ziphiidae	*Mesoplodon densirostris*

Table 3 Summary of the cetacean fossils discovered from the Holocene Gulf of Ayutthaya

Site	Province	Species	Uncalibrated Age (YBP)	Distance from shoreline (km)	References
Bang Saen	Chon Buri	*B. edeni*	-	1	Andersen & Kinze, 1999
Ban Suan	Chon Buri	*B. edeni*	-	1	Lekagul, 2002
Khok Kham	Samut Sakhon	*B. edeni*	-	2	Kaweera & Saetian, 2021
Thai Ban	Samut Prakan	Unidentified	-	2	This study
Laem Fa Pha	Samut Prakan	Unidentified	-	3	This study
Tha Kham	Bangkok	*Z.* cf. *cavirostris*	-	8	This study
Bang Bo	Samut Prakan	*B. edeni*	-	9.5	This Study
Bang Pakong	Chachoengsao	*B. physalus*	>5,730	10	Chantrapornsyl, Adulyanukosol, & Kittiwathanawong, 1996
Rong Hip	Samut Songkhram	Unidentified	1000-6000	14	Kaweera & Saetian, 2021
Bang Phli Noi	Samut Prakan	Unidentified	-	15	Marine and Coastal Resources Research and Development Institute, 2020
Amphaeng	Samut Sakhon	*B. edeni*	3,380 ± 30	15	Kaweera & Saetian, 2021
Phra Pradaeng	Samut Prakan	*B. edeni*	-	16	Chantrapornsyl, Adulyanukosol, & Kittiwathanawong, 1996
Bang Na	Bangkok	*B. edeni*	1500-2500	18	Andersen & Kinze, 1999
Nong Nor	Chon Buri	*N. phocaenoides*			
		Steno sp.	3908 ± 58	25	Fordyce, 1997
		Delphinus/Stenella sp.			
Bang Khen	Bangkok	Unidentified	-	38	Prince Pramun Thanarak, 1921; Wonghtes, 2005
Huntra	Phra Nakhon Si Ayutthaya	Unidentified	-	93	Kaweera & Saetian, 2021
Pa Ngio	Ang Thong	Unidentified	-	121	Kaweera & Saetian, 2021

3.3. Comparison of paleo and present Cetacean faunas

A total of 7 Cetacean taxa had been identified from the 17 fossil sites composing of *Balaenoptera edeni*; *Balaenoptera physalus*; *Neophocaena phocaenoides*; *Delphinus/Stenella* sp.; *Steno* sp.; and *Ziphius* cf. *cavirostris*, with *B. edeni* being the most abundant species discovered in the Thai Lower Central Plains out of the identified Cetacean tax (n = 7) (Table 1). Moreover, as the identified Cetacean taxa of the paleo-Gulf

are compared with the 20 taxa of the present-day Gulf of Thailand (Adulyanukosol *et al*., 2014; Department of Marine and Coastal Resources, 2023; Chantra *et al*., 2023), it can be seen that 6 out of the 7 paleo taxa are still present amongst the taxa of the present-day Gulf of Thailand, presenting that Cetacean and other taxa of the paleo-Gulf could continue to populate within the area (Chitnarin, 2021; Khamha, 2021) (Table 2).

3.4. Discussion

The new use of vertebrate fossils, especially cetacean taxa, as an indicator is preliminarily explored and proven successful. Nonetheless, a further study of cetacean fossils towards the east of the Lower Central Plain is strongly suggested due to the lack of cetacean fossils in the area which would help strengthen the use of cetacean fossils as an indicator of marine regression.

Even though most cetacean fauna of the paleo-Gulf of Ayutthaya are actively present in the present-day Gulf of Thailand, the new, preliminarily identified *Ziphius* cf. *cavirostris* specimen from Tha Kham sub-district, Ban Khun Thian district, Bangkok is still not reported from the Gulf of Thailand. It is the only *Z. cavirostris* specimen recorded from both the paleo-Gulf and the Gulf of Thailand (Adulyanukosol *et al*., 2014). Moreover, only one sighting of the family Ziphiidae (in which *Z. cavirostris* belongs) was reported from the Gulf of Thailand, comprising the live stranding of *Mesoplodon densirostris* from Songkhla Province in 2023 (Department of Marine and Coastal Resources, 2023), the possibility of a yet undiscovered population of *Z. cavirostris* in the Gulf of Thailand should not be ruled out. However, further identifications of the *Ziphius* cf. *cavirostris* specimen are recommended to verify its systematic placement.

4. Conclusion

In conclusion, 17 cetacean fossil sites have been identified from the Thai Lower Central Plains, with the oldest records dating back over 100 years. From these sites, seven different cetacean taxa were identified: *Balaenoptera edeni*; *Balaenoptera physalus*; *Neophocaena phocaenoides*; *Delphinus/Stenella* sp.; *Steno* sp.; and *Ziphius* cf. *cavirostris*, all being found in the marine Bangkok Clay Formation and dating from 1,000 – 6,000 YBP, with *B. edeni* being the most abundant species discovered (n = 7) (Table 3). Moreover, these cetacean fossil sites also provide the necessary information for the preliminary interpretation of the maximum transgressions of the paleo-Gulf of Ayutthaya, placing the paleo-shorelines as far as Ang Thong and Phra Nakhon Sri Ayutthaya Provinces, in line with previous interpretations from other indicators, demonstrating the utilization of cetacean fossils as an indicator of sea level transgression. Lastly, almost all cetacean taxa from the paleo-Gulf are actively present in the present-day Gulf of Thailand, except for the newly identified *Ziphius* cf. *cavirostris*. Therefore, the possibility of an undiscovered population of *Z. cavirostris* in the Gulf of Thailand should be explored.

5. Acknowledgements

Many thanks to Prof. Charles Higham; Asst Prof Dr. Marut Fuangarworn; Dr. Carl Kinze; Dr. Kongkiat Kittiwattanawong; Veterinarian. Rachawadee Chantra; Miss Watcharee Chompoo; Mr. Charoon Youngprapakorn and Mr. Wisanu Khengsamut for information support on cetacean fossil sites, Prof. Dr. Santi Pailoplee for imagery support, Dr. Sumalin Lekroengsin for various supports and the Prachinburi National Museum; Chulalongkorn University Museum of Natural History; Local Museum of Bangkok

- Bang Khun Thian; Baan Khun Samut Chin Community Museum; Phanthai Norasing Witthaya School; Samut Prakan Crocodile Farm & Zoo; and the Vichitra Thani Village for granting access and providing information on cetacean fossils.

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