

# First Record of the Diamondback Squid *Thysanoteuthis rhombus* Troschel, 1857 (Cephalopoda: Thysanoteuthidae) in the East Malaysian Coastal Waters

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## ABSTRACT

This study documents the first confirmed record of the diamondback squid, *Thysanoteuthis rhombus* Troschel, 1857, along the east coast of Peninsular Malaysia. Two individuals, a subadult male and a female, were collected from a local fish market in Terengganu. Although *T. rhombus* is typically associated with warm tropical and subtropical offshore waters, its occurrence in Malaysian coastal waters had not been previously reported. Morphological identification was conducted and further validated through molecular analysis using mitochondrial cytochrome c oxidase subunit I (COI) gene sequencing. Phylogenetic comparisons revealed that the specimens clustered within the same clade as populations from the Pacific region, including Japan, the Philippines, and Viet Nam. This finding significantly extends the known distribution range of *T. rhombus* and contributes new data to the cephalopod biodiversity of Malaysian waters. The presence of this oceanic squid species in local fish markets suggests possible changes in distribution patterns, which may be influenced by oceanographic or climatic factors. Given the ecological role and potential fishery value of *T. rhombus*, continued monitoring and further studies are warranted to assess its population status, habitat preferences, and implications for local fisheries. This record provides a valuable baseline for future taxonomic, ecological, and conservation research in the Southeast Asian marine region.

**Keywords:** Distribution, Migration, New record, Rhomboid squid, South China Sea

## INTRODUCTION

*Thysanoteuthis rhombus* Troschel, 1857, commonly known as the diamondback squid or rhomboid squid, derives its name from its distinctively diamond-shaped mantle and fins, which are characteristically rhombic and broadest at the midpoint (Jereb and Roper, 2010; Sundaram and Mane, 2019). Troschel (1857) first described the species *T. rhombus*, based on type specimens collected from the Mediterranean Sea. *T. rhombus* is currently the only species within the family Thysanoteuthidae.

The diamondback squid is a large, muscular oegopsid species distributed throughout tropical and subtropical oceans worldwide. It typically inhabits epipelagic and mesopelagic zones, thriving in waters between 23–26 °C (Nigmatullin *et al.*, 1995; Jereb and Roper, 2010). Its distribution is influenced by major oceanic currents, such as the Tsushima, Kuroshio, Agulhas, and Brazil Currents, as well as the Gulf Stream, which enable it to extend its range into temperate waters (Deville *et al.*, 2024). *T. rhombus* has been recorded in the waters of South Africa, the Americas, and the Sea of Japan. In Japan, particularly around Okinawa Prefecture

and the Sea of Japan, it holds significant commercial value due to its firm and flavorful flesh (Bower and Miyahara, 2005).

*T. rhombus* has a relatively short life cycle of approximately one year. Individuals of both sexes can reach a mantle length of 100–130 cm and typically mature within seven months, with a maximum body weight of 24–30 kg (Nigmatullin *et al.*, 1995; Nigmatullin and Arkhipkin, 1998; Jereb and Roper, 2010). Adults exhibit diel vertical migrations, ascending to near-surface waters at night and descending to mesopelagic depths during the day. While paralarvae and juveniles are primarily epipelagic, subadults and adults migrate vertically within the upper 600–800 m of the water column (Nigmatullin and Arkhipkin, 1998). Despite their wide dispersal capability, horizontal movement is largely passive and driven by ocean currents rather than active swimming for feeding or reproduction (Miyahara *et al.*, 2008; Onitsuka *et al.*, 2010). Small groups of two or more individuals are frequently observed at the surface, possibly associated with reproductive behavior or predator avoidance (Roper *et al.*, 1984). Due to its broad distribution and lack of significant threats, *T. rhombus* is currently listed as Least Concern on the IUCN Red List (Barratt and Allcock, 2020).

Occurrences of *T. rhombus* in the Gulf of Thailand have been previously reported (Okutani, 1995; 2015; Dunning, 1998; Chen and Liu, 2009; Chen *et al.*, 2009; 2019; Roper and Jereb, 2010), including nearby areas off Terengganu, such as Songkhla and Narathiwat (Chotiyaputta *et al.*, 1992). However, the species remains rare in this region compared to its more frequent presence in the Andaman Sea (Nabhitabhata and Ikeda, 2014). Globally, *T. rhombus* has been documented in various locations, including Japan (Nishimura, 1966), the East China Sea (Osako and Murata, 1983), the Andaman Sea (Nateewathana and Hylleberg, 1989), the Arabian Mediterranean (Bello, 1998), the Colombian Caribbean Sea (López and Pinto, 2002), the South Atlantic (Haimovici *et al.*, 1989; Brunetti *et al.*, 1999; Haimovici *et al.*, 2002; Santos and Haimovici, 2002), the Brazilian coast (Cunha and Oliveira, 2014), India (Batcha *et al.*, 2009), Sulawesi (Billings *et al.*, 2000), the Aegean

Sea (Salman *et al.*, 2003; 2012), the Adriatic Sea (Marčić *et al.*, 2009), and the Catalan coast (Fernández-Álvarez *et al.*, 2021). More recently, it has been recorded in the Gulf of Mannar (Rajkumar *et al.*, 2022), and an egg mass has been sighted in Indonesian waters (Billings *et al.*, 2000).

Despite these global records, sightings in Terengganu's coastal waters remain rare, and little information is available regarding its size, age, or distribution in the South China Sea. Although *T. rhombus* is not a commercially targeted species in Malaysia, it is actively exploited in the Sea of Japan (Figure 1). This study presents the first confirmed record of *T. rhombus* collected as bycatch by trawlers in Terengganu's coastal waters in June 2023.

## MATERIALS AND METHODS

### *Specimen collection and morphological studies*

On June 19, 2023, two specimens were collected from a local fish market in Kuala Terengganu, Malaysia (Figure 2). The specimens were reportedly caught by trawl in Terengganu coastal waters, at an estimated depth of 30–80 m. Each specimen was photographed, and measurements were taken following the methods and morphological terminology described by Roper and Voss (1983), along with taxonomic characteristics described by Roper *et al.* (1984). The hectocotylus was examined, and the mantle was dissected to determine the sex of each individual. Both specimens were subsequently deposited in the South China Sea Repository and Reference Center, Universiti Malaysia Terengganu, under accession numbers UMTMoll 3113 and UMTMoll 3114.

### *Genetic analysis*

Species identification was confirmed based on DNA sequence analysis. Genomic DNA was extracted using the salt-extraction protocol (Aljanabi and Martinez, 1997). A ~650 bp fragment of the mitochondrial cytochrome oxidase I (COI) gene was amplified via PCR using primers and protocols established by Folmer *et al.* (1994). Successful amplicons were purified and sent for sequencing at Apical Scientific Sdn. Bhd.

The COI gene was selected as widely recognized as a standard molecular marker for DNA barcoding and species identification in marine invertebrates (Ghazali *et al.*, 2025), including cephalopods (deWaard *et al.*, 2019). Previous studies have successfully utilized COI for species confirmation in squids (Yalla and Mohanraju, 2019; Rosli *et al.*, 2022; Xu *et al.*, 2022), making it a reliable and widely accepted marker for identifying *T. rhombus* in this study.

Species confirmation was conducted by comparing the obtained COI sequences with reference sequences available in GenBank (<http://blast.ncbi.nlm.nih.gov>) (Benson *et al.*, 2013), applying a 97% similarity threshold as the criterion for species-level identification (Yalla and Mohanraju, 2019). The newly generated COI sequences were deposited in GenBank under accession numbers OR582429 and OR582430.

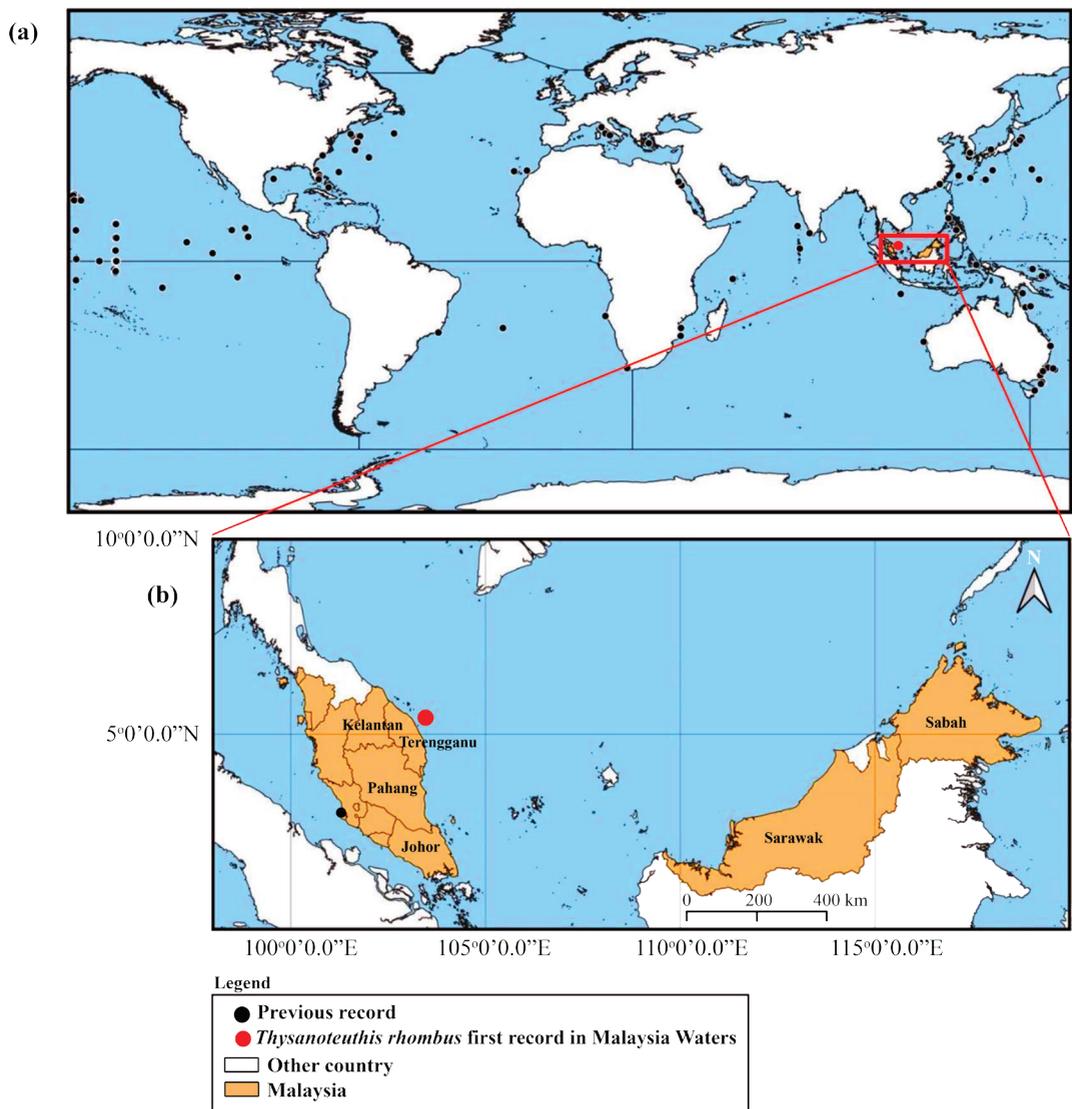


Figure 1. Global and regional distribution of *Thysanoteuthis rhombus*. (a) Global distribution (black circle) based on records from the Global Biodiversity Information Facility (GBIF) (2021). (b) New record of *T. rhombus* (red circle) in Terengganu coastal waters, Malaysia.

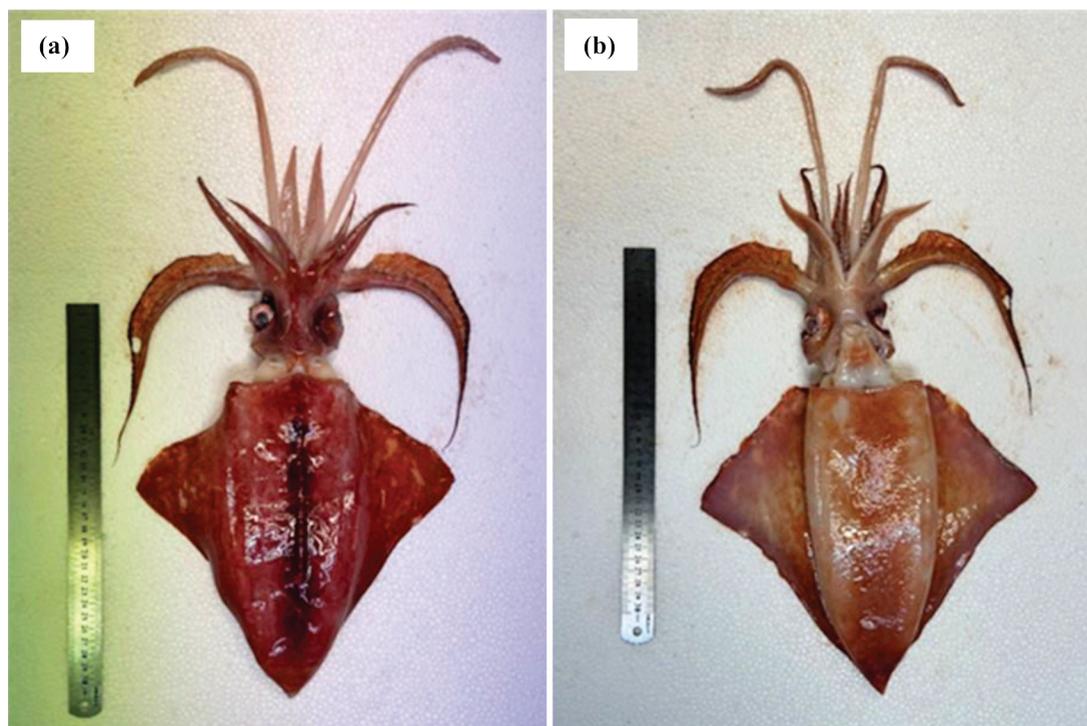


Figure 2. *Thysanoteuthis rhombus* UMTMoll 3114. (a) Dorsal view. (b) Ventral view.

## RESULTS AND DISCUSSION

### *Morphological description*

The morphology of *T. rhombus* exhibited notable differences between the female (UMTMoll 3113) and male (UMTMoll 3114) specimens, particularly in body weight, mantle dimensions, and appendage lengths. The ventral mantle lengths of UMTMoll 3113 and UMTMoll 3114 were 282 mm and 287 mm, respectively. The female, identified by the presence of nidamental glands and the absence of a mature gonad (Figure 3a), weighed slightly more than the male (894.1 g vs. 882.0 g), despite having a shorter head (60 mm vs. 75 mm) and tentacles (294–295 mm vs. 345–350 mm).

The male specimen was confirmed by the presence of testes (Figure 3b) and exhibited relatively larger fins (280 mm length, 290 mm width). Both specimens had similar eye diameters (20–21 mm) and head widths (90 mm), with slight variation observed in arm lengths (Table 1).

Stomach content analysis revealed that the female (UMTMoll 3113) contained fragments of unidentified fish bones, while the male (UMTMoll 3114) had an empty stomach.

The specimens were identified as *T. rhombus* based on diagnostic features described by Roper *et al.* (1984). The mantle is thick and muscular, tapering to a blunt posterior tip. The elongated rhomboid-shaped fins extend the full mantle length, being broadest at the midpoint and narrowing at both ends. The head, which is wider than it is long, is distinctly separated from the body by a well-defined neck. The species is further characterized by large, non-projecting eyes and long tentacles, with approximately half of each tentacle length occupied by the cirri cover the lengthy oral arms and are enclosed by a surrounding membrane, providing protection. The outer lateral arms are longer than the inner dorsal arms and possess a crest-like muscular projection at their base.

Table 1. Morphometric measurements of *Thysanoteuthis rhombus* Troschel, (1857), for specimens UMTMoll 3113 and UMTMoll 3114.

Variable	UMTMoll 3113		UMTMoll 3114	
	Left	Right	Left	Right
Total weight (g)	894.1		882.0	
Dorsal mantle length (mm)	250.0		255.0	
Ventral mantle length (mm)	282.0		287.0	
Mantle width (mm)	135.0		140.0	
Fin length (mm)	263.0		280.0	
Fin width (mm)	260.0		290.0	
Head length (mm)	60.0		75.0	
Head width (mm)	90.0		90.0	
Eye diameter (mm)	20.0	21.0	20.0	20.0
Arm I length (mm)	110.0	112.0	110.0	111.0
Arm II length (mm)	245.0	244.0	240.0	242.0
Arm III length (mm)	131.0	132.0	135.0	135.0
Arm IV length (mm)	90.0	90.0	99.0	98.0
Tentacle length (mm)	295.0	294.0	350.0	345.0

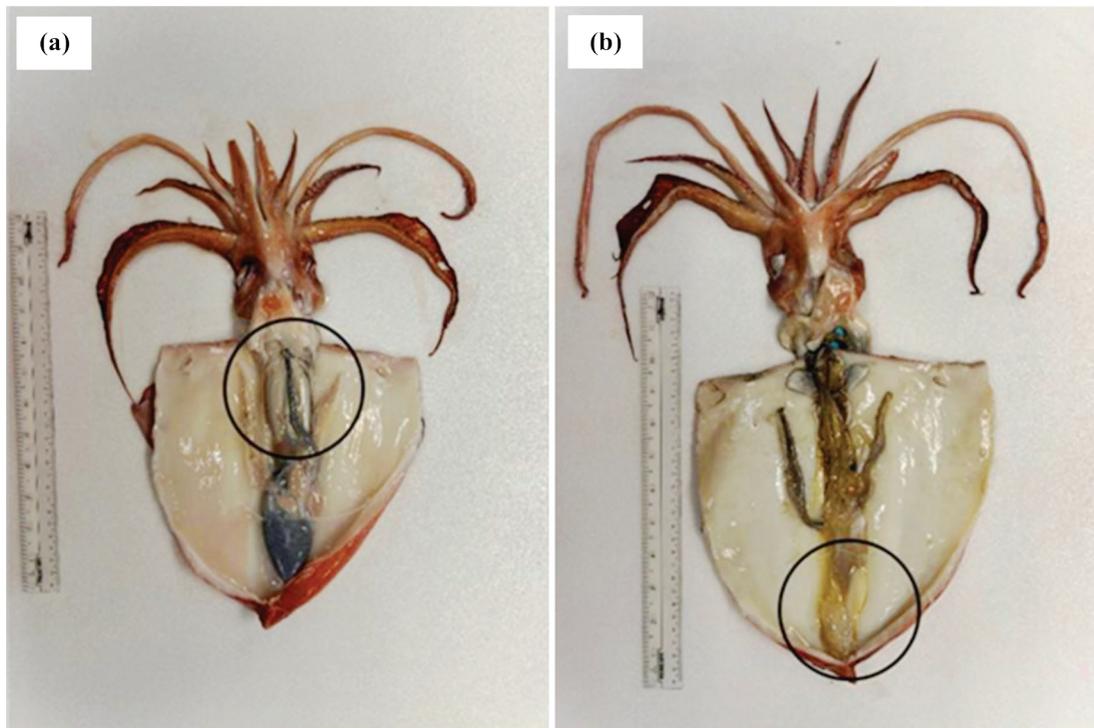


Figure 3. Internal anatomy of *Thysanoteuthis rhombus*. (a) UMTMoll 3113 (female), showing the presence of nidamental glands (circled in black) and the absence of mature gonads. (b) UMTMoll 3114 (male) showing the absence of nidamental glands and the presence of testes at the posterior of the mantle (circled in black).

The two *T. rhombus* specimens collected from Terengganu in June were subadults, each with a mantle length of less than 300 mm. According to Jereb and Roper (2010), males typically mature at 400–550 mm (170–200 days old), while females reach maturity at 550–650 mm (230–250 days old). Compared to specimens from other regions, the individuals from Terengganu exhibited smaller mantle lengths. Nigmatullin *et al.* (1995) reported *T. rhombus* reaching 750–800 mm in mantle length and 17.5 kg in weight, indicating rapid growth within approximately 300 days. Similarly, specimens from the Gulf of Mannar (Rajkumar *et al.*, 2022) ranged from 370–1,070 mm in mantle length, supporting the likelihood that the present specimens were immature or affected by temporal and spatial environmental factors. In contrast, a 93-mm specimen recorded

on the Catalan coast (Fernández-Álvarez *et al.*, 2021) was classified as a juvenile. According to Guerra *et al.* (2012), the species can grow up to 100 cm in mantle length and weigh as much as 24 kg (Guerra *et al.*, 2012). These regional differences in size suggest that environmental factors, growth rates, and ontogenetic development significantly influence the size and maturation of *T. rhombus* across its distribution.

#### Genetic analysis

The COI sequence obtained from the present specimens showed 100% similarity to *T. rhombus* sequences previously deposited in GenBank (accession numbers OP970837, OP970852, OP970860), originating from Japan, the Philippines, and Viet Nam (Figure 4).

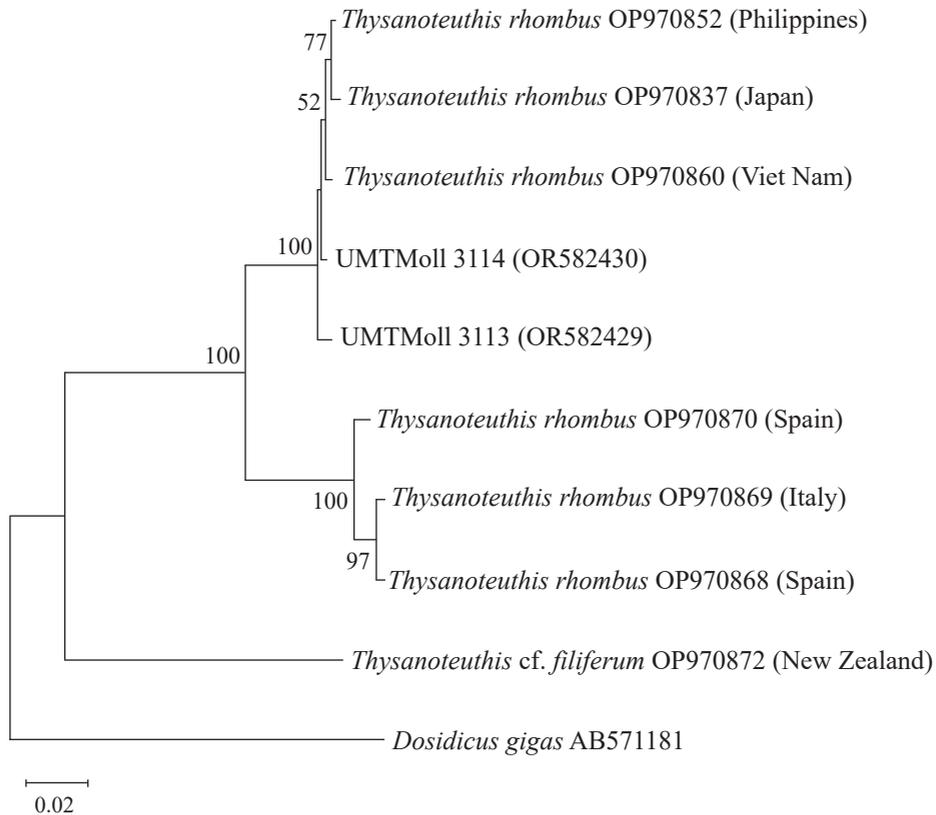


Figure 4. Maximum likelihood phylogenetic tree based on mitochondrial cytochrome c oxidase I (COI) gene sequences showing the relationship between *Thysanoteuthis rhombus* specimens from Terengganu (UMTMoll 3113 and UMTMoll 3114) compared with reference sequences retrieved from GenBank. Bootstrap values (>70%) are indicated at the nodes. Sequences from Japan, the Philippines, and Viet Nam cluster with the Terengganu specimens, confirming their identity as *T. rhombus*. *Dosidicus gigas* was used as the outgroup.

### *Taxonomic challenges in *Thysanoteuthis rhombus**

Genetic studies have revealed divergence within the *T. rhombus* species complex, indicating the need for further investigation to refine its taxonomic classification (Deville *et al.*, 2024). Expanding the geographical scope of genetic sampling would help clarify evolutionary relationships and distribution patterns. In addition to molecular approach, detailed morphological studies remain essential for interpreting phenotypic plasticity and its taxonomic implications. While Roper and Voss (1983) and Roper *et al.* (1984) provided key diagnostic features, integrating modern techniques such as geometric morphometrics could enhance species delineation and identification (Zelditch *et al.*, 2004; Sattari *et al.*, 2021). Re-examination of type specimens using updated methodologies would further resolve taxonomic ambiguities within this species complex.

### *Distribution and migration of *Thysanoteuthis rhombus* in the South China Sea*

The Pacific Ocean hosts the highest global diversity of cephalopods, with *T. rhombus* being particularly abundant in the southwestern Sea of Japan yet rarely reported in the South China Sea (Rosa *et al.*, 2019; Roper *et al.*, 1984; Jereb and Roper, 2010). Confirmed records exist from Andaman Sea, Indonesia, and the Philippines, emphasizing the importance of continued biodiversity monitoring in the region (Nateewathana and Hylleberg, 1989; Billings *et al.*, 2000; Norman *et al.*, 2016; De Chavez *et al.*, 2021). Commercially exploitation of *T. rhombus* began in the Andaman Sea in 1989 (Nateewathana and Hylleberg, 1989) and in the Philippines in 1988, where squid jigs and milkfish bait are used at depths of 145–720 m during the June–October fishing season.

In contrast, records from Malaysian waters place *T. rhombus* at shallower depths of 10–100 m. Globally, the species has been observed at 50 m depth off Peru (Roque-Sánchez and Donayre Salazar, 2021) and at 300–650 m during the day, ascending to 0–150 m at night near Okinawa, Japan, indicating diel vertical migration (Bower

and Miyahara, 2005). Juvenile *T. rhombus* is known to occur around northeastern Taiwan and the Okinawa Islands from June to July, and in the Sea of Japan and Kuroshio Extension from August to September (Ohshimo *et al.*, 2023). Their appearance in Terengganu in early June suggests a northward migration possibly influenced by ocean currents.

Although adults typically inhabit deeper waters (>400 m), paralarvae and juveniles occupy the epipelagic zone (Sajikumar *et al.*, 2020). In the Sea of Japan, *T. rhombus* is mainly found at 75–100 m (Ohshimo *et al.*, 2023). However, the southern South China Sea, including Terengganu, is a shallow continental shelf basin averaging only 60 m in depth (Akhir and Chuen, 2011). A previous record from the Gulf of Mannar at 20 m depth (Rajkumar *et al.*, 2022) further supports *T. rhombus* adaptability to shallow waters.

Several studies suggest that the distribution and migration of *T. rhombus* are strongly influenced by oceanic surface circulation (Nigmatullin *et al.*, 1995; Wakabayashi *et al.*, 2005; Miyahara *et al.*, 2008; Onitsuka *et al.*, 2010). Ocean currents play a crucial role in transporting paralarvae and juveniles across vast distances, thereby shaping habitat colonization and enhancing population connectivity (Wakabayashi *et al.*, 2005). During the northeast monsoon, surface currents in the South China Sea facilitate the dispersal of fish larvae and juveniles across both coastal and open ocean regions, impacting recruitment dynamics (Wu *et al.*, 2022). The presence of *T. rhombus* in Terengganu likely reflects similar migratory patterns to those observed in the Andaman Sea and the Philippines, suggesting a broader distribution within the South China Sea.

The shallow coastal waters of Terengganu may serve as a transient habitat, offering favorable conditions such as food availability and reduced predation pressure. Further comparative research is needed to investigate the ecological drivers of *T. rhombus* distribution, which would contribute to a better understanding of its population dynamics and support future conservation and management strategies.

## CONCLUSIONS

This study presents the first confirmed record of *Thysanoteuthis rhombus* in the coastal waters of Terengganu, thereby extending the species' known distribution within the South China Sea. Morphometric characteristics and cytochrome c oxidase I (COI) gene analysis confirmed that the specimens were genetically related to Pacific populations. These findings provide new insights into the species' dispersal patterns, particularly highlighting the potential role of northeast monsoon currents in transporting paralarvae or juveniles from the Sea of Japan to more southern regions, thereby contributing to regional ecosystem connectivity. Its presence along the east coast of Malaysia suggests either a recent range expansion or the presence of an overlooked local population, warranting further investigation on habitat use and recruitment dynamics. Given its ecological and economic importance, continued monitoring is necessary to assess its seasonal occurrence, population structure, and potential role in regional fisheries. Ultimately, these findings enhance our understanding of cephalopod biogeography and provide valuable baseline data to inform sustainable fisheries management and biodiversity conservation strategies in the South China Sea.

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