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First Record of the Critically Endangered Fan Mussel *Pinna nobilis* (Linnaeus, 1758) in the Great Bitter Lake, Suez Canal

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ABSTRACT
Pinna nobilis is an endemic species to the Mediterranean Sea, and it has been documented as "Critically Endangered" on the IUCN Red List. The present study recorded the first occurrence of *P. nobilis* in the Suez Canal. Samples were randomly collected by fishermen using free diving. Only nine living specimens of *P. nobilis* were collected during June, July and September 2023. In the laboratory, samples were washed with water, and their biometric parameters were measured. The sediment of the study area was mostly consisted of muddy sand. The total length of pinnid samples ranged from 21.2 to 45.4cm. The soft body wet weight accounted for 14.8% of the total wet weight. Seven epibiont taxa belonging to five groups of macro-epibionts were registered. The current study suggested that the Suez Canal is a suitable environment for *P. nobilis*.

INTRODUCTION

The family Pinnidae (Leach, 1819) includes about 50 species of large fan-shells or noble pen shells, placed in the order Ostreida **(Lemer *et al.*, 2016)**. This family comprises two genera, Atrina and Pinna **(Lemer *et al.*, 2014)** and 61 commercially important species **(Vásquez-Luis *et al.*, 2017)**. **Rosewater (1961)** stated that pinnids are semi-infaunal shells that live in muddy and sandy sediments, typically in sea-grass beds. The anterior part of the shell is always vertically embedded in the substrate, while the enlarged posterior one bare above the sediment **(Yonge, 1953)**. It supports a rich epibionts community representing a secondary hard substratum **(Cosentino & Giacobbe, 2007, 2008)**.

The total length of the pen shell, *Pinna nob*ilis, can reach up to 120cm, and its lifespan can exceed 45 years **(Zavodnik *et al.*, 1991; Rouanet *et al.*, 2015)**. Pinnids are benthic filter feeders and usually occur in aquatic environments with high suspended particulate matter **(Davenport *et al.*, 2011; Trigos *et al.*, 2014; Alomar *et al.*, 2015)**.

During the 20th century, major populations of *P. nobilis* populations suffered from clear drop due to anthropogenic activities comprising fishing by bottom nets, trawlers and unintended killing by anchoring **(Richardson *et al.*, 2004)**. Additionally, there is a high mortality rate caused by infection with the parasite *Haplosporidium pinnae* in the Mediterranean Sea. Hence, *P. nobilis* was recorded in the IUCN Red List and protected by the European Council Directive **(EEC, 1992; Kersting *et al.*, 2019)**.

P. nobilis is an endemic species to the Mediterranean Sea. It was mostly reported in the northwestern Mediterranean, with additional sightings along the coasts of Southeast Italy and Cyprus **(Marrocco *et al.*, 2018; Aguilar *et al.*, 2018; Marrocco *et al.*, 2019)**, followed by observations on the Dardanelles Strait **(Acarli *et al.*, 2021)**, and the Sea of Marmara **(Çinar *et al.*, 2021)**. It is capable of anchoring itself to the substrate using byssus threads, which can reach lengths of up to 6cm. These byssus threads, often referred to as "silk-like," have been historically utilized to produce high-value textiles **(Maeder *et al.*, 2004)**. Additionally, they are considered as a food source in certain Mediterranean counties as turkey **(Öztürk *et al.*, 2005)** and Greek restaurants **(Katsanevakis *et al.*, 2016)**.

Thus, the current study aimed to highlight the first presence of a new location for *P. nobilis.* Therefore, in the future, this would help taxonomic and biodiversity studies of bivalves within this canal.

MATERIALS AND METHODS

Study area

This study was carried out in the Great Bitter Lake (Abu-sultan area) which is located on the Suez Canal between 30° 13′ 15″ and 30° 24′ 55″ N and 32° 18′ 15″ and 32° 28′ 31″ E (Fig. 1). It covers about 85% of the Suez Canal area. The lake's surface area is 194km^2, and its maximum depth is 28m. It is a hyper-saline lake. Since the Suez Canal has no locks, the sea water fairly moves into the Suez Canal from both the Mediterranean and the Red Sea, presenting a path for migration of biota.

Sampling

Nine living individuals were handpicked during June, July and September 2023 at a depth of six to eight meters from Abu-Sultan area, Great Bitter Lake of the Suez Canal (Fig. 1). The samples were partially submerged in the sediment. They were washed with water over a 0.5mm mesh size sieve and gently scraped to remove all adhere epibionts. The epibionts were identified to the nearest taxonomic level, with the aid of the following references **(Por & Lerner- eggev, 1966; Millar, 1970; Por, 1978; Tarjan, 1980)**.

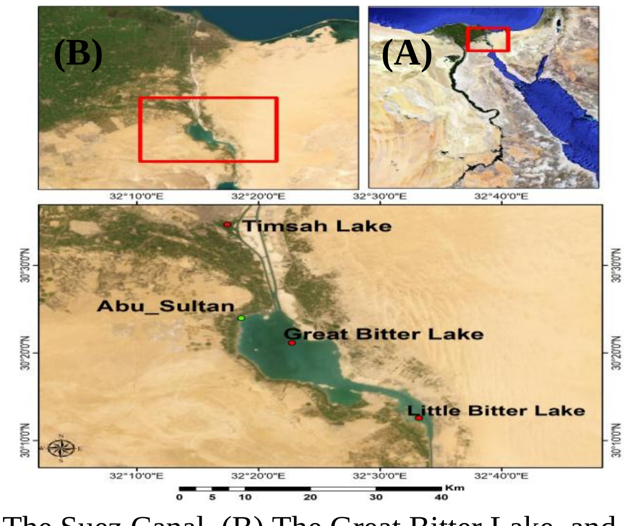

Fig. 1. Map showing: (A) The Suez Canal, (B) The Great Bitter Lake, and (C) The sampling site "Abu-Sultan "

Morphological descriptions were identified and classified based on their exterior morphology according to **Tebble (1966)**. All biometric parameters were measured by a varnier caliper, with an accuracy of 0.1mm (Fig. 2). While total weight (TWt) and soft body weight (SWt) were measured by means of an electronic balance, with an accuracy of 0.1g.

Posterior shell length (PL) is the height of the shell portion above the sea floor, which was detected by the shell area that was occupied by epifouling materials. While, the anterior shell length (AL) is the height of the shell part buried within the substratum and was determined as the pinnid area bared of epibionts (Fig. 2). The meat yield was calculated using the following formula:

$$\text{Total meat yield (\%)} = = \frac{\text{Soft body weight}}{\text{Total weight}} \times 100$$

$$\text{Muscle yield (\%)} = \frac{\text{Posterior and anterior adductor muscle weight}}{\text{Soft body weight Or Total weight}} \text{X100}$$ **(Galvao *et al.*, 2015)**

Sediment analysis

A sediment sample was randomly collected from the study area for analyzing the grain size. Sediments were placed in labeled plastic bags and dried in an oven at 60°C overnight until obtaining a constant weight. Sediment particle size was analyzed using a standard sieving technique **(Folk, 1974)**.

RESULTS AND DISCUSSION

Specimens of the present study exhibited distinctive shell morphology and mantle coloration, without showing any species misidentification or indications of supposed hybrids. The shell is elongated and narrow with a triangular outline. The width of the shell is relatively narrow compared to its length. The posterior end of the shell is wider and rounded, while the anterior end is tapered to a pointed tip. The shell consists of two symmetrical valves connected by a flexible ligament along the dorsal side. The shell color is usually bright brown or beige (Fig. 2). The outer surface of the shell is slightly convex, while the inner is concave. The shell shows protruding radial ribs that extend along each valve from the umbo towards the margin. These ribs are relatively thick, with rounded or marginally flattened surfaces. The umbo, located anteriorly, is a raised, beak-like protrusion. serving as the oldest and most central part of the shell. The hinge situate dorsally where the two valves are connected. A sign marked by the sediment on the shell distinguishes the emerged portion in the bottom.

Classification (WoRMS, 2019)

Kingdom: Animalia
Phylum: Mollusca
Class: Bivalvia
Subclass: Pteriomorphia
Order: Ostreida
Family: Pinnidae
Superfamily: Pinnoidea
Genus: *Pinna*
Species: *Pinna nobilis* (Linnaeus, 1758)

Synonyms (WoRMS, 2019)

Pinna incurvata Born, 1778
Pinna squamosa Gmelin, 1791
Pinna saccata Poli, 1795
Pinna gigas Röding, 1798
Pinna vulgaris de Roissy, 1804
Pinna cornuformis Nardo, 1847
Pinna squammosa Requien, 1848
Pinna obeliscus E. von Martens, 1866
Pinna nobilis var. aequilatera Weinkauff, 1867
Pinna ensiformis Monterosato, 1884
Pinna nigella De Gregorio, 1885
Pinna nobilis var. gangisa De Gregorio, 1885
Pinna nobilis var. intermilla De Gregorio, 1885
Pinna nobilis var. latella De Gregorio, 1885
Pinna nobilis var. maga De Gregorio, 1885
Pinna nobilis var. pisciformis De Gregorio, 1885
Pinna nobilis var. polii Bucquoy, Dautzenberg and Dollfus, 1890
Pinna nobilis var. rarisquama Bucquoy, Dautzenberg and Dollfus, 1890
Pinna nobilis var. dilatata Pallary, 1906
Pinna nobilis var. nana Pallary, 1919

Hence, the current study documented the new occurrence of *Pinna nobilis* in the Suez Canal. Nonetheless, the detection of *P. nobilis* in the Great Bitter Lake of the Suez Canal implies that either this species has existed there but remained undocumented, or otherwise that its geographical distribution range has recently expanded into the Egyptian Mediterranean water.

The distribution range of many marine bivalves depends on several factors, including the availability of suitable habitat, temperature, currents, and interspecific relations **(Dunstan & Bax, 2007)**. Species with pelagic larval stages generally display higher spreading potential, assisted with currents **(Donelson *et al.*, 2019)**. *P. nobilis* usually populate in the seagrass meadows as *Posidonia oceanica* and *Cymodocea nodosa* **(Zavodnik *et al.*, 1991)**, and its distribution is fairly affected by the existence of *P. oceanica* **(Richardson *et al.*, 1999)**. In the study area, soft bottom was mainly covered with some seagrasses (*Halophila stipulacea* and *Holodule uninervis*) and seaweed (*Caulerpa prolifera* and *Ulva* sp.).

Benthos are commonly distributed according to the sea bottom habitat **(Galuppo *et al.*, 2007)**. **García-March and Vicente (2006)** recorded *P. nobilis* inhabiting areas of sandy,

sandy pebbled and muddy seabed. Sediment of the study area is mostly consisted of muddy sand. The sediment analysis revealed that mud is the dominant form (71.56%) followed by sand (24.23%) and pebbles (4.21%).

The present study also found that *P. nobilis* inhabit heterotrophic environment (Bitter Lakes) and highly suspended matter due to the continuous dredging of the lake, as well as the passage of ships and tankers **(Madkour *et al.*, 2006)**. This result disagree with **Butler *et al.* (1993)** who stated that *P. nobilis* inhabits oligotrophic clean water with low suspended matter.

Biometric study of *P. nobilis*

The total length of pinnid samples ranged from 21.2 to 45.4cm, these sizes were also recorded by **Fischer (1987)** and **Turan and Dogdu (2021)**. All morphometric measurements are represented in Table (1).

Table 1: Minimum, maximum and mean of morphometric measurements of *P. nobilis* collected from the Great Bitter Lake. (Number of individuals = 9).

Variable	Minimum	Maximum	Mean
PL (cm)	11.8	25.3	18.83
AL (cm)	9.4	20.1	15.13
SL (cm)	21.2	45.4	33.95
MW (cm)	5.69	18.5	12.51
mw(cm)	3.5	10.37	8.14
ST (cm)	2.58	5.08	4.27
BL (cm)	4.2	12.2	9.30
TWt (g)	38.5	827.8	444.71
SWt (g)	2.58	118.67	65.72
PAWt (g)	0.79	36.2	20.05
AAwt (g)	0.05	2.42	1.35

Legend: PL, posterior shell length; AL, anterior shell length; SL, total shell length; MW, maximum width; mw, minimum width; ST, shell thickness; BL, byssal thread length; TWt, total weight; SWt, soft body weight; PAWt, posterior adductor weight; AAwt, anterior adductor weight.

The yield of posterior and anterior adductor muscle (muscle yield) accounted for 33.25% of soft body wet weight and 4.9% of total weight. The total meat yield was 14.8%; this means that approximately up to 85% of total wet weight was referred to the shell. Adductor muscles yield in *P. nobilis* is similar to that of some other pinnids such as *P. bicolor*, where adductor made up 3.5% of total wet weight and 12.8% of soft body weight **(Beer & Southgate, 2006)**. The same result is found in the giant clam, *Tridacna derasa* **(Watson & Heslinga, 1988)**. On the other hand, it is lower than in the scallops, *Crassadoma gigantea*, where the adductor muscle weighs up to 50% of soft body weight **(Rhee, 1993)**.

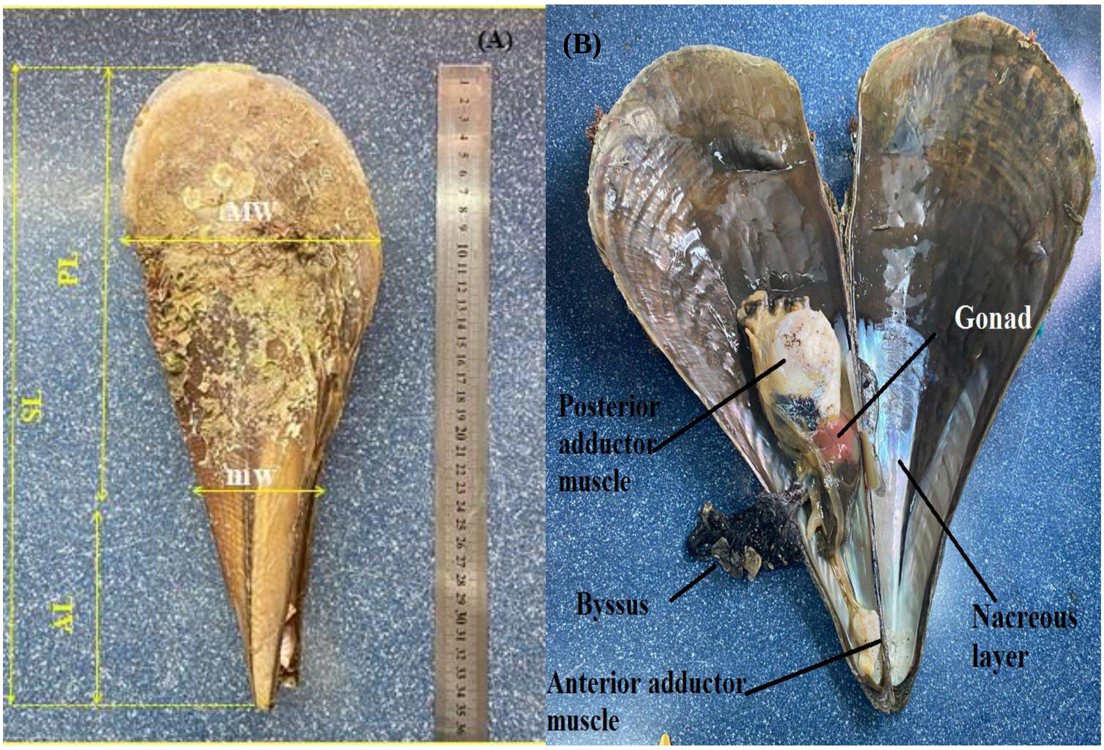

Fig. 2. (A) Morphometric parameters of *Pinna nobilis* (SL: Maximum shell length, PL: Posterior length, AL: Anterior length, MW: Maximum width, mw: Minimum width) and (B) Its internal anatomy

Assemblages of epibiont recorded in this study represent high variation in the diversity and density of species. Epibionts were totally attached to the pinna shells and were difficult to be removed. Seven epibiont taxa belonging to five groups of macro-epibionts were recognized (Table 2). These groups include hydrozoans (Cnidaria), serpulids (Annelida, Polychaeta), barnacles (Crustacea, Cirripedia), bryozoans (Bryozoa) and rhodophyta (Fig. 3).

Table 2: Different epibionts covering the shell of *Pinna nobilis* from the Great Bitter Lake.

Epibionts	Species
Rhodophyta	*Galaxaura* sp
Hydrozoans	*Obelia geniculata* (Linnaeus, 1758)
Serpulids	*Hydroides elegans* (Haswell, 1883) *Hydroides dirampha* Mörch, 1863
Barnacles	*Balanus amphitrite* (Darwin,1854) *Balanus eburneus* (Gould, 1841)
Bryozoans	*Bugula sp.*

Shell roughness was greatly variable in this species. The role of ornamentation in encouraging the settlement of epibionts was clear, mostly for the young densely roughed *P.*

nobilis **(Cosentino & Giacobbe, 2006)**. In the large smooth specimens, epibionts assemblages are appropriately structured, eliminating the need for sculpture maintenance.

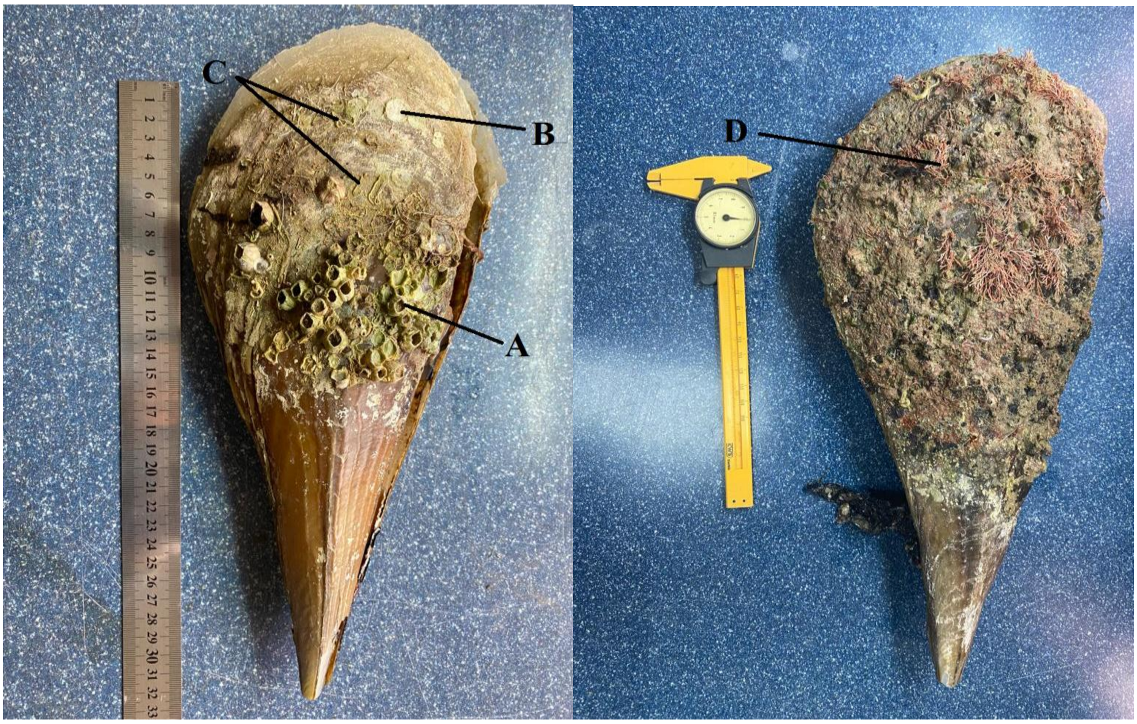

Fig. 3. *Pinna nobilis* covered with epibionts showing: **A-** Barnacles, **B-** Spat of barnacles, **C-** Serpulids, and **D-** Rhodophyta

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