diversity

MDPI

Interesting Images

Rare Observation of a Female *Argonauta argo* in the Northeastern Aegean Sea: A Contribution to Mediterranean Cephalopod Records

Efstratios Kamatsos [1], Maria-Eleni Chaniotaki [2] and Yiannis G. Zevgolis [1,*]

[1] Biodiversity Conservation Laboratory, Department of Environment, University of the Aegean, 81132 Mytilene, Greece; kamatsos.stratos@gmail.com
[2] Department of Marine Sciences, University of the Aegean, 81132 Mytilene, Greece; mchaniotaki@marine.aegean.gr
* Correspondence: zevgolis@env.aegean.gr

Abstract: *Argonauta argo* (Linnaeus, 1758), commonly known as the greater argonaut, is a pelagic octopod with a circumglobal distribution in warm and temperate seas. Although the species is occasionally reported in the Mediterranean Sea, confirmed in situ observations of live individuals remain scarce, particularly in the eastern basin. Here, we document the occurrence of a live female *A. argo* entangled in aquaculture nets at a sea bass (*Dicentrarchus labrax*) facility off the coast of Lesvos Island in the northeastern Aegean Sea, Greece. This represents the first confirmed observation in this part of the Mediterranean and only the second confirmed observation of a live individual in Greek waters. The individual was photographed in situ and identified based on diagnostic morphological features. The encounter occurred under specific hydrodynamic and environmental conditions potentially favorable to the species, including enhanced prey availability and structural refuge within the aquaculture infrastructure. This record contributes to the limited dataset on Mediterranean argonauts and underscores the need for further research into their ecology, distribution patterns, and potential interactions with anthropogenic marine structures.

Keywords: Cephalopoda; eastern Mediterranean; greater argonaut

check for updates

Academic Editor: Bert W. Hoeksema

Received: 4 May 2025
Revised: 17 May 2025
Accepted: 19 May 2025
Published: 19 May 2025

Citation: Kamatsos, E.; Chaniotaki, M.-E.; Zevgolis, Y.G. Rare Observation of a Female *Argonauta argo* in the Northeastern Aegean Sea: A Contribution to Mediterranean Cephalopod Records. *Diversity* **2025**, *17*, 361. https://doi.org/10.3390/d17050361

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

The Mediterranean Sea, recognized as one of the world's most biologically diverse semi-enclosed marine ecosystems, supports a broad array of cephalopod species, including members of the family Argonautidae. Among these, *Argonauta argo* (Linnaeus, 1758), commonly referred to as the greater argonaut or paper nautilus, is a pelagic octopod characterized by its fragile, coiled shell, which is produced by females [1]. Although *A. argo* is typically associated with subtropical and tropical waters [2], its presence within the Mediterranean basin is infrequent and remains poorly documented.

Despite its global classification as "Least Concern" on the IUCN Red List, indicating a stable population trend, considerable uncertainties persist regarding the species' ecology, life history, and regional distribution—particularly within the eastern Mediterranean. Only four argonautid species are currently known from the basin, namely *A. argo*, *Ocythoe tuberculata*, *Tremoctopus violaceus*, and the non-native *Tremoctopus gracilis* [3]. However, direct in situ observations of live individuals are exceedingly rare, with most records arising from incidental strandings or predator stomach content analyses [4–6].

In this context, we report the following novel and significant observation of a live female *A. argo* in the northeastern Aegean Sea. This record represents the first confirmed observation of an individual in this part of the Mediterranean and only the second live

record for Greek waters. Prior documented encounters in the region include specimens from Gökova Bay, Turkey [4], and Rhodes Island, Greece [5]. As such, our finding contributes to the limited yet growing knowledge base concerning the spatial ecology of *A. argo* and underscores the importance of continued monitoring efforts in the eastern Mediterranean.

The observation was made during a SCUBA-based underwater biodiversity survey conducted at the Agrilia aquaculture farm, located off the southern coast of Lesvos Island in the northeastern Aegean Sea. The facility consists of 24 sea bass (*Dicentrarchus labrax*) culture cages—six with a diameter of 40 m and eighteen measuring 60 m—anchored within a site characterized by bathymetric variation ranging from 10 to 70 m. Underwater observations were carried out within a 0–30 m depth range using standard SCUBA equipment, with continuous video documentation captured by a Sony HDR-AS50 action camera mounted on the diver's mask. To ensure accurate spatial measurements without physically handling the organism, a standardized underwater measuring tape was employed. Additionally, detailed field notes were maintained, recording dive parameters, water temperature, and other relevant environmental conditions, while prioritizing non-invasive data collection protocols to minimize disturbance to the marine habitat.

On 6 April 2020, during the course of an underwater survey at 11:17 EEST, a cephalopod-like organism exhibiting a delicate shell was observed by an experienced diver (E.K.). It was entangled in the netting of one of the sea bass cages at the Agrilia aquaculture facility on Lesvos Island, Greece (39°00′18.3″ N, 26°35′59.4″ E; Figure 1), and was located at a depth of approximately 8 m, where the seawater temperature was 15.6 °C.

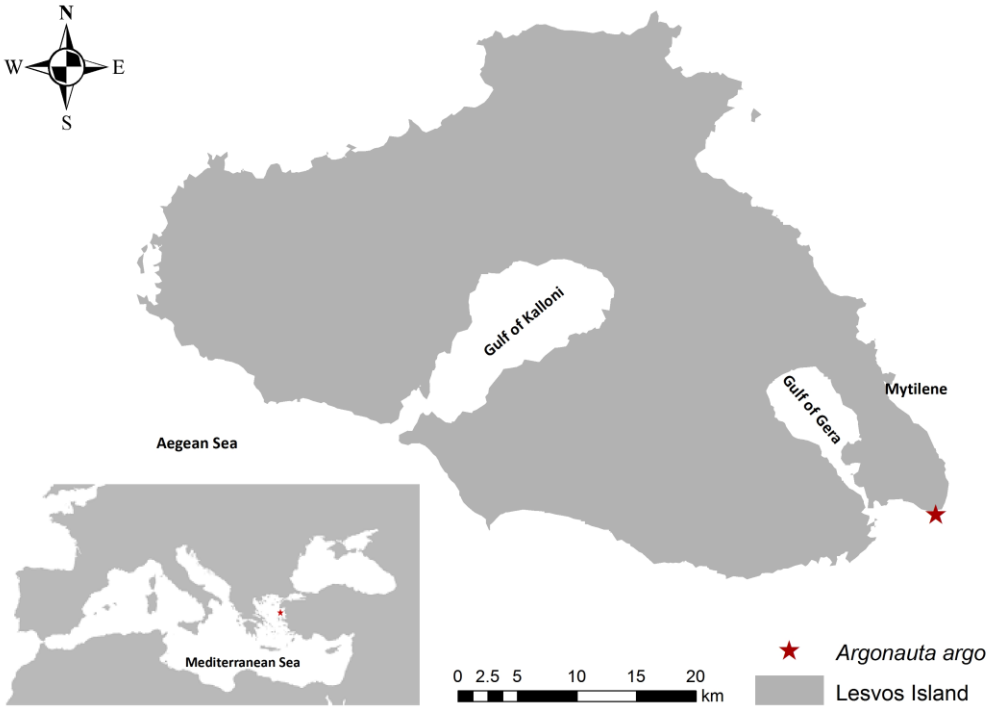


Figure 1. Map of Lesvos Island (northeastern Aegean Sea, Greece), showing location (red star) where a female *Argonauta argo* was discovered within aquaculture facility. Inset map indicates broader geographic context within Mediterranean Sea.

Despite the presence of moderate to strong currents, conditions allowed for clear in situ observation and documentation. The organism displayed a fragile, uniquely coiled shell structure, prompting further visual examination. High-resolution photographs were captured underwater to document the individual and its immediate surroundings (Figure 2).

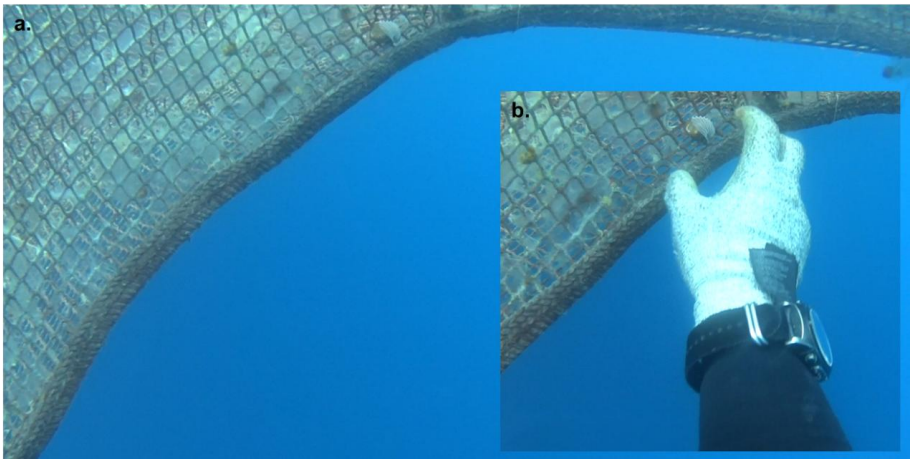


Figure 2. Initial observation of *Argonauta argo* entangled in aquaculture net: (**a**) *A. argo* entangled in mesh of sea bass (*Dicentrarchus labrax*) culture cage; (**b**) Close-up photograph showing diver carefully approaching individual prior to disentanglement.

The individual was gently disentangled from the netting and closely monitored, appearing to be in good physical condition following removal (Figure 3).

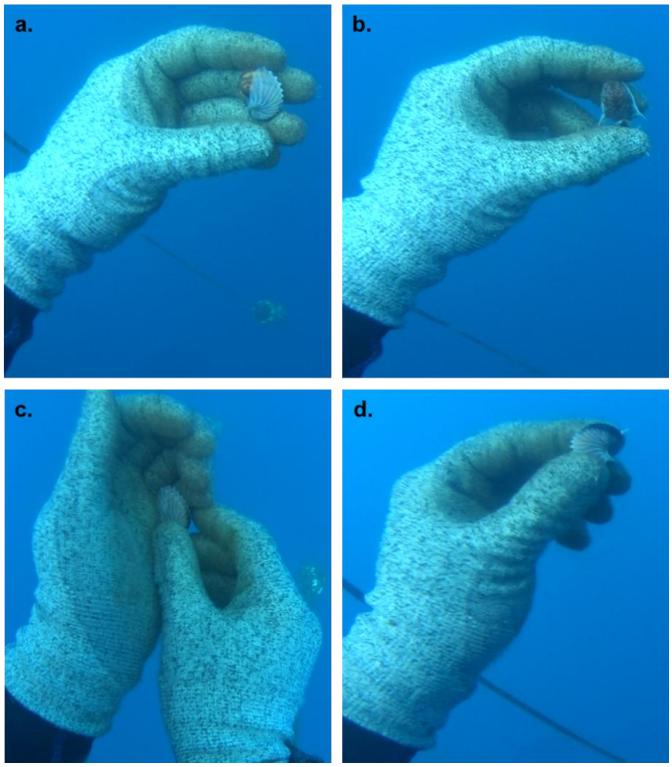


Figure 3. In situ documentation of *Argonauta argo* following removal from net. Several underwater photographs were captured, illustrating different views of individual: (**a**) Lateral view of shell; (**b**) dorsal view; (**c**) ventral view showing aperture; and (**d**) oblique angle highlighting shell's morphology and texture.

Morphometric data showed a marine mollusk with a distinctive coiled shell, approximately 3.6 cm in length and 2.5 cm in width, as estimated using a standardized underwater measuring tape positioned adjacent to the individual during photography. The shell, delicate and paper-thin in texture, was coiled in a single plane, forming a spiral that appeared laterally compressed, with a prominent keel running along the center of this compressed

form, adding further structural support [7]. The surface of the shell featured numerous small bumps or nodules, creating a textured exterior, and the large aperture stood out in contrast to the overall shell size. Based on these key morphological features and a comparison with taxonomic keys [2,8], the organism was identified as a mature female *Argonauta argo.* Juvenile females, even when copulated, do not possess a visible shell [9], and while an early view suggested late-life shell formation without growth, the prevailing understanding is that eggcase secretion begins within days of hatching and continues until reproductive maturity [10].

The individual was observed for approximately two minutes before being released back into the open water. Upon release, it exhibited a typical defensive behavior by expelling a concentrated cloud of ink, after which it swam away without apparent impairment.

The unexpected encounter with a live *A. argo* within the confines of an aquaculture facility on the island of Lesvos constitutes a novel observation and a noteworthy addition to the limited body of knowledge concerning the species' spatial ecology in the Mediterranean Sea. Historically regarded as a pelagic species associated with subtropical and tropical waters, *A. argo* is rarely encountered in the eastern Mediterranean, particularly in live condition and in coastal settings. This record marks the first confirmed occurrence of a live individual in the northeastern Aegean Sea and only the second verified live observation from Greek territorial waters, thereby extending the known distributional range of the species in this region.

The rarity of such observations can be largely attributed to the species' pelagic and cryptic lifestyle, which presents considerable challenges for direct, in situ study. Female argonauts are distinguished by their production of a lightweight, calcareous shell that facilitates buoyancy regulation in surface and epipelagic layers [11]. However, this adaptation also renders them vulnerable to a suite of upper trophic-level predators, including dolphins, billfishes, tunas, and sharks [1,12]. As a consequence, much of the available data on *A. argo* in the Mediterranean have been derived from predator stomach content analyses rather than from direct observation [4,6,13].

The context of the present finding—within an operational aquaculture site—raises important questions regarding the potential influence of anthropogenic environments on the distribution and detectability of pelagic cephalopods. The aquaculture facility in question is characterized by strong hydrodynamic conditions and elevated nutrient inputs associated with fish farming activities [14]. These factors may promote localized productivity, thereby increasing the availability of zooplankton and other potential prey items that could attract pelagic foragers such as *A. argo*. Simultaneously, the structural complexity of the aquaculture nets may provide temporary refuge from natural predators, such as cetaceans and large pelagic fishes [2,15], which are known to inhabit the surrounding waters (pers. obs.).

While such interactions between marine organisms and aquaculture infrastructure remain underexplored, this case highlights the potential for artificial habitats to serve as incidental aggregation points for rarely observed species. However, causality cannot be established from a single encounter, and additional evidence is needed to evaluate whether these facilities influence the spatial ecology or survivorship of pelagic taxa such as *A. argo*. To better understand the drivers underlying this observation, future research should incorporate long-term monitoring of aquaculture-associated biodiversity, as well as concurrent assessments of oceanographic conditions, prey field composition, and predator presence. Integrating such data with focused studies on the behavioral ecology and developmental biology of *A. argo* will be essential to elucidate the mechanisms shaping its occurrence in marginal or atypical habitats within the Mediterranean Sea.

Author Contributions: Conceptualization, Y.G.Z.; methodology, E.K., M.-E.C. and Y.G.Z.; investigation, E.K.; resources, E.K., M.-E.C. and Y.G.Z.; writing—original draft preparation, M.-E.C. and Y.G.Z.;

writing—review and editing, E.K., M.-E.C. and Y.G.Z.; visualization, M.-E.C. and Y.G.Z.; supervision, Y.G.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: All aspects of this study were conducted in full compliance with Hellenic national law (Presidential Decree 67/81: "On the protection of native flora and wild fauna and the determination of the coordination and control procedure of related research") on the humane use of animals.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Roper, C.F.E.; Sweeney, M.J.; Nauen, C.E. *Cephalopods of the World: An Annotated and Illustrated Catalogue of Species of Interest to Fisheries*; FAO Specie; FAO Fisheries Synopsis: Rome, Italy, 1984.
2. Finn, J.K. Taxonomy and biology of the argonauts (Cephalopoda: Argonautidae) with particular reference to Australian material. *Molluscan Res.* **2013**, *33*, 143–222. [CrossRef]
3. Battaglia, P.; Pedà, C.; Rizzo, C.; Stipa, M.G.; Arcadi, E.; Longo, F.; Ammendolia, G.; Cavallaro, M.; Rao, I.; Villari, A.; et al. How Rare Are Argonautoidea Octopuses in the Mediterranean? New Data from Stranding Events, Stomach Contents and Genetics. *Biology* **2023**, *12*, 420. [CrossRef] [PubMed]
4. Salman, A.; Katagan, T.; Avni Benli, H. Vertical distribution and abundance of juvenile cephalopods in Aegean Sea. *Sci. Mar.* **2003**, *67*, 167–176. [CrossRef]
5. Corsini-Foka, M.; Lorenzini, P.; Tirrò, F.; Sottile, G.; Kondylatos, G. On the recent occurrence of females *Argonauta argo* (Mollusca: Cephalopoda) in the Adriatic and Aegean Seas with observations on aquarium maintenance. *Vie Milieu-Life Environ.* **2011**, *61*, 35–39.
6. Foskolos, I.; Alexiadou, P.; Koutouzi, N.; Frey, S.; Thompson, K.F.; Boisseau, O.; Frantzis, A. Insights into the distribution and ingestion of prey-like plastic fishing lures in Mediterranean rough-toothed dolphins. *Mar. Pollut. Bull.* **2023**, *188*, 114701. [CrossRef] [PubMed]
7. Young, R.E.; Vecchione, M.; Donovan, D.T. The evolution of coleoid cephalopods and their present biodiversity and ecology. *S. Afr. J. Mar. Sci.* **1998**, *20*, 393–420. [CrossRef]
8. Jereb, P.; Roper, C.F.E.; Norman, M.D.; Finn, J.K. *Cephalopods of the World: An Annotated and Illustrated Catalogue of Cephalopod Species Known to Date*; FAO Species Catalogue for Fishery Purposes: Rome, Italy, 2016; Volume 3, ISBN 978-92-5-107989-8.
9. Vidal, E.A.G.; Haimovici, M.; Hackbart, V.C.S. Distribution of paralarvae and small juvenile cephalopods in relation to primary production in an upwelling area off southern Brazil. *ICES J. Mar. Sci.* **2010**, *67*, 1346–1352. [CrossRef]
10. Mitchell, P.R.; Phakey, P.P.; Rachinger, W.A.; Hirsch, K.F.; Smillie, A.C. Ultrastructural observations of the Argonaut shell. *Scanning Microsc.* **1994**, *8*, 35–46.
11. Finn, J.K.; Norman, M.D. The argonaut shell: Gas-mediated buoyancy control in a pelagic octopus. *Proc. R. Soc. B Biol. Sci.* **2010**, *277*, 2967–2971. [CrossRef] [PubMed]
12. Staudinger, M.D.; Juanes, F.; Salmon, B.; Teffer, A.K. The distribution, diversity, and importance of cephalopods in top predator diets from offshore habitats of the Northwest Atlantic Ocean. *Deep Sea Res. Part II Top. Stud. Oceanogr.* **2013**, *95*, 182–192. [CrossRef]
13. Peristeraki, P.; Tserpes, G.; Lefkaditou, E. What cephalopod remains from *Xiphias gladius* stomachs can imply about predator-prey interactions in the Mediterranean Sea? *J. Fish Biol.* **2005**, *67*, 549–554. [CrossRef]
14. Tsagaraki, T.M.; Petihakis, G.; Tsiaras, K.; Triantafyllou, G.; Tsapakis, M.; Korres, G.; Kakagiannis, G.; Frangoulis, C.; Karakassis, I. Beyond the cage: Ecosystem modelling for impact evaluation in aquaculture. *Ecol. Modell.* **2011**, *222*, 2512–2523. [CrossRef]
15. Romeo, T.; Battaglia, P.; Pedà, C.; Perzia, P.; Consoli, P.; Esposito, V.; Andaloro, F. Pelagic cephalopods of the central Mediterranean Sea determined by the analysis of the stomach content of large fish predators. *Helgol. Mar. Res.* **2012**, *66*, 295–306. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.