Kuwait Journal of Science 51 (2024) 100078

Contents lists available at ScienceDirect

Kuwait Journal of Science

journal homepage: www.sciencedirect.com/journal/kuwait-journal-of-science

Short communication

In-situ observations of swarming pelagic tunicate *Pegea confoederata* (Forskål, 1775) (Tunicata: Thaliacea) in coral reef habitats of Kuwait

Amani Al-Yaqout [a], Manickam Nithyanandan [a,*], Yiannis Issaris [b], Rakhesh Madhusoodhanan [a], Gopkirishna Mantha [a], Mohammad Al-Kandari [a], Musaad Al-Roumi [a], Stamatis Zogaris [b]

[a] *Environment and Life Sciences Research Center, Kuwait Institute for Scientific Research, P.O. Box 1638, Salmiya 22017, Kuwait*
[b] *Hellenic Centre for Marine Research, Anavissos, 19013 Attiki, Greece*

ARTICLE INFO

Keywords:
Pelagic tunicates
Zooplankton
Chlorophyll
Arabian Gulf
Kuwait
Coral reefs

ABSTRACT

Pelagic tunicates (order Salpida) have the highest filtration rates among filter feeding marine zooplankton. This is the first-ever *in situ* observation of the salp, *Pegea confoederata* (Forskål, 1775), in northwestern Arabian Gulf (NWAG), off Kuwait. Swarms of *P. confoederata* with chain-like blastozooids (~1 m) and solitary oozoids were observed in offshore coral reef habitats. Coastal fishes, *Diplodus sargus kotschyi* and *Abudefdef vaigaiensis,* were observed feeding on *P. confoederata* tests. In Kuwait, higher summer density of phytoplankton (<20 μm) supports *P. confoederata* aggregation. Concerted studies on salps in the Arabian Gulf may offer insights into pelagic carbon cycling pathways and carbon sequestration.

Introduction

The diversity and distribution of gelatinous zooplankton such as salps are poorly documented in the Arabian/Persian Gulf (a.k.a., Arabian Gulf or the Gulf, hereafter). The Pinkish-brown Salp, *Pegea confoederata* (Forskål, 1775), is a semi-cosmopolitan pelagic tunicate (Madin, 2023) occurring in the euphotic zone during daylight hours with limited vertical migration (Sakai et al., 2018). The Gulf is a shallow marginal sea (average depth: ~30 m) with hypersaline conditions – its northwestern part is incredibly distinctive since it is fed by freshwater runoff through the extensive Mesopotamian delta and thus has very different physico-chemical conditions from the rest of the ecoregion (Sheppard et al., 2010; Al-Yamani, 2021). This paper describes two *in-situ* observations of *P. confoederata* (Forskål, 1775) aggregations from Kuwait's coral reef habitats during summer. Kuwait, on the northwestern edge of the Gulf, has a coastline of 499 km with diverse intertidal and subtidal habitats with nine islands and islets (Neelamani et al., 2022). In Kuwait, prominent coral communities are fringing reefs in and around three offshore islands (Khubbar, Qaru, and Umm Al-Maradim) and patch reefs near the coast (Carpenter et al., 2018; Al-Yamani, 2021).

Materials and methods

Chain-like swarms and solitary individuals of salps-like gelatinous organisms exhibiting slow pulsating movements were recorded during coral reef monitoring surveys (by SCUBA diving at ~ 5 m depth) around Qaru island on 30th May 2013 and at Taylor Rock reef on 25th July 2021 (Fig. 1). Underwater photographs and videos of the aggregations were taken using digital cameras (NIKON D200 and Cannon 5D Mark IV) in waterproof casings (Subal ND20, Nauticam NAD6DIV). The swarms were present during both day and night hours in May 2013 but only during the day hours in July 2021. On 25th July 2021, a portable CTD profiler recorded essential ocean variables such as sea water temperature (°C), salinity, and Chlorophyll *a*.

Results

The salps were identified as *P. confoederata* (Forskål, 1775) (Fig. 2) based on morphological characteristics described by Gershwin et al. (2014). The test is smooth, thick with solitary and aggregate forms. The solitary forms have a prominent stolon coiled around the gut mass, whereas the aggregate forms are arranged in two rows of compact coils at right angles to the central axis. Both solitary and aggregate forms had four muscle bands arranged in an "X" fashion in two groups. The swarm was composed of gelatinous chain-like blastozooids (sexual phase) arranged in two rows measuring up to 1 m in length with numerous barrel-shaped solitary oozoids (asexual phase) (Fig. 2a–c). On the night of 30th May 2013, the currents around Qaru island concentrated the swarm of *P. confoederata* along its southwest coast (Fig. 2b). The seawater parameters recorded on 25th July 2021 showed an average daytime

* Corresponding author.
E-mail address: nandan.ocean@gmail.com (M. Nithyanandan).

https://doi.org/10.1016/j.kjs.2023.07.004
Received 22 May 2023; Received in revised form 27 June 2023; Accepted 9 July 2023

Fig. 1. Locations where *P. confoederata* swarms were reported during underwater SCUBA explorations in 2013 and 2021.

temperature of 29.8 °C, salinity of 40.6, and Chlorophyll *a* (Chl *a*) of 2.11 μg l^{-1}. The swarm was monospecific and extended up to several meters in diameter. Predation by common coastal fishes (including one-spot seabream *Diplodus sargus kotschyi* and sergeant major *Abudefdef vaigaiensis*) during the daytime was observed (30th May 2013) (Fig. 2d).

Discussion

Salps like *P. confoederata* are herbivores, actively filter-feeding on nano- and picoplankton (Henschke et al., 2016). Most documentation of salps is usually at low densities, and swarms are rarely documented (Hereu et al., 2010). It is known that salps form dense aggregations or swarms due to their high population growth rates and the alternation of sexual and asexual phases (Madin and Deibel, 1998). The alteration of the generation of aggregate and solitary life stages helps Salps establish in marine systems where even harsh environmental conditions prevail.

The influence of salinity and temperature on salp abundance is documented in tropical and temperate waters (Ishak, 2014; Sampson and Giraldo, 2014). Due to the synoptical nature of this study, the influence of temperature and salinity couldn't be correlated and even in southern Gulf (U.A.E) waters no significant relationship was observed between hydrographical parameters and zooplankton abundance (Sharaf and Al-Ghais, 1997). Although, ocean Chl *a* is a valuable indicator of phytoplankton biomass, the average Chl *a* level recorded at Taylor Rock reef on 25th July 2021 fell within the Chl *a* range (0.4–9.44 μgl^{-1}) reported from Kuwaiti offshore waters during July (Al-Yamani, 2021). Recent studies in Kuwaiti waters revealed seasonal bimodal peaks exhibited by nanophytoplankton (January–February and May–August, respectively). Long-term data sets (2002–2015) from time-series observations suggest that environmental changes in the past two decades favor smaller phytoplankton over larger ones in Kuwaiti waters (Al-Said et al., 2022). Further, fractionation of Chl *a* into pico (0.2–3 μm), nano (3–20 μm), and micro (>20 μm) phytoplankton fractions suggests that nanoplankton (size: 3–20 μm) are mainly responsible for the spatiotemporal variations in phytoplankton Chl *a* (especially those in the size category of 10–20 μm) in Kuwaiti waters, and contributes >60% of the total phytoplankton stock (Rakhesh et al., unpublished data).

As suggested by several authors (Alldredge and Madin, 1982; Sola et al., 2019; Sutherland, 2022) the swarming of *P. confoederata* in the coral reef habitats of Qaru island and Taylor Rock reef could have benefitted from the higher standing stock of small-sized phytoplankton in Kuwaiti waters during the summer months (Al-Said et al., 2017). Since salps like *P. confoederata* filter feeds on sub-micron size particles (up to 3230 ml. Animal $^{-1}$. h^{-1} in aggregate form) through an effective filter-feeding mechanism (Harbison and Gilmer, 1976), they are considered the "vacuum cleaners of the Sea." They directly compete with microzooplankton for smaller phytoplankton, thereby indirectly shunting carbon export away from the microbial loop (Luo et al., 2022). Thus, their intensive feeding rates tremendously impact the microbial communities in the ocean (Al-Said et al., 2022) by creating a "short-circuit" in the microbial loop and thus disrupting the canonical pathway of carbon transfer in the plankton food web (Gorsky and Fenaux, 1998; Sutherland and Thompson, 2022). By packaging sub-micron size particles into rapidly sinking fecal pellets, *P. confoederata* substantially changes the particle-size spectra in the upper ocean and increases the downward fluxes of particulate matter in the ocean (Sutherland et al., 2010) and thereby facilitating ocean carbon sequestration (Al-Said et al., 2022) and pelagic-benthic coupling in areas like island coral reef ecosystems. Salps are recently identified as a food source for hard corals. For example, from northwest Borneo, Hoeksema and Waheed (2012) reported salpivory by polystomatous solitary mushroom corals. Similarly, in the Caribbean, large scleractinian corals (*Madracis auretenna*, *Meandrina meandrites* and *Montastrea cavernosa*) were more efficient in capturing several solitary zooids simultaneously (ter Horst and Hoeksema, 2021).

In the Arabian Peninsula, pelagic tunicate aggregations are documented from the Red Sea (Sola et al., 2019). In the western Gulf coast of the United Arab Emirates, pelagic tunicates such as *Dolioum denticulata*, *Dolioletta gegenbauri*, *Thalia democratica*, *Oikopleura* (*Vexillaria) dioica*, and *Salpa cylindrica* have been identified as dominant members (13%) of the mesozooplankton community (Sharaf and Al-Ghais, 1997). *Oikopleura* (*Vexillaria) dioica* is an essential part of the mesozooplankton

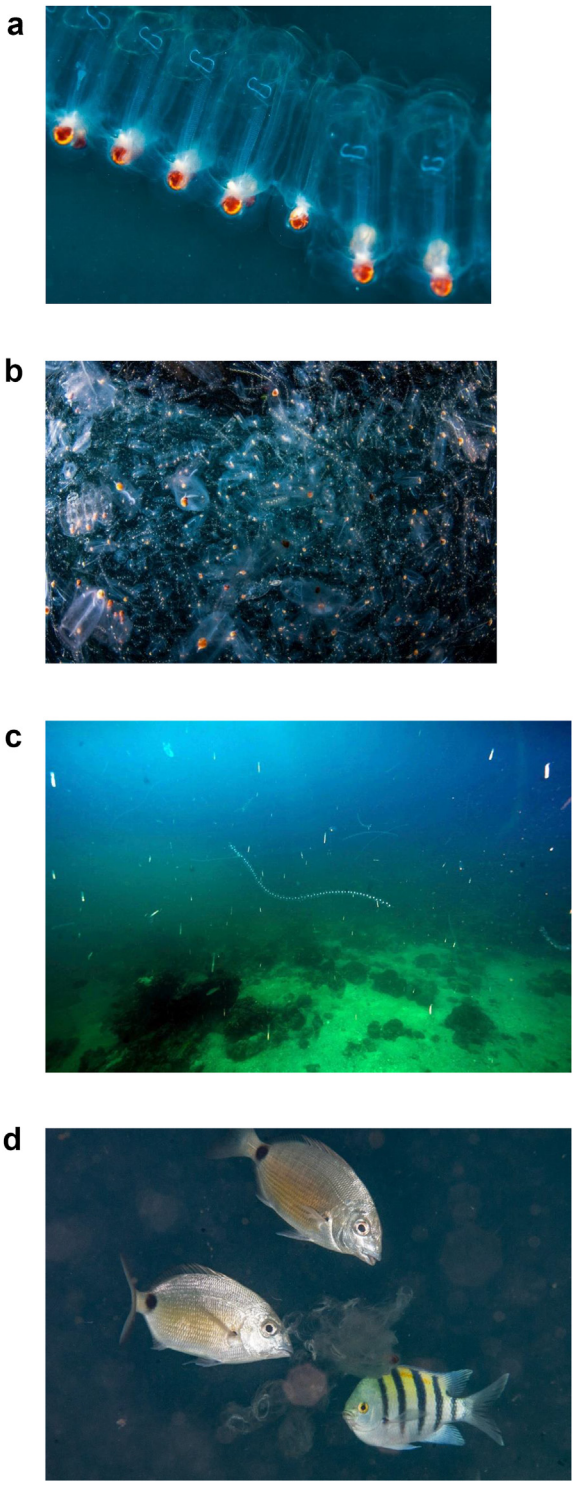

Fig. 2. (a). The Salp, *Pegea confoederata* (Forskål, 1775) documented from the coral reef habitats of Qaru island, Kuwait during daylight hours (31st May 2013, photo, Yiannis Issaris). (b). Night time aggregation of *P. confoederata*, solitary and aggregate phases in the southwest coast of Qaru island (31st May 2013; photo, Yiannis Issaris), (c) *P. confoederata* aggregation in Taylor rock coral reef (25th July 2021; photo, Eslam Basuny) and (d) Coastal fishes, *Diplodus sargus kotschy* and *Abudefdef vaigaiensis* feeding on *P. confoederata* swarm. (Photo, Yiannis Issaris).

community in the Kuwaiti and Saudi territorial waters of the Arabian Gulf. Similarly, an earlier study (2002–2003) in the Saudi territorial waters has reported several tunicates belonging to the family Doliolidae (*Doliolum* sp., *Doliolina* sp., *Doliolina (Doliolina) mulleri*, *D. gegenbauri*), especially in the southern waters closer to Qatar (Joydas et al., King Fahad University of Petroleum and Minerals, Saudi Arabia, personal communication). Although the present observations occurred at an interval of eight years, but it is important to note that both the *P. confoederata* swarming events occurred only during summer months (May and July) when small sized phytoplankton abundance was higher in Kuwaiti waters (Al-Said et al., 2022).

Conclusions

Due to the scarcity of studies on pelagic tunicates, we did not encounter any reports on the swarming of salps from the Gulf, especially in the NWAG. The present study thus provides the first-ever *in situ* observation of *P. confoederata* from the northwestern Gulf and discusses the possible environmental scenario supporting the swarming behavior of salps in this hypersaline marine ecosystem. Since divers and citizen scientists can readily identify such gelatinous aggregations, efforts to collect and document their diversity, distribution, and abundance are deemed necessary to understand their impact on the pelagic food web and benthic ecology of the Gulf waters.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We would like to thank Kuwait Institute for Scientific Research (KISR) for all the facilities and funding support through oceanographic research activity, Dr. Turki Al-Said (KISR), Project Leader, “Marine protected area in Sulaibikhat Bay-Project” for sharing physicochemical data, the Kuwait Oil Company (KOC) for financial assistance (FM 130C) and the reviewers for their valuable comments.

References

Al-Said, T., Al-Ghunaim, A., Subba Rao, D.V., Al-Yamani, F., Al-Rifaie, K., Al-Baz, A., 2017. Salinity-driven decadal changes in phytoplankton community in the NW Arabian Gulf of Kuwait. Environ. Monit. Assess. 189, 268. https://doi.org/10.1007/s10661-017-5969-4.

Al-Said, T., Al- Kandari, M., Yamomoto, T., Farvin, S., Al-Ghunaim, A., Al-Zekri, W., Ahmed, A., Polikarpov, I., Uddin, S., Fernandes, L., Thuslim, F., Alagarsamy, S., Al-Baz, A., Al-Fakhraldeen, S., Al-Enezi, M., Nithyanandan, M., Mantha, G., Chen, W., Abusam, A., Ahmed, N., Martinez, K., Hussain, S., Al-Haddad, S., Sebastain, J., Al-Hammad, A., Raghu, M., 2022. Marine protected area in Sulaibikhat Bay-project claim 5000460 physicochemical assessment and biological oceanography of the marine protected area. Final report 1 and II. Kuwait Institute for Scientific Research.

Al-Yamani, F.Y., 2021. Fathoming the Northwestern Arabian Gulf: Oceanography and Marine Biology. Kuwait Institute for Scientific Research, p. 413.

Alldredge, A.L., Madin, L.P., 1982. Pelagic tunicates: unique herbivores in the marine plankton. Bioscience 32, 655–663. http://www.jstor.org/stable/1308815.

Carpenter, K.E., Harrison, P.L., Hodgson, P., Al-Saffar, A.H., Al-Hazeem, S., 2018. The Corals and Coral Reef Fishes of Kuwait. Kuwait Institute for Scientific Research, p. 166.

Gershwin, L., Lewis, M., Gowlett-Holmes, K., Kloser, R., 2014. The pelagic tunicates. In: Pelagic Invertebrates of South-Eastern Australia: A Field Reference Guide. Version 1.1. CSIRO Marine and Atmospheric Research, Hobart.

Gorsky, G., Fenaux, R., 1998. The role of appendicularia in marine food webs. In: The Biology of Pelagic Tunicates. Oxford Univ. Press, pp. 161–170.

Harbison, G.R., Gilmer, R.W., 1976. The feeding rates of the pelagic tunicate *Pegea confoederata* and two other salps. Limnol. Oceanogr. 21, 517–528. https://doi.org/10.4319/lo.1976.21.4.0517.

Henschke, N., Everett, J.D., Richardson, A.J., Suthers, I.M., 2016. Rethinking the role of salps in the ocean. Trends Ecol. Evol. 31, 720–733. https://doi.org/10.1016/j.tree.2016.06.007.

Hereu, M.C., Lavaniegos, B.E., Goericke, R., 2010. Grazing impact of salp (Tunicata, Thaliacea) assemblages in the eastern tropical North Pacific. J. Plankton Res. 32, 785–804. https://doi.org/10.1093/plankt/fbq005.

Hoeksema, B., Waheed, Z., 2012. It pays to have a big mouth: mushroom corals ingesting salps at northwest Borneo. Mar. Biodivers. 42, 297–302. https://doi.org/10.1007/s12526-012-0110-y.

Ishak, N.A.H., 2014. The Bloom Dynamics and Tropical Ecology of Salp and Doliolids in Storm Bay, Tasmania. Ph.D. Thesis. University of Tasmania, p. 213.

Luo, J.Y., Stock, C.A., Henschke, N., Dunne, J.P., O'Brien, T.D., 2022. Global ecological and biogeochemical impacts of pelagic tunicates. Prog. Oceanogr. 205, 102822. https://doi.org/10.1016/j.pocean.2022.102822.

Madin, L., 2023. World list of thaliacea. *Pegea confoederata* (forskål, 1775). Accessed through: World Register of Marine Species at. https://www.marinespecies.org/aphia.php?p=taxdetails&id=137266. (Accessed 17 January 2023).

Madin, L.P., Deibel, D., 1998. Feeding and energetics of thaliaceans. In: Bone, Q. (Ed.), The Biology of Pelagic Tunicates. Oxford University Press, Oxford, pp. 81–105.

Neelamani, Al-Houti, D., Al-Ragum, A., Al-Saleh, A.H., Al-Salem, K., 2022. Coastal vulnerability index for Kuwaiti coast. Kuwait J. Engg. Res. 10, 1–22. https://doi.org/10.36909/jer.11513.

Sakai, D., Kakiuchida, H., Nishikawa, J., Hirose, E., 2018. Physical properties of the tunic in the pinkish-brown salp *Pegea confoederata* (Tunicata: thaliacea). Zool. Letters 4, 7. https://doi.org/10.1186/s40851-018-0091-1.

Sampson, L., Giraldo, A., 2014. Annual abundance of salps and doliolids (Tunicata) around Gorgona Island (Colombian Pacific), and their importance as potential food for green sea turtles. Rev. Biol. Trop. 62, 149–159.

Sharaf, G.M., Al-Ghais, S.M., 1997. Distribution of zooplankton in offshore waters of the west coast of the United Arab Emirates. Kuwait J. Sci. Eng. 24, 131–144.

Sheppard, C., Al-Husiani, M., Al-Jamali, F., Al-Yamani, F., Baldwin, R., Bishop, J., Benzoni, F., Dutrieux, E., Dulvy, N., Durvasula, S.R., Jones, D.A., Loughland, R., Medio, D., Nithyanandan, M., Pilling, G., Polikarpov, I., Price, A.R.G., Purkis, S., Riegl, B., Saburova, M., Namin, K.S., Taylor, O., Wilson, S., Zainal, K., 2010. The Gulf: a young sea in decline. Mar. Pollut. Bull. 60, 3–38. https://doi.org/10.1016/j.marpolbul.2009.10.017.

Sola, J., Klein, S.G., Martin, C., Agustí, S., Duarte, C.M., 2019. Gelatinous zooplankton in the surface layers of the coastal central Red Sea. Front. Mar. Sci. 6, 726. https://doi.org/10.3389/fmars.2019.00726.

Sutherland, A.W. Thompson, 2022. Pelagic tunicate grazing on marine microbes revealed by integrative approaches. Limnol. Oceanogr. 67, 102–121. https://doi.org/10.1002/lno.11979.

Sutherland, K., Thompson, A.W., 2022. Pelagic tunicate grazing on marine microbes revealed by integrative approaches. Limnol. Oceanogr. 67, 102–121. https://doi.org/10.1002/lno.11979.

Sutherland, K.R., Madina, L.P., Stocker, R., 2010. Filtration of submicrometer particles by pelagic tunicates. Proc. Natl. Acad. Sci. USA 107, 15129–15134. https://doi.org/10.1073/pnas.1003599107.

ter Horst, L.J.V., Hoeksema, B.W., 2021. Salpivory by colonial reef corals at Curacao, southern Caribbean. Diversity 13, 560. https://doi.org/10.3390/d13110560.