On the presence of the non-native *Beroe ovata* Bruguière, 1789, and the spread of the invasive *Mnemiopsis leidyi* A. Agassiz, 1865 in the Lebanese waters, eastern Mediterranean Sea

Ali Badreddine[#1], Ghazi Bitar[#2], Anthony Ouba[#3], Tamara Shiganova[#4]

[#1,2] *Department of Marine Biology, Faculty of Sciences, Lebanese University, Hadath, Beirut, LEBANON*
[#3]*Faculty of Sciences, American University of Technology-AUT, Fidar - Halat, Byblos, LEBANON*
[#4]*Shirshov Institute of Oceanology, Russian Academy of Sciences, 36 Nahimovskiy Prospekt, Moscow, RUSSIA, 117997*

Abstract

The two non-native ctenophores Beroe ovata Bruguière, 1789, and Mnemiopsis leidyi A. Agassiz, 1865, were reported off the Lebanese waters. Beroe ovata Bruguière, 1789, a specialized predator on Mnemiopsis leidyi, was collected and photographed on May 2th 2019, during fieldwork in Beirut waters. While Mnemiopsis leidyi was reported for the first time on April 27th, 2009, to date, it is widely distributed from the south to the north of the Lebanese waters. The possible pathway of introducing those species is spreading or bringing with ballast waters from the Black Sea.

Keywords — *Beroe ovata, Mnemiopsis leidyi, non-native species, Lebanese waters, eastern Mediterranean Sea.*

I. INTRODUCTION

Beroe ovata Bruguière, 1789, known as the American brown comb jelly, and its prey *Mnemiopsis leidyi* A. Agassiz, 1865, known as the American comb jelly, are native to the Atlantic coast of the Americas ([1]). As genetic analyses identified it, both have been introduced by ballast waters first in the Black Sea from the vicinity of the Gulf of Mexico or Caribbean areas ([2], [3]) and expanded into the Azov, Caspian, Baltic, and North seas ([1], [4], [5], [6], [7], [8]).

In the Mediterranean Sea, the American *Beroe ovata* was first reported in November 2004, in the northern Evoikos Gulf, Greece ([9]) and a year later, in the Bay of Piran, northern Adriatic Sea, where *B. ovata* has been found with its prey, *M. leidyi* ([1]). Accordingly, *M. leidyi*, with a higher capacity of invasion, was first found, in 2005 ([1]), in the Mediterranean Gulf of Trieste (northern Adriatic Sea), and near Marseille in the Berre Lagoon. Successively, *M. leidyi* spread to different locations of the northern, western and eastern Mediterranean basin ([10], [11], [12], [13], [14], [15], [16], [17], [18], [27], [28]).

In the Southern Levantine Sea, *M. leidyi* was reported for the first time in 2009 ([17]), *B. ovata* went after its prey in 2011 ([20]). Recently, *B. ovata* is well reported in this area of the Mediterranean ([14], [20]). While its prey, the invader *M. leidyi* has already been well established in this region ([16], [17], [19]).

So, our note's goal is first to report the presence of the brown comb jelly, *B. ovata*, in the Lebanese waters and its well-established prey, the invasive comb jelly, *M. leidyi*, in this region.

II. MATERIALS AND METHODS

One specimen of *B. ovata* was collected and photographed on May 2nd, 2019, during fieldwork offshore Beirut waters (33°52'42.67"N, 35°.28'11.15"E, Fig. 1). Concerning *M. leidyi*, it was first observed by one of the authors (Ghazi Bitar), on April 27th, 2009, also in Beirut waters (33°54'11.25"N, 35°28'57.64"E). Subsequently, the full list of *M. leidyi* sightings along the entire Lebanese coast is presented in Table 1 (see Figure 1). Additional supporting information regarding the sightings, including the location, date, proofs based on photos/personal communications with experts and divers, and references (when available), are provided in Table 1.

III. RESULTS AND DISCUSSION

From a morphological point of view, *B. ovata* and its prey *M. leidyi* (Fig. 2A, B; 3A, B) in the Lebanese waters is similar to the specimen described in the Southern Levantine Sea ([16], [17], [20]) and in the Black Sea ([8]).

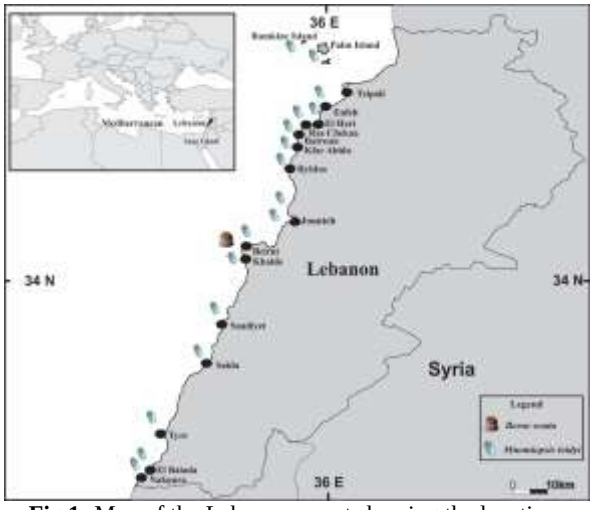

Fig 1: Map of the Lebanese coast showing the location where *Beroe ovata* were collected and photographed and all *Mnemiopsis leidyi* records' locations.

Beroe ovata has a wide miter-shaped flattened body with remarkable lateral compression. Its body is not less than three times compressed in the paragastral plane. The body's aboral end is rounded, while the oral end is almost straight and wider than the body width, which is characteristic only for *B. ovata*. The meridional canals lay under 8 rows of ciliary combs, which extend about three-quarters of the distance from the apical sense organ towards the mouth. Side branches (devirticulae) may be placed in connection one with another by means of an anastomosing network of them in the body (Fig. 2A, B) ([8]).

Fig 2: Specimen of *Beroe ovata* photographed in the Lebanese waters. **2A.** The photo showed the rounded aboral end and the widened oral end of *Beroe ovata*; **2B.** The photo showed the meridional canal with the typical anastomoses of *Beroe ovata* (Photo: Ali Badreddine).

The presence of two lateral lobes characterizes Mnemiopsis leidyi originated near the aboral organ level, and four smaller auricles under the two oral lobes, which is characteristic only for *M leidyi* in comparison with other species belonging to the order Lobata (Fig. 3A, B).

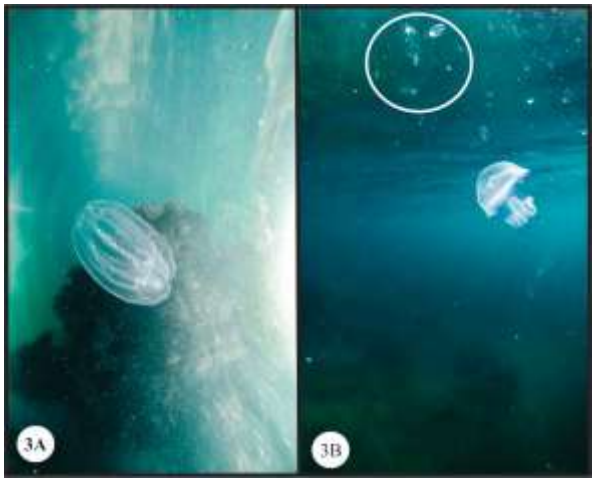

Fig 3: *Mnemiopsis leidyi* in the Lebanese waters. **3A.** *M. leidyi* in the Palm-Island waters; **3B.** Aggregations of *M. leidyi* with the indigenous jellyfish *Rhizostoma pulmo* in the Palm-Island waters (Photos: Hilal Sfarjalani).

It is worth noting that the way of introduction of *B. ovata* in the Lebanese waters, as its prey *M. leidyi*, is more related to ballast waters.

Concerning the current status of the invader *M. leidyi*, the results of observations indicate a significant increase in the abundance of this comb jelly along the Lebanese coast since its first record in 2009 until today, when the species spread along the entire Lebanese coast from the south to the north (Table 1, Fig. 1).

TABLE I

Records of *Mnemiopsis leidyi* along the Lebanese coasts from 2009 until 2020

Location	Date	Photo	References/ or proofs/ or comments
Nakoura	23-03-2011	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
El-Baiada (Nakoura)	28-08-2013	Yes	[31].
	16-09-2015	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
	20-09-2015	Yes	The result was confirmed by one of the authors (Ghazi

			Bitar) during fieldwork.
	22-09-2015	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
Tyre	19-09-2009	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
	17-10-2009	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
	30-05-2010	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
	06-04-2011	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
	Many records in 2019	Yes	Personal observations by one of the authors (Anthony Ouba) during fieldwork.
Saida	12-08-2020	Yes	Result confirmed by professional diver Captain Mohammad-El Serge during fieldwork.
Saadiyet	02-04-2010	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
Khalde	18-04-2010	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
Beirut	27-04-2009	Yes	The first record of *M. leidyi* was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
	03-07-2009	Yes	The result was confirmed by one of the authors(Ghazi Bitar) during fieldwork.
	15-09-2009	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
	07-07-2010	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
	29-03-2011	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
	Many records in 2019	Yes	Personal observations by one of the authors (Anthony Ouba) during fieldwork.
Jounieh	22-04-2013	No	[33]
	05-03-2016	No	[33]
Byblos	03-10-2016	Yes	[32]
Kfar Abida	17-04-2010	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
Batroun	26-09-2010	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
Ras Chekaa	18-06-2011	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
	24-06-2012	Yes	[31]
El-Heri	27-08-2015	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
Enfeh	25-04-2010	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
	22-06-2011	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
	02-08-2012	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
	23-06-2013	Yes	[31].
	13-08-2014	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during

			fieldwork.
	18-03-2015	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
	31-08-2015	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.
Palm Island	30-05-2019	Yes	Result confirmed by a diver Hilal Sfarjalani.
Rankine Island	29-05-2011	Yes	The result was confirmed by one of the authors (Ghazi Bitar) during fieldwork.

The present record of *B. ovata* and the spread off its prey, *M. leidyi*, in the Lebanese waters confirms the fact that the two non-native ctenophores are tolerant of a wide range of salinity and temperature ([4], [6], [8] [10], [14], [21]). As predicted by reference [21], they are now recorded in the warmest (South Levantine Sea) areas.

The importance of our note proofed again by the fact that *M. leidyi* is one of the most harmful invasive species, which is a simultaneous hermaphrodite and capable of self-fertilization. In addition, it has high feeding and growth rates potential ([10], [21]). Moreover, *M. leidyi* is also known for its high quality of zooplankton consumption, including eggs and larvae of fish and invertebrates ([10], [21]). As a consequence, the high abundance of *M. leidyi* may promptly reduce the local zooplankton stocks and affects indirectly their consumers planktophagous fish (through the trophic cascade), as it was demonstrated in all the seas invaded by this species such as the Black, Baltic, Caspian, and even the Mediterranean ([5], [8], [10], [12], [18], [19], [21], [22],; [24], [25], [26], [27]). As a result, in the Southern Levantine Sea, the spreading of this invasive ctenophore caused the decrease of the fish stocks, damage the fishing gears of the fishermen and disrupt some coastal installations ([14], [16], [18]). Also, a decrease of the zooplankton stock caused by the high predation by *M. leidyi* was observed in the Levantine Sea ([14]).

From another point of view, *B. ovata* in the Lebanese waters may probably be capable of controlling the populations of *M. leidyi.* As proved, it has been confirmed a decrease on the population of *M. leidyi* in the presence of its essential predator *B. ovata* in the Black Sea ([4], [5], [8]) and outside of it, in the Sea of Marmara ([29]). As well as, in the Southern Levantine Sea, the native comb jelly *Beroe cucumis sensu* Mayer, 1912, was recently observed and photographed preying on the invasive American comb jelly *M. leidyi* ([30]).

In this context, it is really important to follow up on the current status of the non-native ctenophore *M. leidyi* in the Lebanese waters, to reduce the risk of their impacts as a competitor on local commercial species stocks and total ecosystem state. To encourage monitoring of these gelatinous invaders *B. ovata* and *M. leidyi*, and other harmful gelatinous species, we launch an awareness campaign on jellyfish along the Lebanese coast (Fig. 4) that will help to detect new species of jellies and evaluate the current status of those that already present, especially the non-native ones, as *B. ovata* and *M. leidyi* that are not easily recorded during monitoring by traditional methods.

Fig 4: Poster with the discovered jellies in the Lebanese waters published at ©Facebook and presented to society in many Lebanese coast sites.

ACKNOWLEDGMENT

T. A. Shiganova performed the study within the framework of State assignment of the Ministry of Education and Science of the Russian Federation - theme #0149-2019-0010.

REFERENCES

[1] T. A. Shiganova and A. Malej, "*Native and non-native ctenophores in the Gulf of Trieste, northern Adriatic Sea*." Journal of Plankton Research, 31, 61–71. 2009.

[2] S. Ghabooli, T. A. Shiganova., A. Zhan, M. E. Cristescu, P. Eghtesadi-Araghi, H. J. MacIsaac, "*Multiple introductions and invasion pathways for the invasive ctenophore Mnemiopsis leidyi in Eurasia*." Biological Invasions, 13 (3), 679-690. 2011.

[3] K. M. Bayha, G. R. Harbison, J. H. Mcdonald, P. M. Gaffney, "*Preliminary investigation on the molecular systematics of the invasive ctenophore Beroe ovata*." Springer, Dordrecht. Ed. Dumont H., Shiganova T. A. Niermann U. In Aquatic Invasions in the Black, Caspian, and Mediterranean Seas (pp. 167-175). 2004.

[4] T. A. Shiganova, E. Alekseenko, L. Moskalenko, P. Nival, "*Modelling assessment of interactions in the Black Sea of the invasive ctenophores Mnemiopsis leidyi and Beroe ovata*." Ecological Modelling, 376, 1-14. 2018.

[5] T. A. Shiganova, H. U. Riisgård, S. Ghabooli, O. S. Tendal, "*First report on Beroe ovata in an unusual mixture of ctenophores in the Great Belt (Denmark)*." Aquatic Invasions, 9 (1), 111-116. 2014.

[6] Z. I. Mirzoyan, M. L. Martynuk, E. V. Vyazun, "*Pattern of development of ctenophores Beroe ovata and Mnemiopsis leidyi in the Sea of Azov. In: Voinova IV (ed.) Selected papers of AzNIIRKH. The main problems of Fishery and protection of water bodies with fisheries in the Azov and Black Sea basin (2004–2005 гг.)*". Rostov on Don, 136-148 pp. 2006.

[7] A. E. Kideys, G. A. Finenko, B. E. Anninsky, T. A. Shiganova, A. Roohi, et al., "*Physiological characteristics of the ctenophore Beroe ovata in Caspian Sea water*." Marine Ecology Progress Series, 266, 111-121. 2004.

[8] T. A. Shiganova, Y. V. Bulgakova, S.P. Volovik, Z. A. Mirzoyan, I. S. Dudkin, "*The new invader Beroe ovata Mayer 1912 and its effect on the ecosystem in the northeastern Black Sea*". Hydrobiologia, 451, 187–197. 2001c.

[9] T. A. Shiganova, E. D. Christou, I. Siokou-Frangou, "*First finding of alien species Beroe ovata Mayer 1912 in the Aegean Sea*". Mediterranean Marine Science, 8, 5–14. 2007.

[10] T. A. Shiganova, U. Sommer, J. Javidpour, J. C. Molinero, A. Malej, et al., "*Patterns of invasive ctenophore Mnemiopsis leidyi distribution and variability in different recipient environments of the Eurasian seas: A review*." Marine environmental research, 152, 104-791. 2019a.

[11] B. Dragičević, O. Anadoli, D. Angel, M. Benabdi, G. Bitar, et al., "*New Mediterranean Biodiversity Records 2019*". Mediterranean Marine Science, 20 (3), 645-656. 2019.

[12] A. Malej, V. Tirelli, D. Lučić, P. Paliaga, et al...T. A. Shiganova, "*Mnemiopsis leidyi in the northern Adriatic: here to stay?*". Journal of Sea Research, 124, 10-16. 2017.

[13] CIESM, "*Report of the Joint 1467 CIESM*". In *ICES Workshop on Mnemiopsis Science [co-edited by S. Pitois 1468 and T. Shiganova]* (pp. 18-20). 2015.

[14] B. S. Galil, "*Truth and consequences: the bioinvasion of the Mediterranean Sea*." Integrative Zoology, 7 (3), 299-311. 2012.

[15] J. H. Costello, K. M. Bayha, H. W. Mianzan, T. A. Shiganova, J. E. Purcell, "*Transitions of Mnemiopsis leidyi (Ctenophora: lobata) from a native to an exotic species: a review*." Hydrobiologia, 690: 21–46. 2012.

[16] C. Turan, N. Uygür, D. Ergüden, B. Öztürk, B. Özbalcilar, "*On the occurrence of invasive ctenophore Mnemiopsis leidyi A. Agassiz, 1865 in Antakya Bay, Eastern Mediterranean Sea*". Biharean Biologist, 4 (2), 179-180. 2010.

[17] B. S. Galil, N. Kress, T. A. Shiganova, "*First record of Mnemiopsis leidyi A. Agassiz, 1865 (Ctenophora; Lobata; Mnemiidae) off the Mediterranean coast of Israel*". Aquatic Invasions, 4, 356–362. 2009.

[18] F. Boero, M. Putti, E. Trainito, E. Prontera, S. Piraino, T. A. Shiganova, "*First records of Mnemiopsis leidyi (Ctenophora) from the Ligurian, Thyrrhenian and Ionian Seas (western Mediterranean) and first record of Phyllorhiza punctata (Cnidaria) from the western Mediterranean*." Aquatic Invasions, 4, 675–80. 2009.

[19] T. A. Shiganova, "*Mnemiopsis leidyi abundance in the Black Sea and its impact on the pelagic community. In: Ozsoy, E., Mikaelyan, A. (eds.). Sensitivity of the North, Baltic Sea and Black Sea to anthropogenic and climatic changes*". Kluwer Academic Publishers Dordrecht/Boston/London, 117– 130. 1997.

[20] B. S. Galil, R. Gevili, T. A. Shiganova, "*Not far behind: First record of Beroe ovata Mayer, 1912 (Ctenophora: Beroida: Beroidae) off the Mediterranean coast of Israel*". Aquatic Invasions, 6 (1), 89-90. 2011.

[21] T. A. Shiganova, E. Alekseenko, A. S. Kazmin, "*Predicting range expansion of invasive ctenophore Mnemiopsis leidyi A. agassiz 1865 under current environmental conditions and future climate change scenarios*". Estuarine Coastal and Shelf Science, 227, 106-347. 2019b.

[22] S. A. Hashemi, S. A. T. Motlagh, A. Hedayati, H. Fazli, "*Fishing-in-balance, mean trophic level, ratio of pelagic and demersal fish landings and piscivory indices of coastal fisheries landings in Iranian part of the Caspian Sea*." Iranian Journal of Ichthyology, 6 (2), 112-122. 2019.

[23] T. A. Shiganova, J. Molinero, U. Sommer, J. Javidpous, A. Malej, E. Chrestou, et al., "*Adaptive strategy of the invader Mnemiopsis leidyi and its predators Beroe spp. in the Eurasian Seas*". In *Report of the Join CIESM/ICES Workshop on Mnemiopsis Science*, 4-11 pp. 2014b.

[24] A. Roohi, A. E. Kideys, A. Sajjadi, A. Hashemian, R. Pourgholam, et al., "*Changes in biodiversity of phytoplankton, zooplankton, fishes and macrobenthos in the Southern Caspian Sea after the invasion of the ctenophore Mnemiopsis leidyi*." Biological Invasion, 12 (1), 2343-2361. 2010.

[25] H. Haslob, C. Clemmesen, M. Schaber, H. H. Hinrichsen, J. O. Schmidt, et al., "*Invading Mnemiopsis leidyi as a potential threat to Baltic fish*." Marine Ecology Progress Series, 349: 303-306. 2007.

[26] T. A. Shiganova, A. Kamakin, D. P. Zhukova, V. B. Ushivtzhev, A. B. Dulimov, E. I. Musaeva, "*New invader in the Caspian Sea - ctenophore Mnemiopsis and its initial effect on the pelagic ecosystem*." Oceanology, 41, 542–549. 2001a.

[27] T. A. Shiganova, Z. A. Mirzoyan, E. A. Studenikina, S. P. Volovik, I. Siokou-Frangou, et al., "*Population development of the invader ctenophore Mnemiopsis leidyi in the Black Sea and other seas of the Mediterranean basin*." Marine Biology, 139, 431–445. 2001b.

[28] B. Öztürk, A. A. Öztürk, "*On the biology of the Turkish straits system*." Dynamics of Mediterranean Straits and Channels, 205-221pp. 1996.

[29] M. Isinibilir, A. N. Tarkan, A. E. Kideys, "*Decreased levels of the invasive ctenophore Mnemiopsis in the Marmara Sea in 2001*". In Aquatic Invasions in the Black, Caspian, and Mediterranean Seas, 155-165 pp. 2004.

[30] B. S. Galil, R. Gevili, "*A moveable feast: Beroe cucumis sensu Mayer, 1912 (Ctenophora; Beroida; Beroidae) preying on Mnemiopsis leidyi A. Agassiz, 1865 (Ctenophora; Lobata; Bolinopsidae) off the Mediterranean coast of Israel*". BioInvasions Records, 2 (3), 191-194. 2013.

[31] RAC/SPA - UNEP/MAP, "*Ecological characterization of sites of interest for conservation in Lebanon: Enfeh*

Peninsula, Ras Chekaa cliffs, Raoucheh, Saida, Tyre and Nakoura." By Ramos-Esplá, A. A., Bitar, G., Khalaf, G., El Shaer, H., Forcada, A., Limam, A., Oscar, O., Sghaier, Y. R., Valle, C. Ed. RAC/SPA - MedMPAnet Project, Tunis: 146 p + annexes. 2014.

[32] SPA/RAC–UN Environment/MAP, "*Ecological characterization of potential new Marine Protected Areas in Lebanon: Batroun, Medfoun and Byblos*." By Ramos-Esplá, A. A., Bitar, G., Forcada, A., Valle, C., Ocaña, O., Sghaier, Y. R., Samaha, Z., Kheriji, A., Limam A. Ed. SPA/RAC. MedMPA Network Project, Tunis: 93 pages + annexes. 2017.

[33] S. Katsanevakis, D. Poursanidis, R. Hoffman, J. Rizgalla, et al., "Unpublished Mediterranean records of marine alien and cryptogenic species." BioInvasions Records, 9 (2), 165–182. 2020.