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Record of Aggregation of Alien Tropical Schyphozoan *Rhopilema nomadica* Galil, 1990 in the Mediterranean Coast of Egypt

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Abstract

Recently, annual swarm of invasive Erythrean schyphozoan *Rhopilema nomadica* Galil, 1990 appeared along Egyptian Mediterranean coasts causing beach closures and fishing problems. The present study conducted survey and field monitoring on *R. nomadica* during blooming season in the Egyptian Mediterranean coast throughout three consecutive years (2015-2017). Three main features of *R. nomadica* bloom were addressed; viz starting date, duration and maximum density of aggregation. In 2015, the bloom started on 28 July, and over the following two years the bloom starting date shifted earlier being 19 July in 2016 and 15 June in 2017. The duration of the bloom varied yearly giving the longest duration in 2017 when the bloom continued in high density for a month. The highest density of *R. nomadica* was about 896 medusae/1000 m^3 in 2017. The medusae diameter ranged between 21 to 112 cm. The average bell diameter for each year displayed gradual increasing values over the years. The consistent annual *R. nomadica* blooming was attributed to the high level of eutrophication and ecosystem degradation occurred along the Mediterranean coast since last decades. The shifting in the annual bloom starting date and duration may reflect the adaptation of *R. nomadica* to the climate change effect on the Mediterranean Sea temperature.

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Introduction

After a decade of the first recorded specimen of *Rhopilema nomadica* from Israeli coast in 1976 [1] and since the mid-1980's, many studies documented the progressive spreading of this species in the Mediterranean basin either as few specimens or massive swarms. Throughout the last forty years, *R. nomadica* stretched its range sequentially from eastern Levantine Sea off Israeli, Lebanon and Syrian coasts [2-8] to northern-east Levantine at Marmara and Aegean seas off Turkey [9-14], passing through Greece and Malta [15, 16] and ending at the westernmost Mediterranean of the Italian island of Sardinia and Tunisia [17, 18].

Since the first appearance of *R. nomadica* in the eastern Mediterranean Sea in 1976 [1], and even though *R. nomadica* purportedly entered to the Mediterranean via Suez Canal [2], no scientific publication documented the blooming of *R. nomadica* in the Egyptian coast. In 2016, a short article pointed to the presence of *R. nomadica* bloom in the Egyptian coast during summer 2015 [19]. Otherwise, Avian et al. [7] in their study on nematocysts of *R. nomadica* in the Eastern Mediterranean stated, "large aggregations have become ubiquitous of *R. nomadica* in the summer and winter months along the Levantine coasts from Egypt to Lebanon". Nevertheless, the presence of *R. nomadica* in the Egyptian coast as mentioned in Avian et al. study [7] lack evidence. Although the first scientific record of *R. nomadica* blooms from the Egyptian coast was in 2015 [19], it has actually occurred before.

However, during last two decades, great complains from increasing jellyfish appeared within bathers and fishermen along Egyptian Mediterranean coast in summer. The nuisance effect of these blooms and severe stings from similar-looking jellyfish along the Egyptian coast were reported in a local newspaper in 22 August 2001 (http://www.ahram.org.eg/Archive/2001/8/22/INVE4.HTM). Although *R. nomadica* bloom is known to have both environmental and economic consequences, including injury to bathers causing beach closures and tourism impact, and reduced fishing harvests due to clogging of fishing net [5], no attention was paid to study the blooming density, causes and implications of *R. nomadica* along Egyptian coast.

The present study conducted survey and field monitoring on *R. nomadica* during blooming season in the Egyptian Mediterranean coast throughout three consecutive years. It aimed to give an overview on the main features of the bloom, represented in the maximum density, the starting date and duration of the aggregation.

Materials and Methods

The outbreak of *R. nomadica* in the eastern Egyptian Mediterranean off Port Said coast (31° 16' N, 32° 19' E) (Fig. 1) was monitored during blooming period (summer season) of the three consecutive years (2015 to 2017). Dispersed medusae of *R. nomadica* were estimated every couple of days at a distance of 1 km inshore using fishermen beach trawling net, with

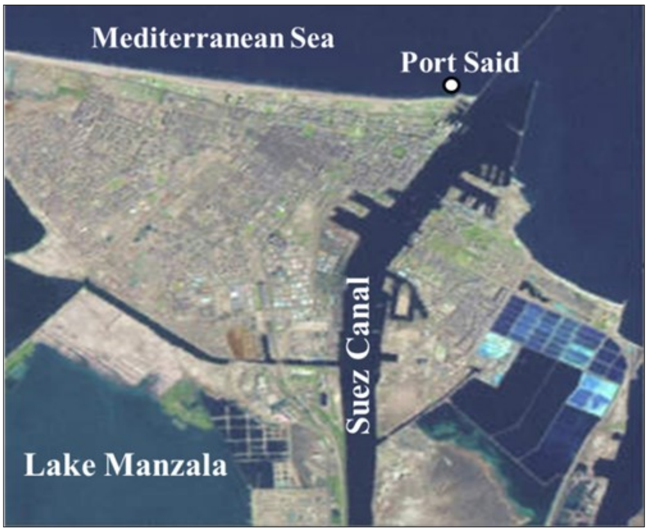

Figure 1. Egyptian Mediterranean off Port Said coast

estimate volume of sampled seawater of 1000 m^3 at each haul. The density of jellyfish was calculated from the total number of medusae counted in hauls and expressed as number of medusae/1000 m^3. Each year, the bell diameter of randomly selected specimens of *R. nomadica* was measured to the nearest cm (the sample size, N, was 505, 97 and 270 specimens for the three consecutive years, respectively). All measured specimens were investigated for the presence/absence of gonads. Surface water temperature was measured *in situ* using thermometer during sample collection.

Results

Jellyfish specimens observed in the water (Fig. 2) and stranded medusa on the beach (Fig. 3) were inspected for species identification and was found to be identical with Galil et al.'s description of *R. nomadica*. The survey was conducted at the onset of *R. nomadica* bloom along Port Said coast in the southeastern Mediterranean of Egypt during the three consecutive years (2015-2017). To evaluate and compare the aggregation of *R. nomadica* per time, three main features were addressed; they are starting date, duration and maximum density of aggregation. There were marked changes over the years in the starting date and duration of the aggregation, but little variation in maximum density of jellyfish (Fig. 4). Considering each of the starting date and duration of the aggregation, in 2015 the bloom started on 28 July, and over the following two years the bloom starting date shifted earlier being 19 July in 2016 and 15 June in 2017. The duration of the bloom varied yearly giving the longest duration in 2017 when the bloom continued with high density for a month, while during the two preceding years (2015 and 2016), the bloom persisted lower period (11 and 7days, respectively), with longer duration in 2015. Considering *R. nomadica* density, the aggregation of jellyfish during these years showed little variation in the maximum density. In 2015, the aggregation peak (866 medusae/1000 m^3) observed on 29th July. The value of this peak decreased insignificantly throughout the following year 2016, giving about 768 medusae/1000 m^3 on 21st July. Then, increased again in 2017 reaching the highest peak (896 medusae/1000 m^3) on 17th June (Fig. 4).

Bell diameter of the measured specimens ranged between the minimum of 21 cm and the maximum of 112 cm. The average bell diameter for each year displayed gradual increasing values over the years from the lowest average of 42.1 ± 7.78 cm in 2015 and the highest average of 46.26 ± 13.03 cm in 2017 (Table 1). In 2015, most of individuals released their gonads (76%), this was inverted in 2017 when only 30% of the investigated medusae shed their gonads, while in 2016 about half of medusae (48%) were empty from gonads (Table 1). Sea surface temperature (SST) ranges throughout three years were 25-31 °C in 2015, 24-33°C in 2016 and 29-38°C in 2017 (Table 1).

Figure 2. Adult *Rhopilema nomadica* in the Mediterranean coast of Egypt. Photo by A. M. El-Gohary .

Figure 3. Collecting dispersed medusae of *R. nomadica* from Port Said coast by beach trawling net.

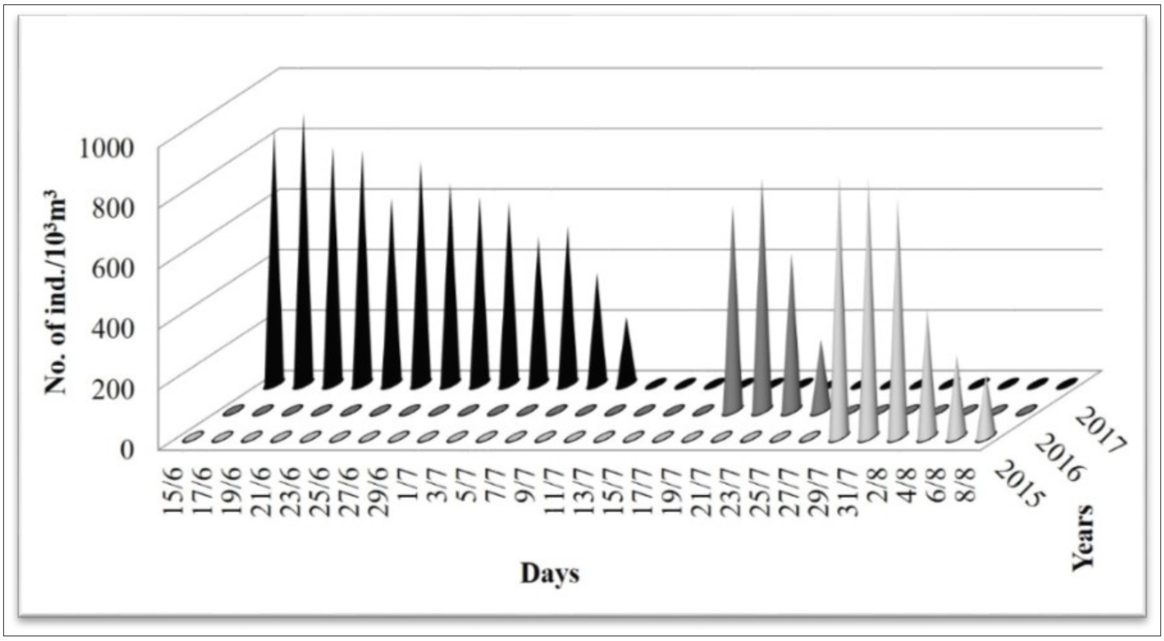

Figure 4. Density of *R. nomadica* in Egyptian coast off Port Said during bloom period throughout three consecutive years (2015-2017).

Table 1. Seawater temperature, medusae diameter and gonads presence/absence of *R. nomadica* in the Egyptian coast off Port Said, during three consecutive years (2015-2017).

Year		2015	2016	2017
Temperature range (°C)		25-31	24-33	29-38
Medusa diameter (cm)	Min.	21	25	28
	Max.	66	68	112
	Mean	42.1 ± 7.78	43.59±8.42	46.26±13.03
Gonad	Presence (%)	122 (24 %)	50 (52 %)	189 (70 %)
	Absence (%)	383 (76 %)	47 (48 %)	81 (30 %)

Discussion

Of the all studies carried out on the proliferation of *R. nomadica* along the Mediterranean basin from the southeastern side to the most western side since its appearance in the mid 1970s [1] up to date, few studies documented its massive occurrence on the coasts. Huge swarms of this species started to appear since late 1980s and were restricted to eastern Levantine Sea off Israeli coast [3, 5], Lebanon and Syria coasts [4], and the Turkey coast at Mersin and Iskendurun Bay [9, 10]. Afterward, scattered individuals have only been occasionally recorded in the central Mediterranean (Maltese islands, Italian island of Pantelleria and Sardinia) [16, 20-22]. While in the most western Mediterranean, *R. nomadica* was consistently recorded each summer since 2010 within the Gulf of Tunis [18], then during 2014-2016, outbreaks of *R. nomadica* started to be established in Bizerte Lagoon, Tunisia [18].

In the present study, the maximum density of *R. nomadica* outbreak (896 medusae/1000 m^3) was close to those recorded in Israeli coast during 1990 (10 medusae/ m^3 [3]). It was much higher than those recorded in Israeli coast during summer 1989 (160,000 medusae/ km^2 [5]), Turkey coast during summer 1995 (38,000 medusae per square nautical mile [9] or in Tunisia coast (4.4 medusae/ km^2 [18]). The rapid proliferation of *R. nomadica* in the eastern Mediterranean had been related to its high reproductive potential where one settled polyp of this species could produce more than 100 ephyrae within 2 months [5]. The strobilation process of the species' polyps of *R. nomadica* seems to be temperature dependence where the synchronization of life cycle and annual occurrence of *R. nomadica* may be controlled by seasonal variations in water temperature regimes [6]. In the present study, the recorded ranges (24-38°C) of sea temperature throughout the three years seems to be highly convenient for attaining the highest blooming density of *R. nomadica* ever recorded before along the Mediterranean. Moreover, decreasing the percentage of individuals that released their gonads with the increasing of sea temperature, suggesting that increasing temperature may induce influx of the *R. nomadica* swarms from the deep sea to the coast, to be stranded, before releasing their gonads.

Swarming of jellyfish in the Mediterranean Sea had been suggested to have positive correlation with pollution [22, 23]. These findings relate jellyfish blooms to the ability of medusae to utilize plankton blooms produced by pollution-caused eutrophication, or by their ability to utilize pollutants directly as food. Another positive correlation between swarming of jellyfish and certain climate change was also found [24]. For *R. nomadica*, previously recorded outbreaks in the coastal waters of Israel [5], Turkey [9] and Tunisia [17] were related to degraded ecosystem in addition to climatic changes, in agreement with Purcell's proposal [25] who stated that jellyfish can be used as indicators of global warming. Also, the establishment of a viable *R. nomadica* population within the Bizerte lagoon, as opposed to a more ephemeral occurrence within the other central Mediterranean areas, have been attributable to the lagoon trophic status (less oligotrophic) and by virtue of the sheltered nature of the lagoon [18]. In the same context, the Egyptian Mediterranean coast had sever pollution impact throughout the last decades because of continuous effluents from the coastal lagoons that connected to the sea. The Egyptian Mediterranean coast receives huge volumes of wastewaters every year loaded by variable amounts and types of pollutants, in addition to great amount of nitrogenous and phosphorous compounds through these lagoons [26]. This situation promotes high level of eutrophication and ecosystem degradation along the Mediterranean coast, providing a great opportunity for consistent annual *R. nomadica* blooming.

The present study revealed that the annual massive occurrence of *R. nomadica* showed continuous shifting in the starting date with time towards the less warm months experienced in the study area. It shifted over the three years from end of July in 2015 to be during mid-June in 2017. When tracing the past observations on the aggregation dates and duration of *R. nomadica* bloom in other locations of the Mediterranean basin, a clear change was noticed. In Israeli coast, Mass swarming of *R. nomadica* used to occur mostly in the summer particularly mid-August and ending between September and November [6]. This change in the annual bloom starting date and duration can be explained in the light of the assumption that the *R. nomadica* adapted itself to the climate change effect on the Mediterranean Sea temperature. Increasing temperature with time was obvious from recorded temperature ranges (Table1).

The size range for medusae diameter in the present study (21-112 cm) was wider than given by previous observations in other locations in the Mediterranean Sea. The previously recorded ranges of medusa size were 20- ~100 cm, commonly 20-60 cm [3], 50-58 cm [9], 10-85 cm [7], 40-42 cm [9, 13, 15, 16]. The largest medusae size recorded in the present study (112 cm) was higher than those recorded before which did not exceed 100 cm [7]. It is worth mentioned that the advance in the starting date of aggregation was associated with bigger medusa size.

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