

Persistent occurrence and life cycle of *Pelagia noctiluca* in the channel of Bizerte (Northern Tunisia)

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ABSTRACT

A daily monitoring of the scyphozoan *Pelagia noctiluca* was performed in the channel of Bizerte (Northern Tunisia) from land station during 2007. Jellyfish density, outbreaks and biometric measurements as well their life cycle were analyzed. Preliminary results pointed out a consistently uncommon observation of this species year round, with a seasonal oscillation in abundance. Highest values were reported mainly during winter. The winter distribution pattern of jellyfish related to the bell diameter appeared to be bimodal, with one small peak for individuals around 2 ± 0.4 cm, and a majority for individuals around 6.5 ± 0.4 cm. The reproduction experiment performed illustrates a relatively high percentage of spawning female reaching the 100% with an egg production rate about 2545 egg d^{-1} during the first 48h of incubation. Planulae appeared during the 24-48 first hours of egg incubation. These planulae settled and metamorphosed into transparent ephyrae fully developed with their typical 8 tentacles. This rapid and direct development of *Pelagia* leads to the appearance of different cohorts in the same season in this brackish ecosystem. Indeed, the absence of benthic stage may increases their outbreaks frequency.

Key words : Scyphozoa, *Pelagia noctiluca*, Life cycle, Tunisian coasts.

Introduction

In recent years, many studies have demonstrated that jellyfish plays a critical role in structuring coastal marine and estuarine ecosystems, and their high production within such ecosystems has increased global concern (e.g., Arai, 2001; Lynam *et al.*, 2005; Purcell, 2005; Purcell *et al.*, 2007; Doyle *et al.*, 2008). This attention is largely the result of jellyfish blooms that have caused ecological and economic losses, which are linked intrinsically to overfishing, eutrophication, climate change, and species invasions (Purcell *et al.*, 2007). Most of the Jellyfish are very voracious predators at the top of the trophic

network. They feed directly on fish larvae and compete with other zooplankton organisms for food, meaning that they drastically alter the trophic structure of marine ecosystems.

Pelagia noctiluca (Forsskål, 1775) (hereafter *P. noctiluca*) is a holoplanktonic epipelagic scyphomedusa with a complex and long life cycle (Russel, 1970). This species have the feature to lack the benthic stage and to directly development from a planula to ephyrae. In addition, it has a very extensive range in the warm waters, distributed widely from coastal to oceanic areas (Hay *et al.*, 1990). *P. noctiluca* can acclimate to a wide range of temperatures (from less than 8°C to greater than 22°C in the

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Mediterranean Sea, (Sandrini and Avian 1991), varying its metabolism to enhance the recruitment of young medusae (Morand *et al.*, 1992), features that enable it to reproduce rapidly under favourable conditions to reach high densities year round. Indeed, analysis of its density during the last century in the Mediterranean Sea reveals that outbreaks of this species usually tend to occur only once every 12 years with 4 years duration (Goy *et al.*, 1989). However, a dramatic spatial increases and temporal shifts in jellyfish distributions were reported during the past several decades (Daly Yahia *et al.*, 2010).

Outbreaks of *P. noctiluca* have negatives socio-economic impacts include damage to tourism, fisheries and industry. This jellyfish species, also known as the "mauve stinger", is well known for its sting, which is very unpleasant due to the numerous venomous nematocysts covering its body (Berline *et al.*, 2013). Indeed, it was admitted that *P. noctiluca* caused mortalities of farmed fish in northeast Ireland and on the Scottish west coast during 2007 (Doyle *et al.*, 2008). A recent example of damage has been reported in the Northern Tunisian coast where jellyfish severely damaged fishing operations causing an overall damage of US\$ 1 million (Daly Yahia Pers Com; Tunisian Ministry of agriculture, unpublished information). Although reports have remained local in scope, scientists agree that a composite understanding of the extent of the problem is still lacking.

During the last decade, the abundance and the seasonal distribution of this gelatinous species in the northern Tunisian coast has been subject of a permanent monitoring by the research unit "*Biodiversité et Fonctionnement des systèmes aquatiques*" of the faculty of Sciences of Bizerte. Density population was highly variable in space and time. Indeed, analysis of the seasonal occurrence of medusae revealed that hydrological and trophic covariates are the strongest forcing factors affecting species distribution (Touzri *et al.*, 2010; 2012). Furthermore, recent studies indicated the extreme sensitivity of pelagic ecosystems in this region (belonging to the western Mediterranean basin) to the influence of North Atlantic climate (Molinero *et al.*, 2005; Daly Yahia *et al.*, 2010).

This work belongs to a long survey of the northern Tunisian brackish ecosystem carried out by the Faculty of Sciences of Bizerte focusing on jellyfish blooms phenomena and the temporary increases in their local population density (e.g. Daly Yahia *et al.*, 2003, 2004; Touzri *et al.*, 2004; Addad *et al.*, 2008;

Touzri *et al.*, 2010). It represents a description on the life cycle of *P. noctiluca* and emphasizes that such baseline studies on important blooming species are a key aspect of understanding this jellyfish species fluctuations. Moreover, this is the first attempt to evaluate the seasonal variation of the medusae quantitatively in the channel of Bizerte.

In this contribution, we present some basic, but hitherto missing, information on the biometry of the widely distributed *P. noctiluca* in the Bizerte channel. Although the intention is to make these data more generally available, more information on the biology and life cycle of this species is also presented. At large scale, these data can be taken into account as support for decision makers as well as local authorities to develop and implement effective remedial programs for improving quality of this ecosystem and develop protection measurements.

Material and Methods

Description of the study area

The channel of Bizerte is located in the Northern Tunisian coast. It connects the second largest Tunisian lagoon, one of the most degraded coastal ecosystems, to the Bay of Bizerte (Fig. 1). This artificial corridor is located in a key connectivity area between both Mediterranean sub-basins. It was created in the early 20th century extending solely over a 7 Km in length and 300 m in width. Its maximum depth reaches at least 12m. This transition area with low amplitude semi-diurnal tidal cycle circulates seawaters with important current velocities reaching 1m/s (Béjaoui *et al.*, 2008). Since the tidal cycles of the bay and the lagoon have an opposite phase, about every 6 h two peculiar currents generate: the "Entrant" (bay toward lagoon waters) and "Sortant" (lagoon towards Bay waters) currents. As a consequence of the different physical and chemical characteristics of the two systems, the channel is also the site of complex hydrodynamic phenomena.

Jellyfish monitoring

Data on *P. noctiluca* distributions were obtained from surveying year round of 2007 a fixed sampling station located in the channel of Bizerte (37°16'1" N; 9°52'50"E). Observations were performed twice a day during the seawater exchange direction in the channel to check jellyfish abundance. Visual identification of this gelatinous was used as an index of

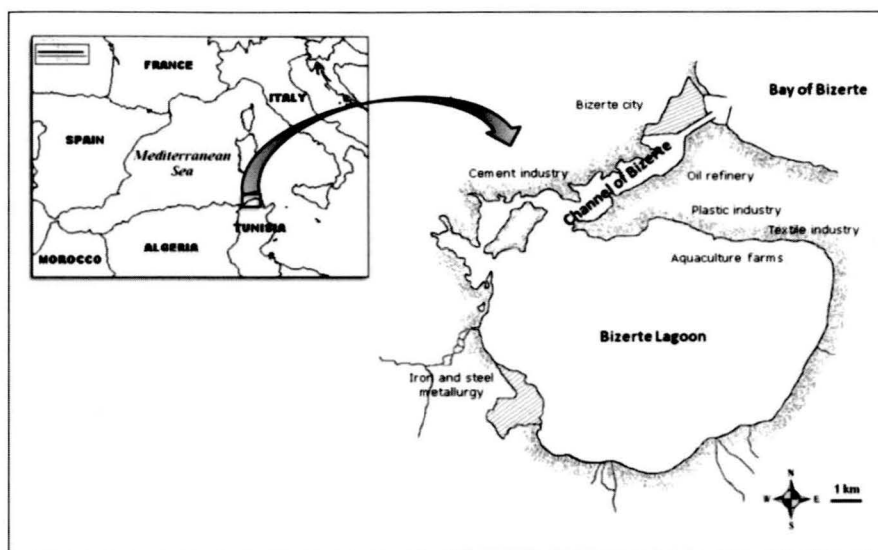


Fig. 1. Geographical location of the channel of Bizerte.

presence. To achieve biometry analysis, a WP2 net with mesh size of 200 μm and a dip net were carefully used to collect jellyfish avoiding capture shocks to the animals as well as accidental breakings of their marginal tentacles and damage to specimens. Live specimens of *P. noctiluca* were transported within half an hour to the laboratory in 30-liter containers with seawater.

For egg production analysis, scyphomedusae were carefully selected *in situ* and maintained in aquaria at the same temperature and light/dark cycle as they would naturally encounter. Due to the fragile nature of jellyfish, we performed biometric measures (bell diameter and arms length) only on individuals collected without damage.

Comparison of sexes

Jellyfish were measured, weighted and their sex and gonadal maturity state were determined using a microscope. The colours of gonads were used like an indicator of separation between males and females. Indeed, testis have a homogenous appearance with colour varying from pink to deep purple and ovary is light to dark brown. Generally, females are easily recognizable due to the clearly visible eggs by naked eyes (Ferraris, 2012). The sex-ratio was determined, and the mean bell diameter of male and female medusae collected was recorded. Temporal variation in the bell diameter between sexes was examined using one-way analysis of variance (ANOVA).

Life cycle

A manipulative experiment was used to estimate the hatching success of *P. noctiluca* in laboratory. A number of 15 females were randomly selected and isolated in different aquaria at the same temperature as they would naturally encounter. The percentage of spawning females (Hereafter PSF) was calculated as the number of females producing eggs out of the total of isolated females. The egg production rate (Hereafter EPR) was expressed as the number of eggs produced per spawning female per day. Eggs found in each aquarium were transferred and carefully combined in a Petri dish filled with filtered sea water and incubated at the spawning temperature.

Hatching success was determined after 24 h of incubation by counting the number of Planula larvae from all resulting eggs. Planulas were then immediately transferred to a second Petri dish in order to estimate the larvae survival rate (Hereafter LSR) 24 h, 48 h and 72 h after hatching until the progress of life cycle to the ephyra stage. These specimens were photographed with a digital camera "Leica" to proceed to biometry.

Results

Population dynamic

Visual survey was carried out over the year (2007) focusing on the transition area between the lagoon and the bay of Bizerte. Observations have been re-

ported year round but the target specie does not appear to be homogenously distributed. *Pelagia* was observed both during northward and southward flow, indicating that medusae were daily transported both from the bay and the lagoon. Based on these evidences, we can infer not only that the *Pelagia* outbreaks are fuelled to a certain extent by passive transport entering the channel from both ecosystems, but also that jellyfish numbers are increasing in the channel as the result of a concurrent increased in both fuelling areas.

Jellyfish abundance fluctuates over the year and tended to increase during winter (mean 6.54 ind.m⁻³ on February, SD=4.57). This gelatinous disappeared from the channel of Bizerte for a short period (April) to reappear again in the latest spring (May and June) to disappear once more from July to October (Fig. 2).

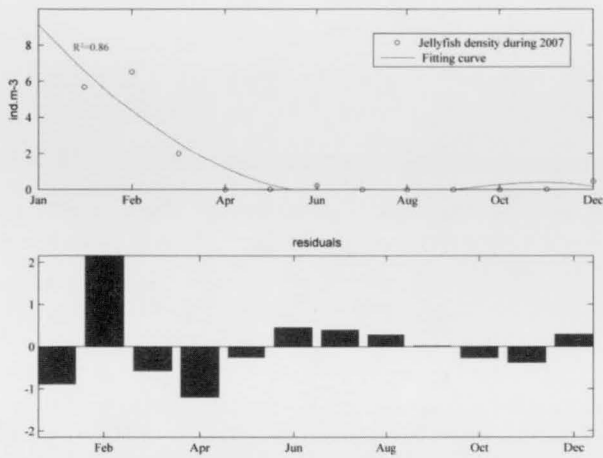


Fig. 2. Temporal variation of jellyfish density in the channel of Bizerte during 2007.

The seasonal variation in the frequency distribution of bell diameter of medusae caught by the hand nets is presented in Fig. 3. Seasonal occurrence of *P. noctiluca* points out a development of multiple cohorts. Indeed, until February 2007 the population consisted of over-wintering individuals with bell diameter of 8–10 cm. New medusae were recruited in February, indicated by a conspicuous increase in the proportion of small specimens (bell diameter: 2–3 cm). The mean bell diameter of the new population was 6.3 cm in March (maximum=7.9cm, SD=0.1), and it gradually increased to 11.9 cm in June (maximum=13, SD=0.4).

A total of 131 specimen of *P. noctiluca* were mea-

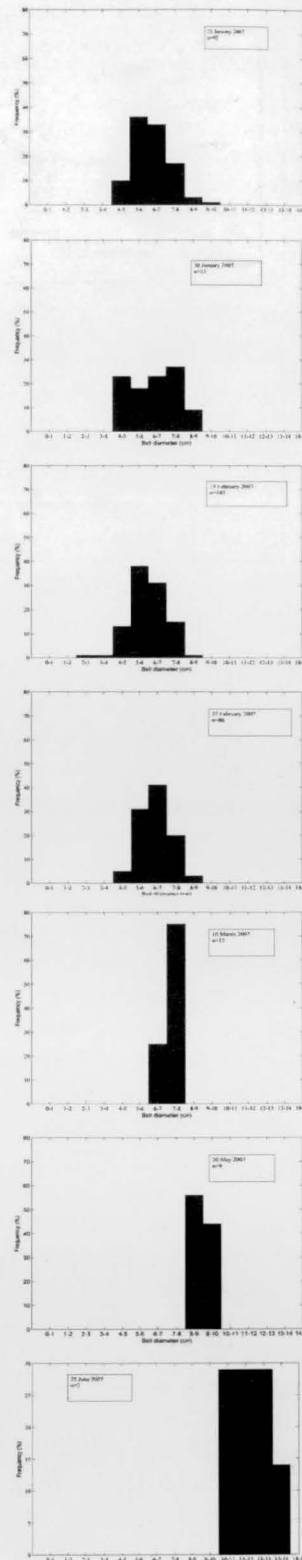


Fig. 3. Frequency distribution of bell diameter of *P. noctiluca* during 2007 monitored in the channel of Bizerte.

sured during the winter. The bell diameter ranged from 3.8 to 8.6 cm, and the fresh weight ranged from 1.74 to 52.45 g. Based on the detection limit, we classified medusa of bell diameter ranging from 1 to 2 cm as undetected. The distribution pattern of jellyfish related to the bell diameter appeared to be bimodal, with one small peak for individuals around 2 ± 0.4 cm, and a majority for individuals around 6.5 ± 0.4 cm (Fig. 4).

The relationship between bell diameters and mass followed a power curve. Medusae dry weights

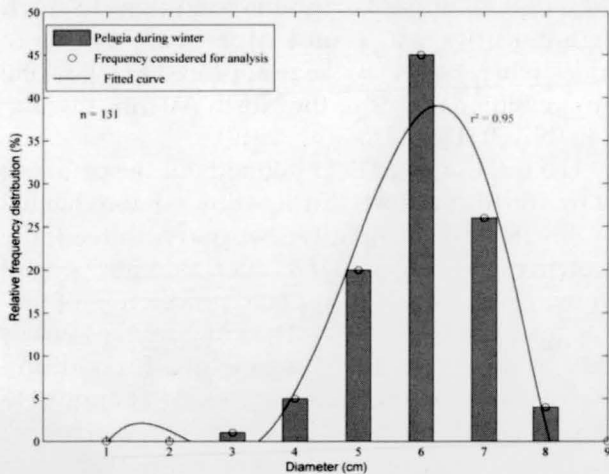


Fig. 4. Frequency distribution of *P. noctiluca* by diameter during winter of 2007.

were calculated from the regression of bell diameter versus dry weight (Figure 5) given by the equation:

$$W = 0.0053D^{2.853} \quad \dots (1)$$

A *T*-test has been performed to determine if bell diameter and dry weight are significantly different from males to females. The null hypothesis cannot be rejected at the 5% significance level as the *p* value is respectively 0.487 and 0.524. Moreover, a comparison of the biometric relationship derived during winter, with those collected during summer, revealed some interesting differences. The population was generally composed of smaller individuals during winter (*t* test, *P*<0.1).

Spawning experiment

The PSF of Jellyfish was relatively high as it reaches the 100% with a number of 33094 eggs obtained in different aquaria (mean=2545, SD=2860). The highest daily egg production observed for a single female was 4224 eggs day⁻¹.

Isolated eggs (2107) were then incubated separately during the next 24h to estimate hatching success (Table 1). Hatching success was quite high with an average value of $27.3 \pm 2\%$ (Range: 18-44). Development time egg – planula larvae was barely 24h.

Over the experimental study, the LSR of *P. noctiluca* indicates a decreasing aspect with signifi-

Table 1. Summary of life cycle jellyfish eggs incubated in different aquaria. HS: Hatching Success, LSR: Larvae Survival Rate

Eggs	Planula			HS (%)			Ephyrae	LSR (%)
	24h	48h	72h	24h	48h	72h		
112	50	36	1	44.64	32.14	0.89	14	16.09
146	27	26	1	18.49	17.81	0.69	17	31.48
109	36	26	10	33.03	23.85	9.17	14	19.44
197	51	48	1	25.89	24.37	0.51	49	49.00
131	33	33	0	25.19	25.19	0	28	42.42
144	40	40	0	27.78	27.78	0	35	43.75
132	34	34	0	25.76	25.76	0	33	48.53
133	33	33	0	24.81	24.81	0	29	43.94
133	33	33	0	24.81	24.81	0	29	43.94
165	46	46	0	27.88	27.88	0	37	40.22
190	35	34	1	18.42	17.9	0.53	24	34.29
129	26	24	0	20.16	18.61	0	23	46.00
118	24	24	0	20.34	20.34	0	20	41.67
128	40	34	2	31.25	26.56	1.56	27	35.53
140	58	42	1	41.43	30	0.71	18	17.82
Mean	37,73	34,20	1,13	27.32	24.52	0.94	26,47	36.94
SD	2,53	1,92	0,65	7.68	4.29	2.33	2,47	11.07

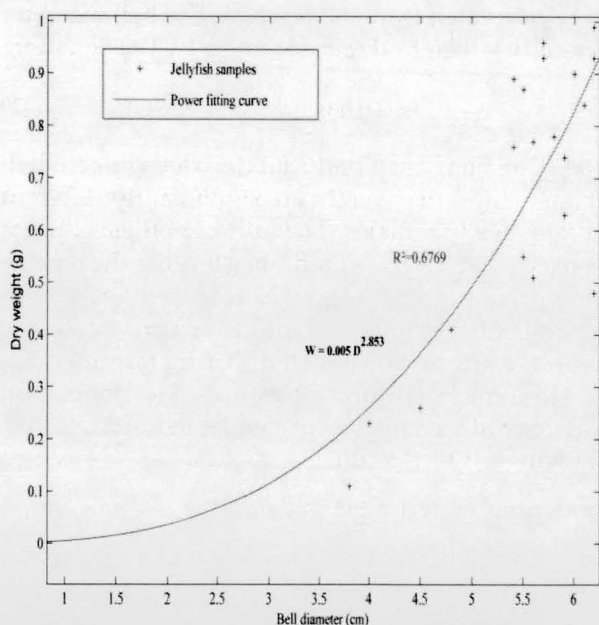


Fig. 5. Relationship between the bell diameter (D) and the dry weight (W) of *P. noctiluca* during winter 2007.

cantly high mean values during the first 24 h after hatching ($27.3 \pm 7.6\%$) than 48 h after hatching ($24.5 \pm 4.2\%$) to 72 h ($0.9 \pm 2.3\%$). After 4 consecutive days of incubation ephyrae were successfully obtained with relatively high values reaching 36.94 ± 11 (range = 17.82 – 49). Those newly liberated ephyrae were approximately 1.4–1.9 mm wide from lappet tip to lappet tip when extended. Ephyrae usually possessed eight marginal lobes.

Discussion

During the study period, *P. noctiluca* pointed out a significant seasonal change. As a whole, the distribution appeared to be patchier in winter-spring and disappear during the summer. Jellyfish occurrence has long been commonly considered following a regular rhythmic abundance each 12 years (Goy *et al.*, 1989; Mills, 2001). This regularity fluctuate during the last decade and this phenomenon was recently described by Daly Yahia *et al.*, (2010) where they confirmed a significant increase in jellyfish abundance not solely in Tunisian waters but also in different areas of the northern hemisphere. Indeed, an interest in the effects of climate variability on biological processes has emerged. Reports demonstrated that climate interacts with population densi-

ties (Molinero *et al.*, 2005). Moreover, Rosa *et al.* (2013) suggest that the high temperatures recorded in summer may cause a metabolic stress leading to the disappearance of *P. noctiluca*.

Aggregation of *P. noctiluca* has been reported at local scale as directly influenced by the very common winds during the winter season having the NW and WNW direction (Daly Yahia *et al.*, 2003). In addition, this species is able to vary its metabolism to enhance the recruitment of young medusae (Morand *et al.*, 1992), features that enable it to reproduce rapidly under favourable conditions to reach high densities year round. Moreover, on a large scale outbreaks of *P. noctiluca* appeared to follow the progression patterns of the North Atlantic Oscillation (NAO) (Licandro *et al.*, 2010).

The bell diameter data pointed out the presence of two distinct cohorts during winter in the channel of Bizerte before and after February. Indeed, the growth curve is sigmoid if it covers the entire period from appearance of ephyrae to production of mature medusae (Arai, 1997). The growth of ephyrae is slow, while that of the young medusa is rapid, and that of the mature medusa is again slowly approaching an upper asymptote, or even negative. *P. noctiluca* can potentially breed more than once yearly and release gametes. Fertilized eggs reach the planula stage solely during 48h, which slowly transform into a larva Ephyra unlike other species that have a polyp stage.

It's assumed that the release of gametes is influenced by environmental parameters such as temperature and food availability (Rottini-Sardini and Avian, 1991). Further studies have speculated also the variation in light intensity effect on this natural phenomenon (Goy, not published data). Nevertheless, no analysis has been elaborated to experiment this hypothesis.

Jellyfish blooms can seriously affect negatively the socioeconomic aspect on tourism (Macrokanis *et al.*, 2004), aquaculture and fisheries (Purcell and Arai, 2001; Purcell *et al.*, 2007). Indeed, the evident positive selection by *P. noctiluca* ephyrae for certain preys like mollusk larvae and especially diverse commercially fish larvae (e.g anchovy) (Sabàtes *et al.*, 2010) proceeded to compete with commercially valuable fisheries and cause a long-term damage. This study seems to be a good reason to develop a management plan that keep under control jellyfish blooms in this sensitive ecosystem. Thus, a combined approach to investigate the occurrences of jel-

lyfish blooms could provide useful information for resource managers. The investigation on the jellyfish density in the channel of Bizerte may indicate that this zone represents an important proliferation and reproduction area for this species. However, the outbreaks of *Pelagia* could also be the result of a passive transport of outbreaks occurring in the neighboring areas influenced by the Modified Atlantic Waters. A large scale investigation on jellyfish presence and persistence seems to be crucial to modulate outbreaks and suggest potentially basic solutions.

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