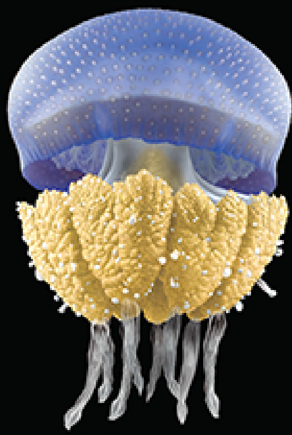
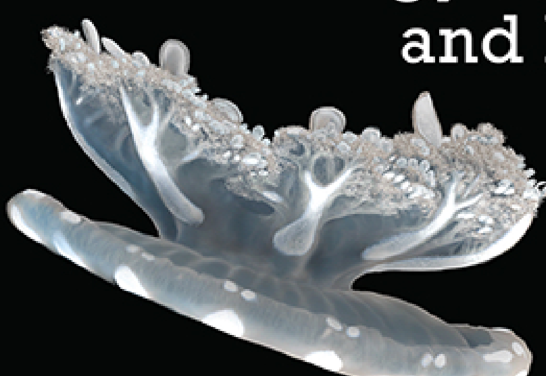
FISH, FISHING AND FISHERIES



Jellyfish

Ecology, Distribution Patterns and Human Interactions



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Chapter 4

THE STRAIT OF MESSINA: A KEY AREA FOR *PELAGIA NOCTILUCA* (CNIDARIA, SCYPHOZOA)

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ABSTRACT

The Strait of Messina is certainly a focal area for the biological cycle of the jellyfish *Pelagia noctiluca* in the Western Mediterranean Sea. By means of both original and literature data, a conceptual model outlining the biological cycle of this species is proposed. *P. noctiluca* reproduces from late winter to late spring in the Aeolian Island Archipelago. From late spring to early summer, currents transport newly produced young individuals (20-30 mm bell diameter) eastwards, towards the Strait. The Strait of Messina ecosystem is not a suitable reproduction area for its intense hydrodynamism that would surely lead to a very low reproductive success due to gamete dispersion. This area, however, represents an optimal site for growth, due to its intensive primary and

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secondary production, but also for an optimal temperature range, lower in summer and higher in winter in respect to the surrounding basins. *Pelagia* remains all the summer inside the Strait, increasing in bell diameter (50-70 mm) and biomass. Subsequently, in late summer-early autumn, the mature specimens, taking advantage of a typical autumnal downwelling transport, move to deep Tyrrhenian waters where overwinter, to upwell in the Aeolian Archipelago by late winter to start a new cycle.

Keywords: *Pelagia noctiluca*, Strait of Messina, Central Mediterranean Sea, life cycle, deep sea-coastal coupling, ecological modeling

INTRODUCTION

Jellyfish blooms have been observed in many coastal and pelagic areas in the Mediterranean Sea [1-6]. In the Western Mediterranean, most blooms are due to the mauve stringer *Pelagia noctiluca* [7, 3, 6, 8-14].

For its widespread distribution (from warm subtropical to temperate waters), conspicuous abundance, high biomass, and for its key role in pelagic marine trophodynamics, *P. noctiluca* received particular attention both from a biological and an ecological point of view [15-18]. Also its negative effects on human health, tourism, fisheries and ecosystem functioning are well known [19-23].

Evidence about how and when jellyfish blooms start and finish is scant: high-density aggregations can suddenly appear and then decline abruptly without clear symptoms of distress [8, 24]. For this reason it is very difficult to predict their spatio-temporal dynamics [4, 25]. Dense blooming periods and drastic fluctuations characterize *P. noctiluca* population biology and ecology, based on a holoplanktonic life cycle and extended spawning [26], opportunistic feeding [6, 27], broad range of vertical migration [28] and survival under a wide range of environmental conditions [11]. The ability of *P. noctiluca* as a holopelagic, non-metagenic species to colonize oceanic waters may drive to an increased intraspecific homogeneity when compared to other metagenic scyphozoan species [29]. Boero [30] hypothesized that species with such dynamics (population blooms followed by population crashes) might lead to genetic bottlenecks and founder effects and, later, Aglieri et al. [31] found support for this scenario in the genetics of Mediterranean populations of *P. noctiluca*.

Studies on the climatic, physical and chemical forcings, that control the occurrence of blooms of this species [10], are not conclusive yet [6, 12, 13]. Canepa et al. [14], based on a literature review and data from stranded *P. noctiluca* associated with marine canyons in the Mediterranean Sea, proposed a model, stemming from personal observations of F. Boero, J. M. Gili, V. Fuentes and from Rosa et al. [6], hypothesizing that *Pelagia* spends the winter in the deep sea, where it grows to maturity. Then it is transported towards the coast by the spring upwellings that trigger the spring plankton blooms. The large, mature specimens spawn and die, often with massive strandings. The young ephyrae have access to abundant food from the copepod spring bloom and become mature in the summer, producing a new cohort that, in the autumn, migrates in deep water, overwinter, and re-emerge with the following spring upwellings, closing the cycle. This proposed model have gained support after finding ephyra of *P. noctiluca* in sediment traps moored in Catalan canyons (over 100 meters deep) (J. M. Gili personal communication) and by the work of Benedetti-Cecchi et al. [32].

These patterns are due to vertical currents (up and downwellings) favoring vertical migrations. Horizontal currents transport the jellyfish away from the spawning areas where the new cohort is produced, spreading them from the upwelling sites and concentrating them at other locations, where they form the summer blooms that affect Mediterranean tourism so much.

Boero [23] explained the increased frequency of jellyfish blooms with a multiple set of drivers, recognizing in overfishing one of the main causes, followed by changes in climate conditions, as Daly Yahia et al. [3] and Rosa et al. [6] suggested. Enhanced recruitment, followed by intensive population growth of gelatinous carnivores (including *P. noctiluca*), have been also linked to climate-related change in hydrographic regimes [18, 33]. Physical pressures, like wind, currents and tides, are the main drivers and may explain both jellyfish aggregations in some smaller areas, such as embayments and ports [34] and connection between large metapopulations, as northern-southern Adriatic and Ionian Sea ones, through the Otranto Strait [29, 35]. Also physicochemical parameters, such as temperature, salinity, light intensity, nutrient concentrations, may affect the life cycle and behavior of *P. noctiluca* [1, 18, 36].

All observations on Adriatic populations of *Pelagia*, however, cannot be taken as representing the normal biology of the species. Stopar et al. [29], in fact, demonstrated with genetic studies, that *Pelagia* is not stably present in the Adriatic Sea and that the blooms in this basin are due to current regimes that transport the species in the basin from other areas (i.e., the Ionian Sea), where *Pelagia* is normally present. According to the model proposed by Canepa et al. [14] and with empirical support Benedetti-Cecchi et al. [32], the presence of *Pelagia* is linked to the presence of ocean topography features like submarine canyons, and this condition does not occur in the shallow central and northern Adriatic Sea, where the species is usually rare, being only occasionally very abundant.

Along the Catalonian coasts, peculiar oceanographic features associated with shelf-slope, fronts, eddies, up- and down-wellings, favored the retention and the aggregation of *P. noctiluca*, with an increase in primary and secondary productivity and consequently in its high abundances and blooms [15, 27, 37]. Considering the physical variables, Rubio and Munoz [38] developed a conceptual model for the arrival of *P. noctiluca* to the coastline of Barcelona. The hypothesis that coastal blooms of both *Velella velella* and *P. noctiluca*, are associated with their life cycle patterns (deep-sea phase for adult and larval stages), extensive seasonal vertical migration in the proximity of canyons and upwelling areas [14, 39], suggests that outbreaks of these species can be driven by different environmental factors than those governing species with a benthic polyp stage, such as *Carybdea marsupialis*, *Aurelia* spp, *Rhizostoma pulmo* and *Cotylorhiza tuberculata* that thrive both in the coastal systems of the shallow Adriatic and in the deepest basins of the western and central Mediterranean Sea. These hypotheses about a link between deep and coastal systems can explain (and are supported by) the high abundance and frequency of both *V. velella* and *P. noctiluca* in the Strait of Messina, where their outbreaks can be linked to the peculiar geomorphology and hydrodynamic regimes of the area.

Rosa et al. and Milisenda et al. [6, 40] suggested that the Strait of Messina is a reproductive area for *P. noctiluca*. In this chapter we suggest the Strait of Messina as rather an area of retention and accumulation of large amounts of individuals that are driven mainly from the adjacent southern Tyrrhenian Sea. This hypothesis is based on the peculiarities of this ecosystem that make it extremely suitable for a “trophic” phase in the biological cycle of *Pelagia*.

THE STRAIT OF MESSINA ECOSYSTEM

The funnel-shaped Strait of Messina separates Sicily from the Italian peninsula (Figure 1) and unites the Tyrrhenian and the Ionian seas, with a North-to-South length of 40 km and a West-to-East width ranging from 2.8 km near the Tyrrhenian edge to about 25 km at the Ionian open boundary. The depth ranges from 1500 m off Capo dell’Armi to a minimum of 72 m along the connection (sill) between Ganzirri and P. Pezzo. North to the sill, the depth reaches 1000 m to the west of Milazzo [41] and 2000 m beyond the Stromboli Island.

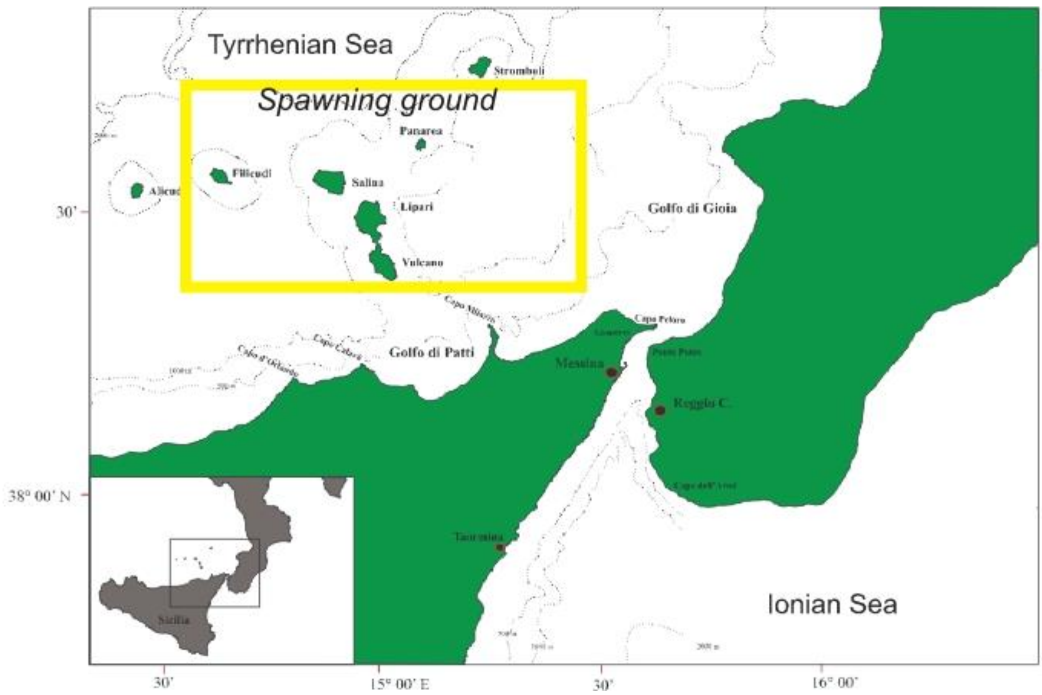

Figure 1.The Strait of Messina.

Periodical and intense upwellings cause a remarkable increase of primary production in the whole area of the Strait. Two alternate currents characterize the dynamics of the Strait [42]:

Tyrrhenian current (from North to South, “scendente”)

Due to tides, the surface Tyrrhenian waters coming from the Aeolian Island Basin flow into the northern entrance of the Strait and move southward. Because of their lower density they remain exclusively in a surface layer, rarely exceeding 30 m in thickness. As soon as they cross the sill, they mix with the upwelled Intermediate Ionian Waters giving rise to a very turbulent body of water that exits the Strait and flows southward along the eastern coast of Sicily.

Ionian current (from South to North, "montante")

Intermediate Ionian Waters dragged by tidal movements rise over the southern steep slope of the sill and emerge in the northern area of the Strait. Nutrient-rich cold Ionian water alongshore and central warmer Tyrrhenian surface water characterize the upwelling process, with sharp thermal fronts that can exhibit horizontal gradients of 10°C in few tens of metres, especially in the summer.

In the Strait, the strong water mixing, coupled with the upwelling processes, prevents the development of a stable summer thermocline [43, 44].

When the tide current is at its maximum, the cold and saltier upwelled water from the Ionian basin reaches the surface and quickly flows northward, where it sinks due to higher salinities, so carrying higher concentrations of nutrients in the deeper waters of Tyrrhenian Sea with respect its surface waters [45].

The above-described physical features have remarkable effects on the abundance and structure of planktonic and nektonic communities, since this enrichment stimulates the living component, leading to high biodiversity in phytoplankton, zooplankton and nekton. High densities of zooplankton and micronekton "deep species" of prevalent eastern origin and spreading towards the western basin communities, characterize the biodiversity of the Strait [46]. Currently, the number of mesozooplanktonic species is on average 70-90% of those recorded in the Mediterranean Basin. Mazzarelli [47] reported the presence of large swarms of the floating hydrozoan *V. velella* in the Strait of Messina.

DATA SET

Data on *Pelagia noctiluca* records in the Strait of Messina were obtained from:

a) Jellywatch CIESM monitoring from 2014 to 2015 (http://www.ciesm.org/marine/programs/jellywatch.htm) and the citizen science program Meteomedusa.
b) Numbers and location of strandings of *P. noctiluca* and *V. velella* along the Ionian and Tyrrhenian shorelines of the Strait of Messina are from a pluriannual data set, property of the Department of Chemical, Biological, Pharmaceutical and Environmental Sciences of the University of Messina, Italy.
c) Visual census daily data from two coastal points, were collected from 2007 to 2011 on abundance, biomass, bell size and sexual maturity [6].
d) Visual census every three days from 2013 to 2015 on a boat, along the Strait of Messina and surrounding Tyrrhenian basin.

PELAGIA NOCTILUCA ECOLOGY IN THE STRAIT OF MESSINA

Spallanzani [48] first recorded *P. noctiluca* in the Strait of Messina in 1785, but reports of massive and regular outbreaks of this species are available only from 1981 [49]. Outstanding masses of *V. velella* and *P. noctiluca* were reported from the sea surface [6], whereas local newspapers regularly report on massive strandings, mainly from April to June, both on the Calabrian and Sicilian shorelines of the Strait. Studies on *P. noctiluca* abundance, growth, reproduction and feeding have been carried out from 2007 to 2011 [6].

To better understand the complexity of interactions between biological and environmental variables during the life cycle of *P. noctiluca* along the Strait of Messina, the three important phases (Figure 2) of its ecology (reproduction, retention and growth, downwelling) will be analyzed separately.

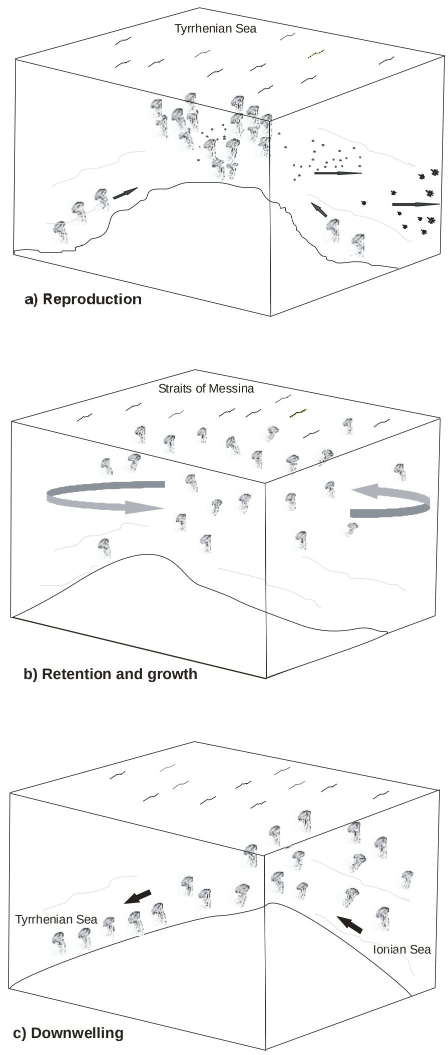

Figure 2.Model of the biological cycle of *Pelagia noctiluca* in the Strait of Messina and the surrounding Tyrrhenian area. (a) Jellyfish coming from the Strait of Messina, reach the Aeolian Island area in late winter-spring, concentrating over a shoal near Panarea Island. Hundreds of specimens assume a “mushroom” shape, where they are each on another to enhance the success of sexual reproduction. A cloud of planulae is produced; (b) in late spring-early summer small jellyfish reach the Strait were they remain for about three-four months during which they get fat [5]; (c) by early autumn the specimens move towards deep Tyrrhenian Sea to overwinter, with a autumnal downwelling transport, to reach then the Aeolian Archipelago for reproduction period.

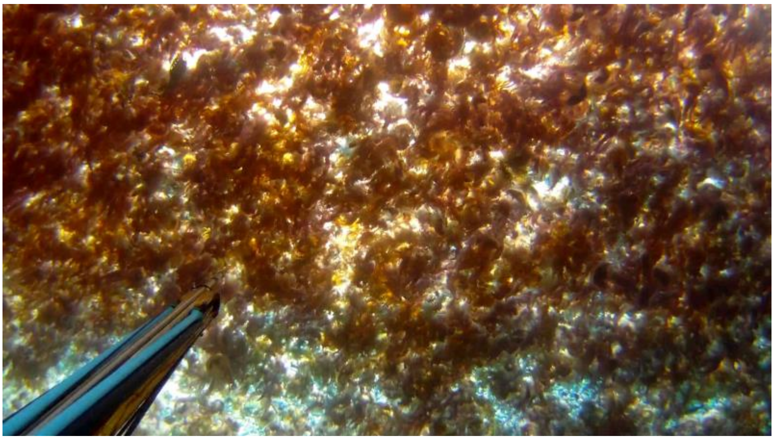

Figure 3.Dense swarm of *Pelagia noctiluca* at Filicudi Island (Aeolian Archipelago) on April 2015 (picture by Dario Lopes).

Reproduction

Data on *in situ* visual observations on *P. noctiluca* spawning are lacking in the scientific literature, but extensive reports and shocking videos and pictures are produced by spear-fishermen who reported that such blooms occur regularly since at least 10 years in the Aeolian Archipelago (Dario Lopes, personal communication) (Figure 3).

Laboratory experiments provided information on the holoplanktonic cycle of *Pelagia*, with notes on larval sizes and times of development from eggs to juveniles [6, 50].

In the framework of the Meteomedusa project, between 2013 and 2015, particular attention was given to monitor the offshore waters of the Aeolian Islands Basin. The fishermen Nino and Giuseppe Donato carried out on boat visual observation every three days, and reported on *P. noctiluca* outbreaks in "spawning formation." A total of 840 observations were registered in all seasons and two "reproduction occasions," with the column like "spawning formation" were detected: 8 June 2013 and 13 June 2014. The two cases were observed about 2 miles off the little rocky island "Lisca Bianca" in the vicinity of Panarea Island. On a shoal with 30 m bottom depth, mature *P. noctiluca* specimens with 5-6 cm bell diameter, moving from deeper layers, were observed positioned on a sub-superficial layer (10-20 m depth), assuming a big figure like a "mushroom" formed by hundreds of individuals (Figure 2a). This peculiar aggregation can represent a shield to external disturbances, as can be the currents. Male and female white in colour specimens were positioned on each other, as already described by Canepa et al. [14], most probably to minimize the loss of sperms that must fertilize the released eggs. A big amount of planulae was produced, that became ephyrae in 48-h. Probably the spawning position is maintained for about 2-3 days, since the white colour of the specimens may indicate that they had spawned already. Furthermore, the presence of ephyrae in June 2013 and 2014 observations may indicate that reproduction occurred about 5-7 days before.

Large aggregations of medusae in spawning phase, for the presence of planulae and ephyrae, were observed and filmed in the water around Filicudi Island as early as in February (http://www.youtube.com/watch?v=wXvKVGrBpuI;https://www.youtube.com/watch?v=D9Htbe4LGnU), by the diver Dario Lopes.

These findings may suggest that *P. noctiluca* reproduces in late winter-spring, about from February to June, and that the Aeolian Islands Basin is a spawning and nursery area for *Pelagia*.

The Aeolian Archipelago is a spawning and nursery area also for many pelagic and coastal fishes [51, 52], as well as for the small pelagic fish *Engraulis encrasicolus* and *Sardinella aurita*. These events coincide with the highest abundance of *P. noctiluca* and a match of ephyra production with a great abundance of fish eggs and larvae might provide optimal conditions for the success of *Pelagia* reproduction [27, 53].

The upwelled jellyfish that emerge in the Aeolian Archipelago produce a new cohort that is dispersed by the main horizontal currents. In the Southern Tyrrhenian Sea, a surface jet of Modified Atlantic Water (MAW) flows eastward parallel to the Sicilian coast, forming a wide cyclonic eddy [54] that continues northward along the Italian peninsula. An overall picture of the Aeolian Island Basin circulation can be deduced by integrating information from atlases and charts of surface currents [55], geostrophic computations of hydrographic datasets [56] and more recent estimates from satellite data and modeling approaches [e.g., 57, 58] (Figure 4). A cyclonic sub-cell (centered at 15.5°E 38.5°N, Figure 10 Rio et al. [57]) calls MAW waters of the main wide eddy to enter from North West in the Aeolian Island Basin and flow south-eastward towards the coasts of Sicily and the Strait of Messina (Figure 4a).

Mean estimated currents reach 5 cm s^{-1} so that a quasi-passive displacement of 50-70 nautical miles from the spawning sites to cross the Aeolian Basin can take in this case up to 20-30 days. In this circulation system, young specimens of *P. noctiluca*, born in late winter-spring, are expected to reach the Strait in late spring-early summer, not before the age of one month (20-30 mm bell diameter).

Since the surface flow of the MAW along the northern coast of Sicily exhibits a clear time variability reaching higher speed in winter and spring, due to wind forcing, compared with summer-autumn [59], this could results in the formation of a large clock-wise recirculation area in the Aeolian Island Basin that temporarily reverse the circulation especially during winter months (e.g., January) (Figure 4b). As a consequence, the water firstly flows northeastward, to the Calabrian coasts, and then towards the Strait: in such case the travel from the spawning sites could almost double in length and last 40-50 days. Young specimens born in late winter are expected to reach the Straits in late spring, at the age of two months (20-30 mm bell diameter), instead specimens born in late spring (June) are expected to reach the Straits in July, at the age of one month with similar bell diameter. Temperature patterns can justify why *P. noctiluca* specimens show the same bell diameter in late spring-summer when entering the Strait. Lower water temperatures delay growth, so the specimens born in the first part of the reproduction period, take twice the time to enter in the Strait, but in any case show the same bell diameter (20-30 mm) of specimens born afterwards. Temperature directly influences also planula growth: at 14°C planulae take twice the time to reach the ephyra stage than at 23°C (5 and 2 days, respectively) [6, 14, 60].

In the Aeolian Island Basin in early summer [61] a clear thermocline can be noted in the upper (0-50m) layer where the temperature decreases from values above 27.5°C at the surface to values in the range 26-15°C in the 10-50 m layer. In late autumn (POR MARE 2 cruise, November 2006) the temperatures east of Capo Milazzo are in the range 20-21°C in the 0-50 m layer (warmer than surface waters influenced by MAW) with salinity always above 38.2

indicating a presence of Tyrrhenian Intermediate Waters in the 20-200 m layer: the influence of the ebbing fluxes from the Strait of Messina is more relevant and pulses of Intermediate Ionian Waters upwelled in the Strait downlift in the Aeolian Basin due to lack of buoyancy.

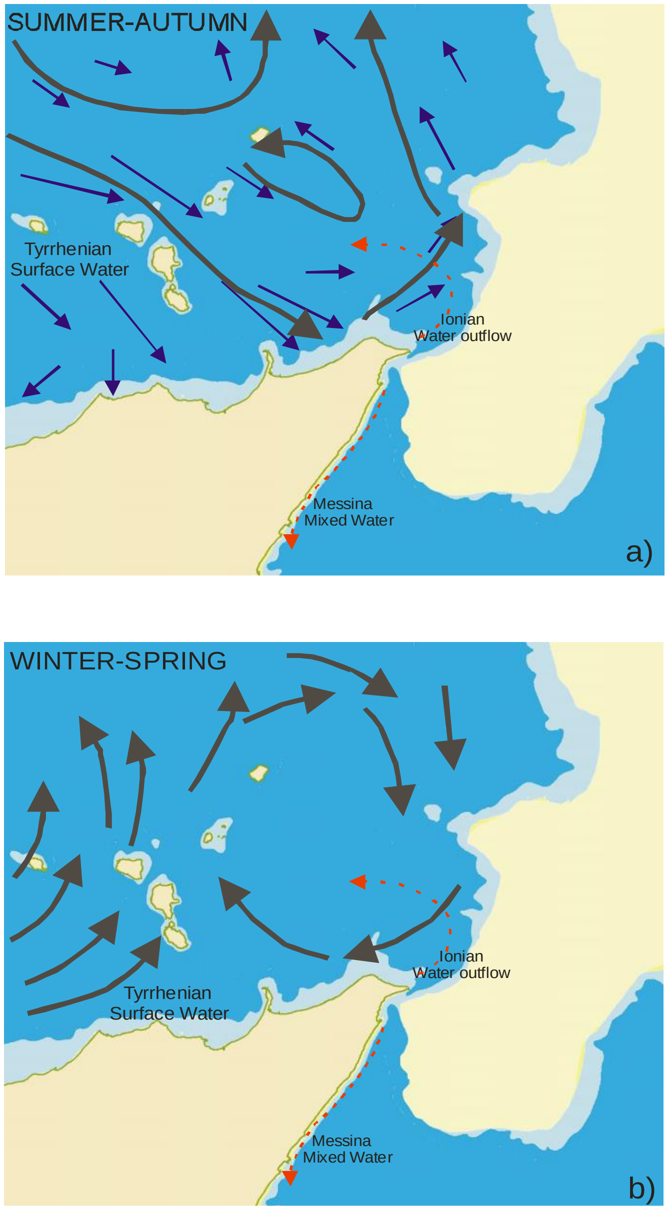

Figure 4.Overall picture of the general surface circulation features in the Aeolian Archipelago (South-Eastern Tyrrhenian Sea) and the adjacent Strait of Messina. The main paths of the relevant water masses is sketched in two seasonal configurations - a) Summer-Autumn conditions and b) Winter-Spring conditions.

Retention and Growth

P. noctiluca distribution and abundance in the Strait of Messina were defined by visual observations at two coastal stations between 2007 and 2011 (by a total of about 1000 records, [6]). Medusae of 20-30 mm (no recognizable sex), continuously coming from Aeolian Islands by late spring until summer, enter from the north side of the Strait carried by the N-S current. They are concentrated mainly near the Sicilian coastline and are transported towards the Ionian Sea. When the current reverses to S-N, the jellyfish occupy the central part of the Strait and the Calabrian coastline. Large blooms were observed mainly during N-S current regimes.

Overall, within the surface layer, there is a net flow from the Tyrrhenian towards the Ionian Sea, mostly along the Calabrian coast. Likewise, plankton specimens entering the Strait from the Tyrrhenian Sea remain trapped within the area for long time, due to the back and forth of the tide movements and are often stranded along the shores due to winds. Furthermore, during the summer, upwelling events are more relevant, enriching surface waters, producing favourable conditions for medusa growth.

This transport and retention of *Pelagia* inside the Strait of Messina (Figure 2b), goes on for the whole summer, when specimens become ripe, reaching a bell diameter of 50-70 mm. This size class is always present during summer season. Field observation and modeling [1] indicated that *P. noctiluca* population in such local blooms is halved in the period of one year and the population cannot sustain itself without continuous inflow of new individuals by neighbouring water masses, as reported for the Adriatic sea. In October ripe female specimens increased in size (63-77%) and bell diameter reached 102-124 mm (0.28-0.30 mm d^{-1}).

A recent wavelet analysis of a 200-year time series, showed that *P. noctiluca* can persist in the Mediterranean Sea at some source regions and occasional hydro-climatic events allow source population size to increase greatly and to be advected into neighbouring coastal regions [62]. In these high productive habitats [63], growth and reproduction of *P. noctiluca* are faster [64, 65], resulting in local blooms.

By late spring until summer, together with the young specimens coming from spawning ground, larger (more than 120 mm) spent specimens enter the Strait, and thereafter disappear, together with the smallest ones that are grown to larger sizes. As a result, at the end of summer, medium-sized jellyfish (50-70 mm) become mature and their abundance has increased.

Figure 5 shows the temperature data during a year recorded at 20 m depth by a fixed platform, in front of Ganzirri beach along Sicilian coastline. During summer strong and rapid fluctuations (up to 13°C) are induced by the two tidal conditions, whereas in winter, even if the tidal movements are active, the differences are in the order of less than 1°C.

Pelagia was observed both during northward and southward flow [6], indicating that medusa specimens are transported daily along coastal and pelagic waters of the Strait, drawn in superficial eddies, caused by the meeting of different water masses, and finally driven to the shore by the waves and particularly S-E wind that lead to exceptional dense patches of medusae [6]. Currieri [66, 67] and Marini [68] already noted accumulation of plankton in some zone of the Strait on account of coastal counter-currents.

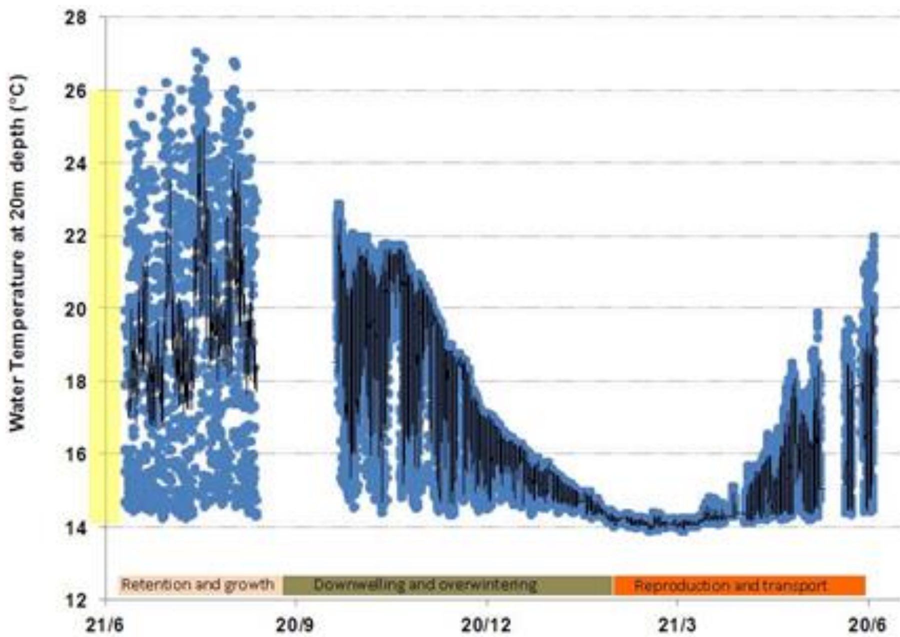

Figure 5.Ganzirri Beach (Sicily coast): Seasonal trend of water temperature at 20 m of depth as recorded by an automatic fixed platform. On the x axis the three phases of the *P. noctiluca* cycle in the area of the Strait are highlighted. On the y axis the optimal range for its growing is indicated.

Figure 6 shows the regional distribution of *Pelagia* abundance observed by visual census during 2015. Most of the observations were done along the Sicilian coast of the Strait and its northern exit.

Individual biomass growth was very fast and occurred just in two or three months. Mean growth rates were 0.73 g d^{-1} in January-March, 1.13 g d^{-1} in March-April and 0.98 g d^{-1} in April-May. These high growth rates and high biomass values are linked to a short and efficient food chain [69]. The mixing of poor Tyrrhenian surface waters with rich Ionian deep waters causes a remarkable increase in primary production (204 mgC m^{-2} d^{-1} in March), at least ten times higher in respect to the waters outside the Strait [70, 71].

Downwelling

In summer, in the upper 30 m layer of Tyrrhenian waters *Pelagia* medusae that entered with the N-S currents, come back in the Tyrrhenian Sea along the Sicilian coast, during the subsequent S-N currents.

In the layer below 30 m depth, where denser Ionian waters, once crossed the sill, invade the Tyrrhenian basin and go down up to 200-300 m depth, at the end of summer, seasonal mechanisms such as the breaking of internal waves generated in the Strait [72] can entrain surface water towards deeper layers and favor the sinking of marine organisms such as jellyfish [14] (Figure 7). In this way plankton specimens, driven from the Ionian current, continually enrich the deeper southern Tyrrhenian layers. Lohman [73, 74] reported that the Strait had a great influence on the spatial and vertical distribution of plankton. Many species were subjected (a) firstly to a passive transport from Ionian deeper strata to surface water in the divergence area and (b) to a downwelling from Ionian to deeper layers of Tyrrhenian Sea, along the Ganzirri-P. Pezzo sill.

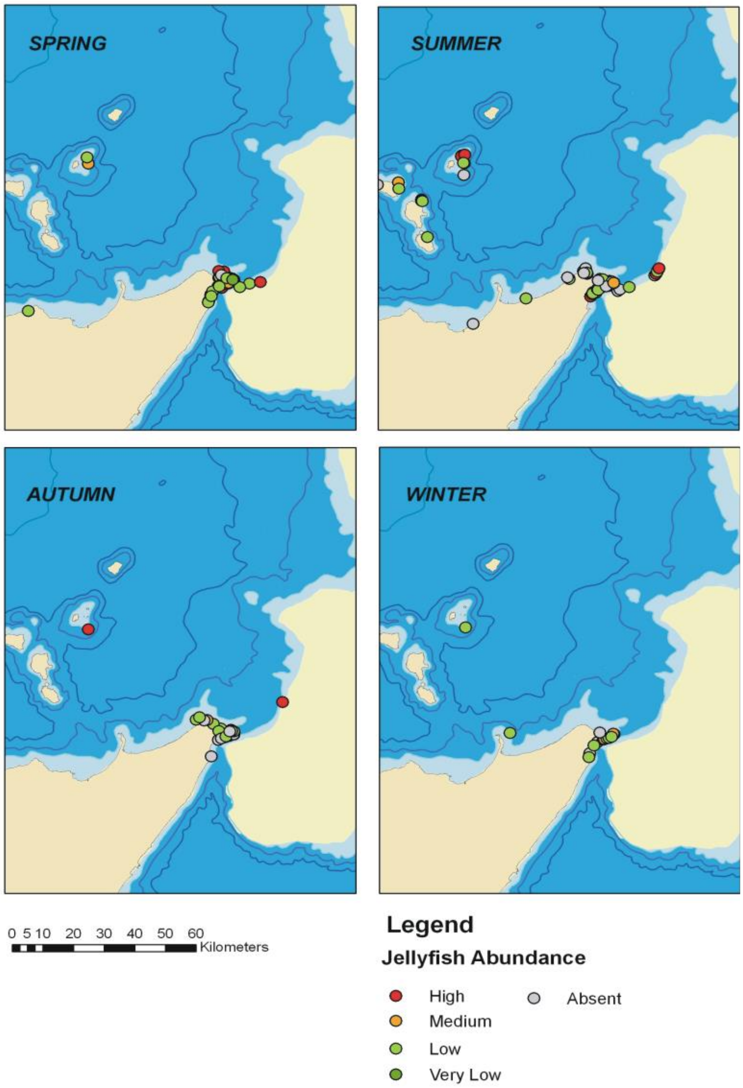

Figure 6.Spatial distribution of *Pelagia noctiluca* seasonal occurrences in the region of the Messina Strait and the adjacent Aeolian Basin in the Tyrrhenian Sea. Records refer to specimens observed by visual census activities carried out in the period March-December 2015. Surface presence/absence of jellyfishes were qualitatively subdivided in five classes.

P. noctiluca seems to follow the same autumnal transport model from surface Ionian waters to deeper Tyrrhenian ones (Figure 2c) where they overwinter before reaching the suggested spawning ground in the Aeolian Archipelago. As already suggested by Canepa et al. [14], *P. noctiluca* during the downwelling transport, seems overlap to the euphausiid vertical distribution, that occupy in the Aeolian Archipelago the mesopelagic layer between 200 and 600 m, representing a suitable food source [75].

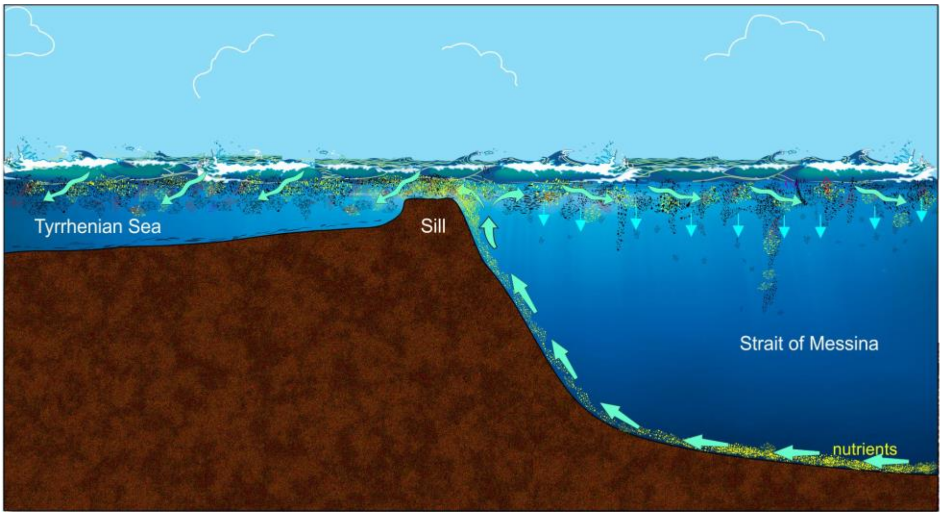

Figure 7.Schematic drawn of up- and down-welling phenomena in the Strait of Messina.

CONCLUSION

The Strait of Messina is certainly a focal area for the biological cycle of *Pelagia noctiluca* in the Western Mediterranean Sea. By means of data sets and available literature, we can suggest a possible conceptual model that outlines the biological cycle of *P. noctiluca* with hydrodynamic and geomorphological features in the Strait of Messina (Figure 8).

P. noctiluca reproduces for quite a long period, from late winter to late spring in the Aeolian Island Archipelago. From late spring to early summer, currents transport newly produced young individuals eastwards, towards the Strait. A part of the new cohort disperses to Calabrian coastline and northwards. Some discolored and empty females can be visible during summer in the Strait, because they move along with the young jellyfish after the reproduction, only to die or be dispersed towards the Ionian basin. Most adult jellyfish die after the early spring spawning.

The Strait of Messina ecosystem is not a suitable reproduction area, because its intense hydrodynamism would lead to low reproductive success due to gamete dispersion. This area instead, is an optimal site for growth due to its intensive primary and secondary production and hence of food availability, but also due to an optimal temperature range, lower in summer and higher in winter in respect to the surrounding basins.

Pelagia remains all the summer inside the Strait, showing in three-four months a high increase in bell diameter and biomass. Subsequently, in late summer-early autumn, the mature specimens, taking advantage of a typical autumnal downwelling transport, move to deep Tyrrhenian waters where overwinter until to upwell in the Aeolian Archipelago by late winter-early spring.

The annual cycle of *Pelagia noctiluca* in the Strait of Messina and in the South-Eastern Tyrrhenian Sea can be summarized as follows:

a) Late-winter to the whole spring (February to June): reproduction in the Aeolian Basin (no available observation of planulae and ephyrae in the Strait), then in time of one-two months, young cohorts (about 20-30 mm bell diameter) continuously reach the Strait.

b) Summer: retention and growth in the Strait of Messina, where *P. noctiluca* can benefit of the favourable conditions (optimal temperature, food availability); specimens reach 50-70 mm of bell diameter in three-four months from their arrival.

c) Late summer-early autumn (September-October): mature specimens exit the Strait, autumnal downwelling currents bring them to the deep layers of the Tyrrhenian sea where they overwinter before moving to the spawning sites and restart the cycle.

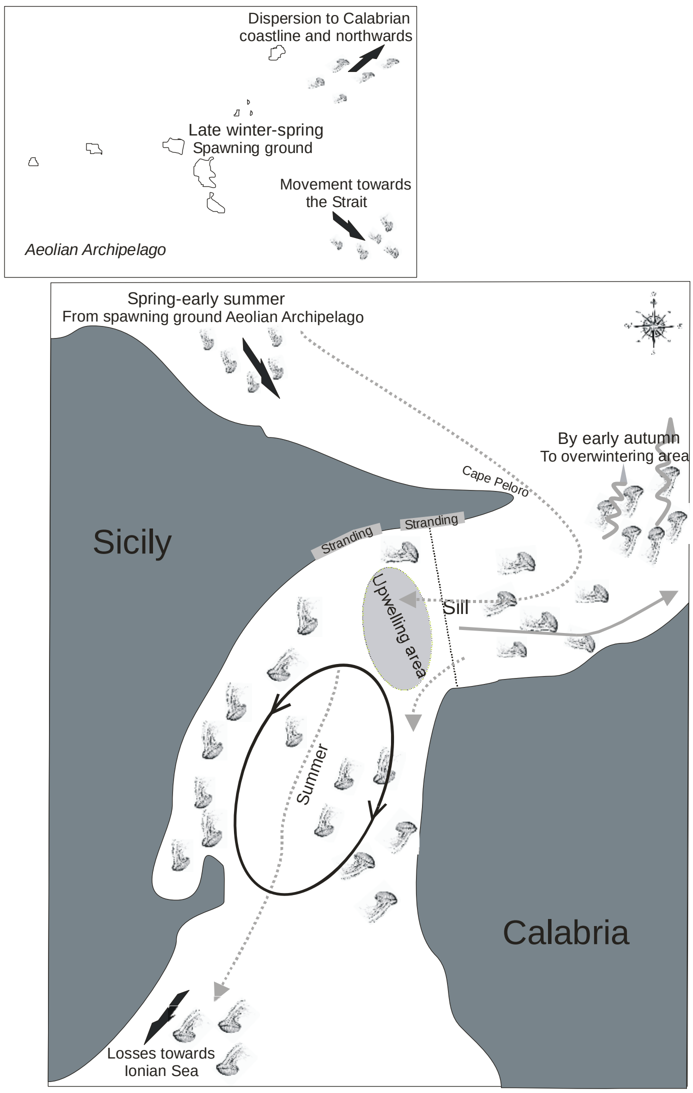

Figure 8.Conceptual model of *Pelagia noctiluca* biological cycle interacting with hydrodinamic features in the Strait of Messina (solid black arrows: jellyfish movements; dotted grey arrows: surface currents; solid grey arrows: downwelling transport).

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