Dynamics of production and mortality of *Aurelia aurita* in Thau Lagoon, Northwestern Mediterranean.

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Abstract

Aurelia aurita ecology is well known. However, critical periods of its life cycle have been overlooked, such as polyps, which are crucial in shaping blooms intensity. Thau lagoon, a coastal lagoon in Northwestern Mediterranean, offers an ideal framework to investigate the life cycle of the species. Here we study the benthic and pelagic dynamics of *A. aurita* in Thau lagoon over a 4-year period, focusing on the sources of population growth and mortality. Field surveys were conducted to assess benthic population distribution, settlement surfaces, density and budding. Pelagic abundances and growth were also monitored. Mortality was assessed by complementary methods consisting in molecular analysis of fish gut contents and predation experiments using *Sparus aurata*. The results of this study show that the dynamics of the species is mainly shaped by temperature, while the benthic phase further benefits from habitat modification. *In situ*, *Sarpa salpa* was confirmed as a predator of *A. aurita*, while in laboratory *S. aurata* consumed all development stages. However, selectivity experiments demonstrated that high quality preys were preferred. Overall, these results shed light on driving factors shaping jellyfish blooms and contribute to the mounting acknowledgment that jellyfish are not dead end in food webs.

Introduction

Pelagic-benthic life-cycle of *Aurelia aurita* is complex and polyp is acknowledged fundamental in bloom onset (Duarte *et al.*, 2012), although field investigations remain scarce. Settlement of planulae is one of the most important processes that influence the establishment of a benthic population. Coastal constructions seems to provide suitable settlement surfaces, enhancing the population of polyps and consequently jellyfish outbreaks (Duarte *et al.*, 2012). Dynamics of *A. aurita* population are highly variable over time and space (Lucas, 2001), supporting the need for further local to regional level studies. When addressing population dynamics, mortality is an important process controlling the abundance of populations (Lucas, 2001). The knowledge of the impact of fish predation on jellyfish is still poorly assessed. However it has been attracting the scientific interest (Milisenda *et al.*, 2014).

Materials and Methods

Thau lagoon is a semi-enclosed system in the south coast of France, with a mean depth of 4m. The entire Thau lagoon was surveyed by free diving in order to assess distribution and settling substrate types of polyps population. Population density and colony density were monitored by underwater picture analysis and budding was assessed by sample analysis. A plankton sampling program was carried out every two weeks for four years. *A. aurita* ephyrae and medusae abundances as well as bell diameter were determined, along with several environmental variables. To assess *A. aurita* mortality, fish gut contents of wild fishes were analysed by PCR determining potential fish predators. This approach was further complemented by laboratory experiments on fish feeding rates and selectivity of *Sparus aurata* on different development stages of *A. aurita*.

Results

A. aurita polyps populations were found over the entire Thau lagoon, where hard substrates were available. The substrate type was essentially artificial and larger colonies were found closer to highly constructed areas. Population density increased over time and was significantly influenced mainly by temperature. Colony density and proportion of budding were not affected by any environmental variable studied. However, both biological variables were correlated with each other. Ephyrae were present in the lagoon during winter months growing to adult stage during spring. Medusae blooms occurred between May and June collapsing afterwards. Pelagic stages were absent until the end of autumn. Temperature and salinity seems to be the driving forces of pelagic dynamics. PCR results demonstrated that only *Sarpa salpa* presented *A. aurita* genomic DNA in their stomach contents. Though, in laboratory, *S. aurata* demonstrated predatory activity over both benthic and pelagic stages. Among *A. aurita* prey items, medusae with 1cm bell diameter were the most consumed and ingestion rate increased with higher prey availability. However, selectivity experiments revealed an equal or higher preference for *Artemia* when compared with ephyrae or polyps.

Discussion

Thau lagoon offers a suitable large scale laboratory to study the dynamics of *A. aurita* population. Our study reveals that the benthic population might have been enhanced by habitat modification, benefiting from the availability of suitable artificial settling surfaces (Duarte *et al.*, 2012). Both benthic and pelagic dynamics were primarily driven by temperature, as reported by other authors (*e.g.* Willcox *et al.*, 2008). When assessing *A. aurita* as a potential source of food for fish community of Thau lagoon, our results demonstrate that jellyfish are not dead ends of the food web. *A. aurita* was shown to be actively consumed *in situ* by *S. salpa* and the diversity of predators is possibly underestimated. In laboratory, all life stages of *A. aurita* were proven to be a potentially source of prey for *S. aurata*, especially medium size medusae (Ø1-4cm). Additionally, higher prey concentration enhanced *S. aurata* ingestion rates. Since *A. aurita* occurs in blooms, high concentrations of this organism may compensate for the low nutritional value. Fishes may satisfy their energy requirements within a very small area preventing energy waste in foraging and capture behaviour (Cardona *et al.*, 2012). Nevertheless, selectivity experiments revealed that as long as high quality prey items were available, *A. aurita* was not preferentially consumed. Still, in the light of the reduction of zooplankton abundance as a possible consequence of jellyfish blooms, gelatinous organisms may gain importance as a complement in fish diets (Milisenda *et al.*, 2014). Thus, as stressed by Purcell and Arai (2001), predation by several fish species with broad diets may be more ecologically important than predation by relatively few specialized gelatinous predators. Although fish predation impact on *A. aurita* populations was not quantified, our results highlight the potential ecological importance of jellyfish, not only as competitor for food resources but also as a source of energy for higher trophic levels.

References

Cardona, L., Álvarez de Quevedo, I., Borrell, A., and Aguilar, A. 2012. Massive consumption of gelatinous plankton by Mediterranean apex predators. PloS one, 7: e31329.

Duarte, C. M., Pitt, K. a, Lucas, C. H., Purcell, J. E., Uye, S., Robinson, K., Brotz, L., *et al.* 2012. Is global ocean sprawl a cause of jellyfish blooms? Frontiers in Ecology and the Environment, 11: 91–97.

Lucas, C. H. 2001. Reproduction and life history strategies of the common jellyfish , *Aurelia aurita* , in relation to its ambient environment. Hydrobiologia, 451: 229–246.

Milisenda, G., Rosa, S., Fuentes, V. L., Boero, F., Guglielmo, L., Purcell, J. E., and Piraino, S. 2014. Jellyfish as prey: frequency of predation and selective foraging of *Boops boops* (Vertebrata, Actinopterygii) on the mauve stinger *Pelagia noctiluca* (Cnidaria, Scyphozoa). PloS one, 9: e94600.

Purcell, J. E., and Arai, M. N. 2001. Interactions of pelagic cnidarians and ctenophores with fish : a review. Hydrobiologia, 451: 27–44.

Willcox, S., Moltschaniwskyj, N. a., and Crawford, C. M. 2008. Population dynamics of natural colonies of *Aurelia sp.* scyphistomae in Tasmania, Australia. Marine Biology, 154: 661–670.