Research Notes…

Spiny Lobster (*Panulirus sp.)* Life Cycle – a review and fisheries management implications

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Abstract

The fishery for spiny lobster around the inner granitic islands of the Seychelles has been closed for two consecutive years (2017-2019). Declining trends in indicators of abundance and the loss of coral reef habitats led to the SeyCCAT funded lobster project, aimed at establishing a science-based restoration of commercially important spiny lobster habitats to help develop a sustainable fishery – a project partnership between the University of Seychelles (UniSey), the Seychelles Fishing Authority (SFA), and the Marine Conservation Society Seychelles (MCSS). Spiny lobsters have a complex mero-planktonic lifecycle from a larva living in the open sea to an adult living on the sea floor. The management of the fishery requires a good understanding on all the stages of the spiny lobster life cycle. In this context, the objective of this paper is to provide a short review of the spiny lobster (*Panulirus sp.*) life cycle and the ecological and fisheries management implications.

Introduction (a Seychelles perspective)

Spiny lobsters (Palinuridae) are one of the most valuable commercial seafood species globally; for example in Australia, lobster is the country's most valuable fishery in terms of both overall production and value of export, with a Gross Value of Production of $610 million AUD in 2014 (Plagányi et al., 2018). The FAO annual catch data of spiny (Palinuridae) and clawed (Nephropidae) lobsters has been steadily increasing over the past few decades and the 2017 global catch estimate was 315,469 t (FAO, 2019). Unlike the global trend, Seychelles' lobster fishery catch has decreased over the past decade, with some of the major challenges being limited recruitment, poaching, and rapid ecosystem change, such as the loss of coral reef habitats due to coral bleaching events.

In Seychelles the targeted spiny lobster species are: Oumar gro Latet (*Panulirus penicillatus),* Oumar Rouz (*Panulirus longipes),* Oumar Ver (*Panulirus versicolor)* and Oumar Blan (*Panulirus*

ornatus) (SFA, 1991). The fishery is managed and regulated by the Seychelles Fisheries Authority (SFA). Management measures include: limited number of fishing licences, minimum size limit, a defined fishing season and sometimes temporal closure of the fishery (SFA, 1991; 1995; 2002). The Seychelles spiny lobster fishery was closed for the first time in 1983 as a management measure to limit the risk of overexploitation, although no research or further monitoring was conducted during the several years of closure (SFA, 1991). The fishery was re-opened in 1989 for a five-month period with a strict condition of selling all catch to the Seychelles Marketing Board (SMB), presently the Seychelles Trading Company (STC). This regulation was aimed at gathering biological data on the catch, however there were numerous unregulated sales to hotels and restaurants, which led to the complete closure of the fishery until 1992 when a long-term fishery independent monitoring survey was established (SFA, 2002). This long-term monitoring program permitted SFA to gather robust data on the status of the population and verify the trends in population indicators to apply objective management measures for the subsequent fisheries season. The landed catch shows variability among the years with a maximum of 11 mt in 2011 (Figure 1). In 2014, the season was opened for one month and 609 kilograms of lobster were caught (Figure 1).
Since then, declining trends in population indicators e.g. total catch, catch per unit effort (CPUE), and the size of females from the main fishing locations have been observed (Figure 2: SFA, 2019). This led to a project partnership between the University of Seychelles (UniSey), the Seychelles Fishing Authority, and the Marine Conservation Society Seychelles (MCSS) aimed at establishing a science-based restoration of commercially important spiny lobster habitats to help develop a sustainable fishery. The project was funded by the Seychelles Climate Change Adaptation Trust (SeyCCAT).

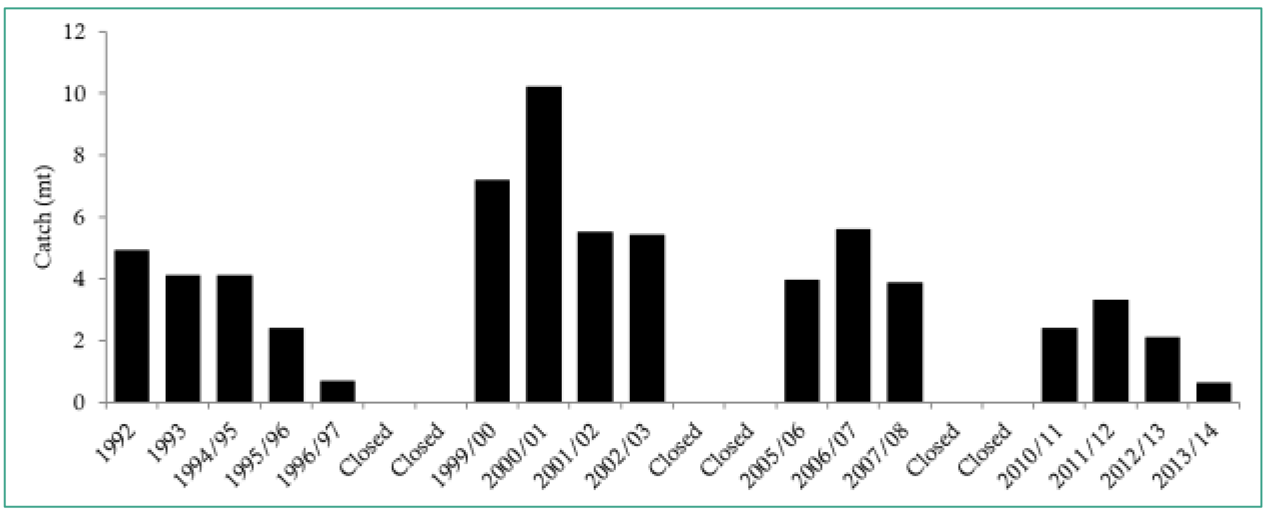

Figure 1. The total catch in Spiny lobster (Panulirus sp.) in the Seychelles from 1992 to 2014
Source: Seychelles Fishing Authority, unpublished data

The sustainability of a fishery relies on the ability to make good, science-based decisions. Spiny lobsters have a complex mero-planktonic lifecycle from a larva living in the open sea (pelagic) to an adult living on the sea floor (benthic), growing by successive moulting. The management of the fishery requires a good understanding, and in some cases specific information, on all the stages of the spiny lobster life cycle. In this context, the objective of this paper is to provide a short review of the spiny lobster life cycle and its ecological and fisheries management implications.

Reproduction

The reproduction strategy of the spiny lobster (*Panulirus sp.*) is adapted to a higly variable environement: a high fecundity with a low survival of the progeny. Tropical panlinurid lobster present sexual dimorphism (i.e. separate sexes) and they can reproduce year-round with rapid and repetitive brood cycle (Quackenbush, 1994; Pollock, 1997). The size of the females has a significant influence on the total numbers of broods per year and the quantity of eggs produced: they can lay 800 eggs per g of body weight to more than 2 million eggs per female (Quackenbush, 1994; Chávez, 2019). During mating, the male deposits a capsule or mass containing spermatozoa, called the spermatophore, on the belly of the female, from which the eggs are fertilized externally (Phillips et al., 2013). Mating in some species of spiny lobster occurs after the female moults, as the moult provides her fresh hair-like structures on the abdominal swimming legs (pleopods) for the attachment of eggs (Kittaka and MacDiarmid, 1994). After being extruded from the ovary and fertilized, the eggs are adhered to the filaments of the female's pleopods where they are carried until spawning.

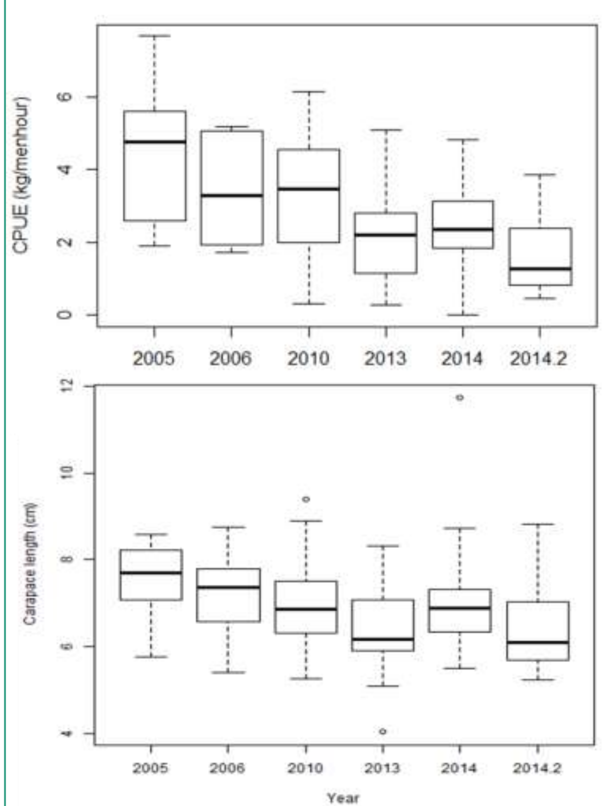

Figure 2. Catch per unit effort and P. penicellatus female carapace length from 2005 to 2014 surveys
Source: Seychelles Fishing Authority, unpublished data

Spawning varies between location and year due to environmental cues such as photoperiod (the period of day to night) and water temperature (Sachlikidis et al., 2005). In Seychelles, as the variability of the photoperiod over the year is constant, we can hypothesise that water temperature is the major factor controlling spiny lobster reproduction. This hypothesis has been demonstrated in other locations: within the temperate-subtropical environment of the

California’s ecosystem, where warmer temperatures during El Niño periods significantly accelerated breeding in *P. interruptus* while the contrary happened with cold La Niña (Velázquez, 2003); and within the tropical ecosystem of South Taiwan coastal water, where the presence of highly reproductive females and repetitive spawning of *P. penicillatus* were linked to higher water temperature (Chang et al., 2007).

Metamorphosis and early-life stage

The newly hatched spiny lobster larva is known as a phyllosoma larva (Figures 3 and 4). This first-stage phyllosoma larva is adapted to drifting in the water column: the body is dorso-ventrally compressed and has well-formed multispinose appendages. Total phyllosoma duration in the natural environment is long and can vary between 8 and 11 months, during which the phyllosoma larvae develop through a number of stages. For example, the larval duration of reared spiny lobster fluctuate from 244 to 296 days with ten larval stages for *P. penicillatus* (Matsuda et al., 2006) and *P. longipes* (Matsuda and Yamakawa, 2000).

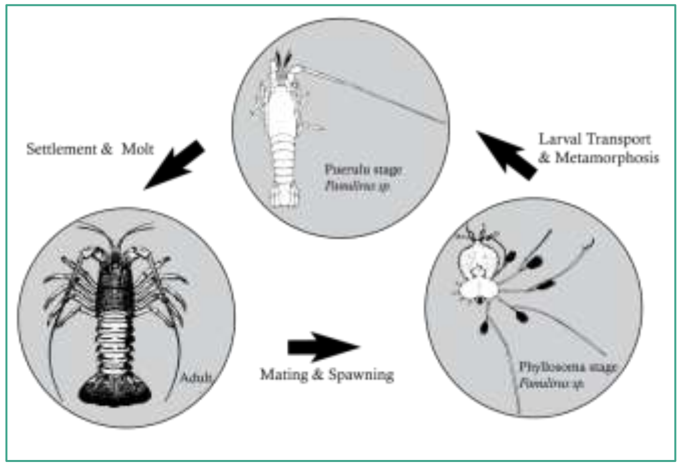

Figure 3. Spiny lobster schematic lifecycle. **Adapted from: Matsuda and Yamakawa (2000)**

The coastal settlement behaviour and benthic phase appear after metamorphosis. Metamorphosis involves a set of physiological, morphological and behavioural transformations. The pelagic, fast-swimming phyllosoma transforms into a benthic puerulus stage (Herrnkind, 1986). This shift from a pelagic to a benthic lifecycle is associated with a strong habitat selection. The pueruli settlement behaviors can result from a complex combination of stimuli such as salinity, turbidity, nutrients, tidal energy and currents (Priyambodo et al., 2017). Habitat selection by puerulus is strongly influenced by the three-dimensional structure and architectural complexity of the seabed and they have often been found sheltering in rock crevices or holes on the reefs overgrown with macroalgae and/or seagrasses (Herrnkind, 1986; Dennis et al., 1997). Moreover, the study from Priyambodo et al. (2015) suggests that both *P. ornatus* and *P. homarus* are most likely to settle at depths between 5 and 17 m. In terms of size, the total body length (BL) of the puerulus collected in the wild ranged from 26.0 to 29.3 mm while cultured pueruli ranged in BL from 20.30 to 23.08 mm (Matsuda et al., 2006).

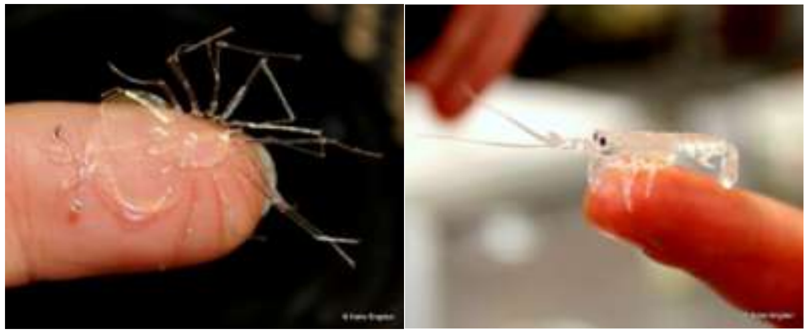

Figure 4. Phyllosoma (left) and Pueruli (right). **Source: Rachel Bridgen, SAERI, 2018**

Larval dispersion and genetic structure

Spiny lobster's larval dispersal refers to the spread of phyllosoma larvae from a spawning source to a settlement site as a puerulus post-larvae. When larvae are released in the water column, they may remain within the water parcel that overlies the adult habitat, or they may be introduced into a different water layer and get distributed by currents. As the spiny lobster has a long-living pelagic larva the probability of being distributed by ocean currents is high and contributes to the large dispersion of these species (Booth and Phillips, 1994). These findings highlight the following problem: does the spiny lobster fished in the Seychelles come from the Seychelles stock?

In terms of genetic structure, the reconstruction of a phylogenetic tree of *P. versicolor* from Indonesian waters with several areas in the Indian Ocean exhibited close kinship between regions by forming a large clade (Pranata et al., 2018). Specifically, Pranata et al. (2018) showed that the *P. versicolor* population between Lombok and Sri Lanka formed a monophyletic clade without genetic structure differences. At larger scales in the Pacific, the *P. penicillatus* lobster population from the Central Pacific forms a monophyletic clade with populations in the Western Pacific (Chow et al., 2011). Similar results were found by Abdullah et al. (2014) for *P. penicillatus* lobster populations from Aceh, Java, Maldives and Madagascar, where no genetic differences in phylogenetic trees were found. As such, we can hypothesize that all *Panulirus sp.* lobster in the Seychelles likely belong to a single unique population in the Indian Ocean, however this hypothesis still needs to be tested.

At the Indian Ocean scale, the Seychelles are influenced by diverse currents and counter currents, forming the northern Indian Ocean gyre. Moreover, the circulation pattern changes with the seasonal monsoons (Schott et al., 2009). During the Southeast trade winds the Northeast and Southeast Madagascar Current (NEMC and SEMC) create the East African Coastal Current (EACC) which influences the Seychelles. During the Northwest tradewinds the South Equatorial Countercurrent (SECC) is the most important circulation pattern. This large-scale ocean circulation might influence the retention and transport of phyllosomas from East Africa to Seychelles and at a larger scale from the Eastern Indian Ocean (Australia and Indonesia) to the Western Indian Ocean. Meso-scale and small-scale ocean circulation data, linked to larva behavior in such oceanographic features, is crucial to fully understand the spatial and temporal patterns of puerulus settlement and recruitment in the region.

Fisheries management implications

The gap in knowledge on the ecology of spiny lobster populations must be fulfilled and a clear understanding of the factors influencing recruitment is necessary for proper fisheries management. Several countries such as Australia, New Zealand, United States, Mexico, Japan, India and Cuba have developed a puerulus settlement monitoring program to predict recruitment and fishery performance (Phillips and Booth, 1994; Cruz and Bertelsen, 2009; Forman et al., 2013; Plagányi et al., 2018). The program in New Zealand shows significant correlations between the level of settlement and the fishery catch per unit effort for most fishery areas (Forman et al., 2013). Moreover, the puerulus settlement index from Bicheno, on the northeast coast of Tasmania is significantly correlated to commercial catch rates, with a lag of 5 years (Gardner et al., 2001). In Seychelles, a puerulus settlement index could make a valuable contribution to the sustainable management of lobster fisheries by providing advanced indication of fluctuations in recruitment and for the potential development of a mariculture industry.

Spiny lobster mariculture is well developed in Indonesia, Vietnam and Australia. In Indonesia and Vietnam, lobster farming utilises the wild populations for seed. Without proper data on the variability of pueruli settlement, the annual removal of 1–2 million pueruli by fishers in Vietnam can significantly impact the demography of the species, particularly that of adult populations (Jones et al., 2010). On the other hand, Australia has already taken the path of spiny lobster aquaculture independent of wild populations, involving hatchery production from first egg fertilisation (IMAS, 2019). However, this kind of mass aquaculture production requires high investment in technology innovation, infrastructure and capacity building.

In a changing ocean, temperature variability can affect all parts of the spiny lobster life cycle and its coral reef habitat, particularly during anomalous conditions associated with El Niño events (Harris et al., 2014; Gudka et al., 2018). In this context, *in situ* temperature data should be taken into account as a management indicator. This indicator can help the sustainability of the fisheries by including the climatic variability in its management and loss of associated coral reef habitat.

Conclusion

The SeyCATT funded Lobster project will gather new data on the life-cycle, trophic ecology, and habitat selection for the Seychelles lobster managed populations. Some data are still under analysis and a full report will be available by the end of 2019. However, the project has developed training materials for the accurate assessment of the different life-cycle phases of the local lobster species, which has been transferred to local participants via the project's training activities.

Finally, if one considers the metapopulation hypothesis for the Western Indian Ocean this denotes an important management implication to ensure the sustainability of the species in this region, as it has to be managed as a single stock. Further research on genetic connectivity is required to validate this hypothesis, with the aim of supporting a possible multi-country management policy on this fishery to ensure the long-term durability of the stock.

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