

Population Dynamics and Host Interactions between Two Isopods, the Commensal *Jaera hopeana* and *Sphaeroma serratum*, in a Lagoon of North Tunisia

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Population Dynamics and Host Interactions of the Commensal *Jaera hopeana* with *Sphaeroma serratum* in Menzel Abd Errahmane, North Tunisia

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Keys words: Seasonal fluctuation, Host size effect, Commensal density, Infestation patterns, Crustacea

Abstract:

In the coastal lagoon of Menzel Abderrahmane (North Tunisia), the small isopod *Jaera hopeana* lives closely associated with its host *Sphaeroma serratum*. This study examines the interplay between the dynamics of both species within the polluted lagoon ecosystem. From August 2015 to July 2016, monthly samples were analyzed to assess population structure, reproductive activity, and patterns of infestation. Both species showed a female-biased sex ratio (1♂:2♀ in *S. serratum* and 3♂:4♀ in *J. hopeana*) and distinct seasonal reproductive rhythms, with breeding peaking in spring and early summer. Interestingly, the reproductive period of *J. hopeana* slightly lagged behind that of its host. Fecundity was strongly linked to body size in *S. serratum* ($R^2 = 0.45$) but showed no such correlation in *J. hopeana* ($R^2 = 0.20$), suggesting different reproductive strategies. The number of commensals per host increased markedly with host size, reaching up to 43 individuals on large male hosts (>11 mm). Infestation intensity varied significantly throughout the year, with the highest densities observed in late spring and early summer. Altogether, these findings reveal that host morphology and seasonal environmental changes play major roles in shaping the dynamics of this commensal relationship. The close ecological association between *J. hopeana* and *S. serratum* illustrates how commensalism can serve as a successful adaptive strategy in unstable, human-impacted lagoon environments.

1. INTRODUCTION

Numerous ecological studies have been conducted on the Bizerte Lagoon, particularly in the Menzel Abdelrahman area, due to its rich biodiversity and its ecological significance as a transitional zone between marine and freshwater environments. These studies have explored key ecological factors such as biodiversity, ecotoxicity, reproductive phenology, and biological rhythms of various species inhabiting this ecosystem Bourguiba and El Gtari, 2017; Ben Souissi et al., 2016; Bejaoui et al., 2020

Biodiversity assessments have revealed that the lagoon harbors a diverse assemblage of marine and estuarine species, playing a crucial role in maintaining ecosystem stability. However, due to increasing

anthropogenic pressures, including industrial discharge, agricultural runoff, and urban expansion, ecotoxicological studies have been conducted to evaluate the impact of pollutants on local species. These investigations have demonstrated significant bioaccumulation of heavy metals and other contaminants, affecting reproductive cycles and survival rates (Saad El-Din et al., 2014).

One of the key biological components of this ecosystem is *Sphaeroma serratum*, a euryhaline isopod species known for its adaptability to fluctuating environmental conditions (Bejaoui et al., 2020; Pantoustier et Prunus, 1977; Wilson and Wagele, 1994). The biological rhythms of *S. serratum* have been extensively studied to understand its behavioral and physiological responses to environmental stressors, particularly salinity variations and temperature shifts. One aspect that has garnered particular interest is the potential role of commensal associations in shaping the ecological dynamics of intertidal communities, as they may influence species distribution, resource utilization, and adaptive strategies in fluctuating environments (Thiel, 2002).

The association between *Sphaeroma serratum* and *Jaera hopeana* has been observed in several regions, including Europe, where this relationship has been previously documented. Similar symbiotic interactions have also been reported in Australia, New Zealand, and California, where another sphaeromatid species, *Sphaeroma quoyanum*, forms a commensal relationship with *Zais californica* (Pantoustier et Prunus, 1977; Menzies et Barnard, 1951; Hurley, 1956; Rotramel, 1975). These studies suggest that such commensal interactions may be more widespread than previously thought, raising important questions about their evolutionary and ecological significance.

The reproductive biology of *J. hopeana* has been well studied in both marine and lagoon environments, highlighting seasonal variations in reproductive output, fecundity rates, and recruitment patterns. However, these studies did not explicitly identify the host species with which *J. hopeana* interacts in different environments. This gap in knowledge underscores the importance of the current study, which aims to analyze both the population structure and the reproductive biology of *J. hopeana* in relation to its host, *S. serratum*.

This study seeks to determine whether host availability and environmental conditions influence the species' reproductive success and population dynamics. Understanding these factors is essential for predicting how environmental changes, including climate fluctuations and pollution, may impact commensal relationships in lagoon ecosystems.

The primary objectives of this study are:

- To assess the seasonal abundance and incidence of *J. hopeana* in relation to *S. serratum* populations.

- To determine whether fluctuations in *S. serratum* population density influence the distribution and density of *J. hopeana*.
- To explore potential ecological benefits or constraints imposed by this commensal relationship, particularly in the context of environmental stressors and habitat degradation.

2. STUDY AREA

The study was conducted on the northern shore of Lake Bizerte, in Menzel-Abderrahmane (N37°13'50.8'' E009°51'17.4''). This area, which suffers from domestic wastewater discharge and pollution from nearby metallurgical industries (Dellali and Aissa, 1998), is home to the lake's only port. Menzel-Abderrahmane has a warm temperate climate, with average monthly temperatures ranging from 11.1°C in January to 25.8°C in August. Precipitation levels vary significantly throughout the year, with an average monthly rainfall of 3 mm in July and 101 mm in December.

3. MATERIAL AND METHODS

The samples of *Sphaeroma serratum*, collected in Menzel Abd Errahmane from August 2015 to July as a part of the study on the species' reproductive cycle (Ben Souissi et al., 2016), were used for collecting *Jaera hopeana*, a commensal species associated with the former. A monthly sampling of approximately a hundred individuals of *Sphaeroma serratum* was carried out, from March 2015 to February 2016, in the mid-littoral zone under the stones resting on a sandy substrate rich in shell debris. Collecting was done manually, and the animals were transported alive to the laboratory.

Once in the laboratory, each specimen of *Sphaeroma serratum* was individually fixed in 70% ethanol to facilitate the collecting of associated *Jaera hopeana*. Specimens of *J. hopeana*, collected from between the pereopods of each preserved sample of *S. serratum*, were counted, sexed, and measured using a stereomicroscope (Leica MS5).

The study focused on fecundity, as determined by the number of eggs in the marsupium. A total of 46 ovigerous females of *Sphaeroma serratum* and 77 ovigerous females of *Jaera hopeana*, both in the early stages of egg development characterized by yellow, rounded eggs, were dissected. The contents of the dissected females were then transferred to a petri dish for accurate egg counting. Before dissection, all ovigerous females were sized, measuring from the anterior edge of the cephalon to the end of the pleotelson, employing a stereomicroscope (Leica MS5) with a precision of ± 0.01 mm.

4. DATA ANALYSIS

To analyze the population structure of *Sphaeroma serratum* and *Jaera hopeana*, specimens from each sample were classified into size groups. *Sphaeroma serratum* individuals, ranging in total length from 2 mm to 14 mm, were categorized into 9 size classes of 1 mm each. In contrast, *Jaera hopeana* individuals were grouped into 0.02 mm size classes. Additionally, the sex and reproductive condition of all isopods were recorded.

5. RESULTS

5.1. Sex ratio

A total of 972 specimens of *Sphaeroma serratum* were collected during the sampling period from August 2015 to July 2016, comprising 521 females and 286 males. The overall sex ratio was 1♂: 2♀, indicating that the *S. serratum* population is predominantly female. A chi-square goodness-of-fit test revealed a highly significant difference from the expected 1:1 ratio ($\chi^2 = 34.36$), $p\text{-value} = 4.57 \times 10^{-9}$. This outcome indicates a significant female bias across the entire study period. Over the course of the year, the monthly sex ratio was skewed toward females, with exceptions noted in August and October (2♂:1♀) and September (1♂:1♀):

For *Jaera hopeana*, a total of 1076 specimens were collected (625 females and 451 males) during the sampling period. The overall sex ratio was 3 ♂: 4 ♀. Similar to *S. serratum*, the sex ratio of *J. hopeana* is in favor of females, except in October.

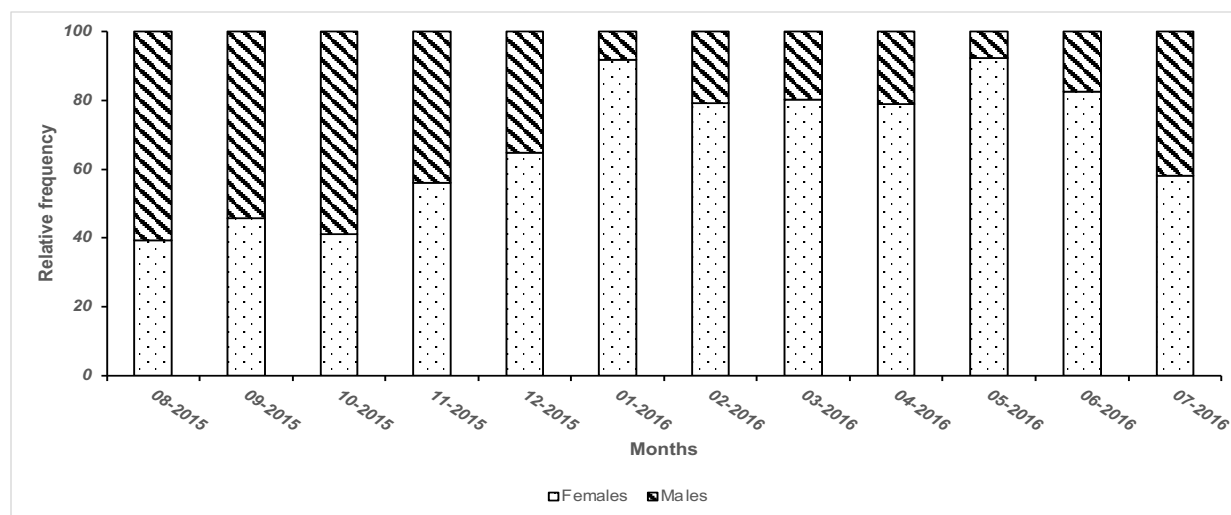


Figure 1: Sex ratio of *Sphaeroma Serratum*

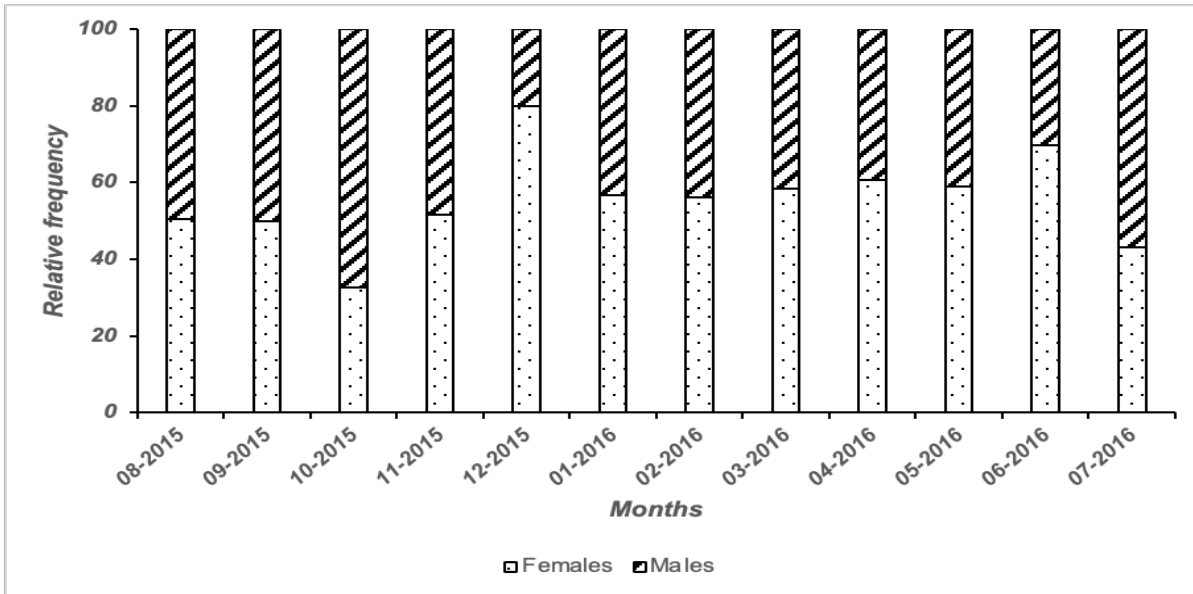


Figure 2: Sex ratio of *Jaera hopeana*

5.2. Population structure

Figure 3 shows the distribution of male and female *S. serratum* individuals across different size classes, clearly highlighting sexual size dimorphism. Females are significantly more abundant in the smaller size classes, particularly between 5–6 mm (41.92%) and 6–7 mm (34.61%), where their numbers peak. Their abundance then decreases sharply with increasing size. In contrast, males are underrepresented in the smaller classes but progressively increase in proportion in the larger size classes, becoming dominant from 8–9 mm (21.05%) and almost exclusive in the largest size classes (9–10 mm to 12–13 mm). This pattern suggests a sexual size dimorphism, with males generally reaching larger sizes than females. Such a distribution may reflect biological differences between sexes, such as earlier sexual maturity in females or prolonged growth and greater longevity in males.

The analysis of the size frequency distribution revealed a highly significant dependence between the sex of the captured individuals and their size class. A chi-square test of independence revealed that the distribution of males and females differed significantly across size classes ($\chi^2 = 394.31$, $df = 8$, $p < 0.0001$).

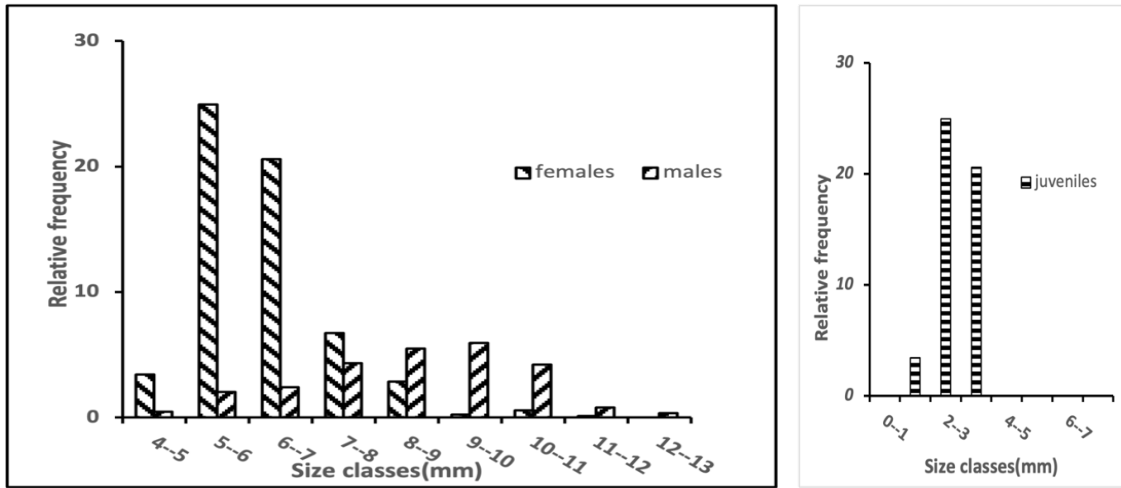


Figure 3: size distribution of the different categories of *Sphaeroma serratum*

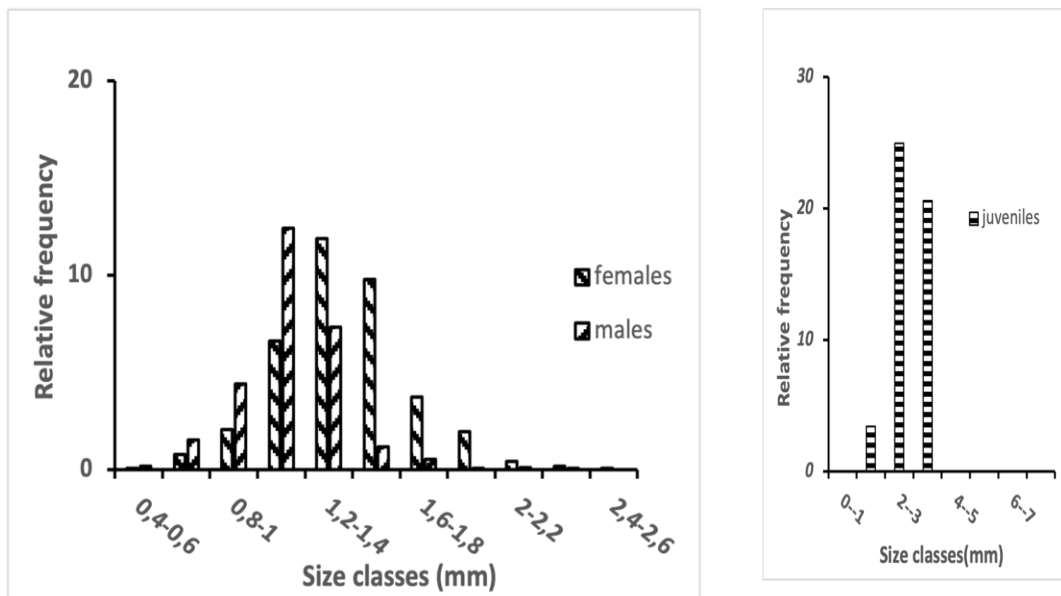


Figure 4: Size distribution of the different categories of *Jaera hopeana*

Figure 4 shows the relative frequency of males and females of *J. hopeana* across size classes. Both sexes display a unimodal distribution centered around the 1.2–1.4 mm class, although there are some differences. Females are generally more frequent than males in the medium to larger size classes (1.4–1.6 mm and above), whereas males are more represented in the smaller size classes (1.0–1.2 mm). This suggests the presence of sexual size dimorphism, with females reaching slightly larger sizes on average. The Chi-square Test of Independence reveals a highly significant dependency between sex and size class ($\chi^2 = 311.95$, $df = 9$, 0.0001).

The undifferentiated (Under 0.5 mm) are present every month except the period from August, with a variable percentage between 0% and 6.25% in December and a maximum in July (62.09%), marking the recruitment phase. The females are present every month, with a maximum in December (75%) and a minimum in July

(16.33%). Males present with significantly lower percentages, with a maximum of 67.44% in October and a minimum of 8.57% in June. The undifferentiated individuals (under 0.5 mm) appear throughout the year except in August. Their proportion fluctuates widely, from 0% to 6.25% in December, and rises sharply to a peak in July (62.09%), reflecting the recruitment period. Females are present year-round, reaching their highest proportion in December (75%) and their lowest in July (16.33%). Males occur in much smaller proportions overall, with a peak in October (67.44%) and a marked decline in June (8.57%).

5.3. Seasonal variation in the reproductive activity

During the sampling period (August 2015–July 2016), the percentages of ovigerous females of *S. serratum* and its commensal species *J. hopeana* exhibited a marked seasonal variation (Figure 5). Both populations showed very low reproductive activity from August 2015 to March 2016, with values below 20% and an almost complete absence of ovigerous females in *S. serratum* during November and December 2015. From March onwards, a gradual increase was observed, peaking in spring. In *S. serratum*, the maximum was recorded in April (70%), followed by a slight decrease in May and a progressive decline until July. In *J. hopeana*, the increase occurred later, with a peak in May (58%) and consistently high percentages maintained until July. This pattern, characterized by overall synchronization but with a slight temporal shift between the two species, suggests that reproduction is driven by spring and summer environmental conditions, while the phase difference may result from biological or behavioral traits specific to the commensal species.

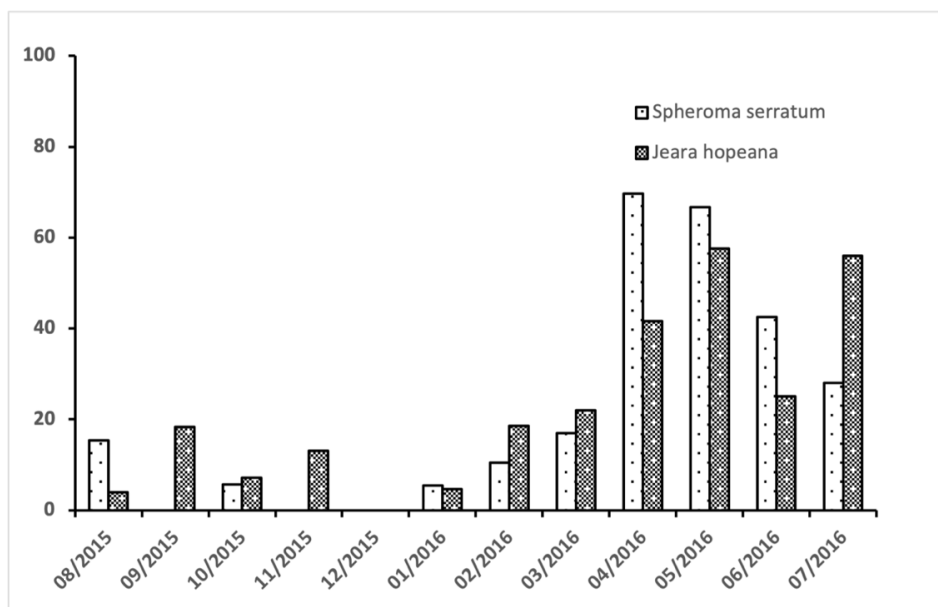


Figure 5: Monthly changes of ovigerous females of *S. serratum* and *J. hopeana*

5.4. Fecundity

The analysis of fecundity in relation to female size revealed contrasting patterns between the two isopod species (Figures 6 and 7). In *Sphaeroma serratum*, the number of eggs varied between 7 and 61, with female sizes ranging from 5.2 to 6.8 mm. A positive correlation was observed between female body size and the number of eggs carried ($R^2 = 0.45$), indicating that larger females tend to produce higher egg numbers. This size-dependent fecundity suggests that maternal size plays an important role in reproductive investment, likely reflecting increased energy reserves and brood capacity in larger individuals. In contrast, *Jaera hopeana* exhibited no significant relationship between female size and fecundity ($R^2 = 0.20$). Ovigerous females produced only 3 to 8 eggs, with body sizes ranging from 1.2 to 1.8 mm, showing a relatively constant clutch size regardless of size variation.

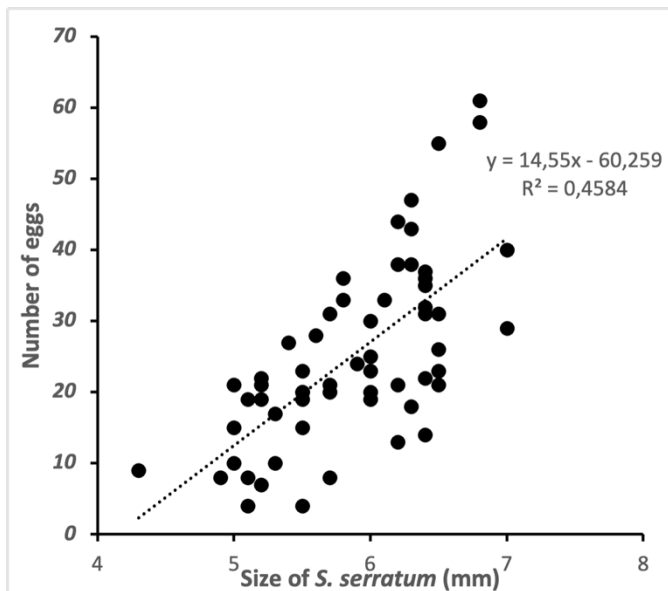


Figure 6: Correlation between egg number and body size in ovigerous females of *S. serratum*

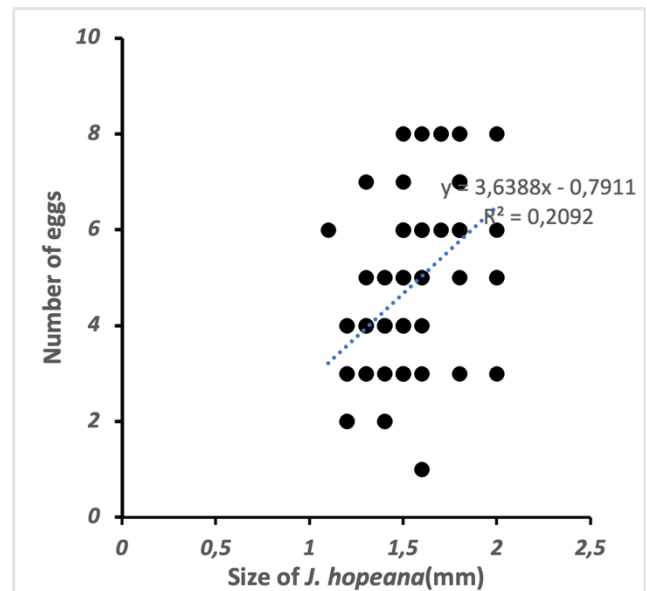


Figure 7: Correlation between egg number and body size in ovigerous females of *J. hopeana*

5.5 Host–Commensal Interaction in *Sphaeroma serratum*

5.5.1. Host size effect on *Jaera hopeana* abundance

No *Jaera hopeana* were observed in *Sphaeroma serratum* smaller than 2.7 mm, and the presence of a single commensal in undifferentiated hosts is considered accidental. The number of commensals varied greatly among hosts. Across 501 specimens of *S. serratum*, the maximum number of *J. hopeana* recorded was 43 in

an individual of 11.7 mm, whereas the largest host (13.3 mm) carried only four. After excluding cases with a single commensal, the mean number of *J. hopeana* per host was 4.61 ± 4.90 , associated with a mean host size of 6.79 ± 1.68 mm.

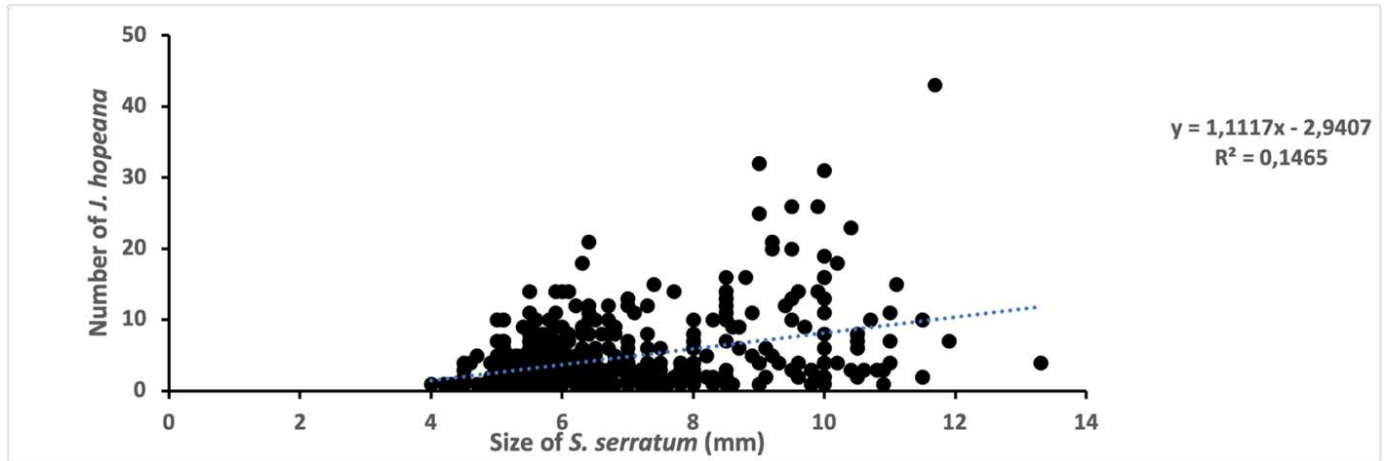


Figure 8 Number of *J. hopeana* in relation to the size of *Sphaeroma serratum*

table 1: Mean number of *Jaera hopeana* attached to *Sphaeroma serratum* grouped into 1-mm size classes

Size class	Female				Male			
	Number of hosts	average number of <i>Jaera</i>	Standard deviation	sum of commensal individuals	Number of hosts	average number of <i>Jaera</i>	Standard deviation	sum of commensal individuals
[4-5[	26	1.81	1.23	47	0	0	0	0
[5-6[	154	3.64	2.80	560	2	1	0	2
[6-7[	131	4.14	3.55	542	13	2.08	2.50	27
[7-8[	43	3.98	3.73	171	19	3.05	2.61	58
[8-9[	9	5.22	3.49	47	30	6.37	4.69	191
[9-10[	0	0	0	0	32	9.53	9, 10	305
[10-11[	0	0	0	0	31	8.00	7.23	248
[11-12[	0	0	0	0	10	11.10	11.95	111
[11-12[	0	0	0	0	0	0	0	0
[12-13[	1	4	0	4	0	0	0	0

The distribution of *Jaera hopeana* among *Sphaeroma serratum* hosts varied markedly according to host size and sex (Table 1). In the smaller size classes (4–7 mm), only females were represented in large numbers, with an average of 1.81 to 4.14 commensals per host

Males were rare in these classes, and when present, carried very few commensal species. Between 7 and 9 mm, both sexes were represented: females maintained mean values of about 4–5 *Jaera* per host, while males carried slightly more (6.37 ± 4.69 at 8–9 mm). In the larger size classes (>9 mm), only males were present. These harbored the highest loads of commensals, with mean values reaching 9.53 ± 9.10 at 9–10 mm, 8.00 ± 7.23 at 10–11 mm and peaking at 11.10 ± 11.95 in the 11–12 mm class. Despite this, females overall accounted for the majority of hosts (72%) and carried 1,371 *Jaera*, compared to 940 in males. This pattern highlights a strong sexual size dimorphism: females dominate in the smaller size classes and thus represent most of the host population, whereas males, restricted to the larger classes, carry higher individual loads of commensals.

Analysis of Variance (ANOVA) was used to evaluate the effect of host size class on the intensity of the commensal association (mean number of *Jaera* per host). A significant difference was found among female hosts, and a highly significant difference was found among male hosts.

These results collectively indicate that host size is a significant factor influencing the number of commensals carried, irrespective of host sex.

5.5.2. Monthly variation in the infestation of *Sphaeroma serratum* by *Jaera hopeana*

Seasonal variation strongly influenced both host size and the number of associated *Jaera hopeana* (Table 2).

The mean host size of *Sphaeroma serratum* fluctuated between 5.86 ± 1.00 mm (May) and 8.10 ± 1.74 mm (November). The mean number of commensals per host also showed marked temporal variation. Low infestation rates were observed in December (1.15 ± 0.37) and October (1.71 ± 0.91), coinciding with relatively smaller sample sizes. Moderate values occurred in late winter and early spring, with averages around 2–3 commensals per host (January to March). Peaks were recorded in April and May (5.82 ± 4.45 and 5.80 ± 4.89 , respectively), despite contrasting host sizes (7.05 mm vs. 5.86 mm). The highest infestation occurred in June, with a mean of 10.77 ± 5.89 *Jaera* per host, followed by a decline in July (4.75 ± 4.58). These results indicate a clear seasonal dynamic, with infestation intensity rising from spring to early summer, suggesting synchronized peaks in commensal abundance with host population cycles.

The ANOVA reveals an extremely highly significant difference in the mean number of commensals per host across the 12 months ($F_{11,530}=10.51$, $p<0.0001$)

This result confirms that the intensity of the commensal association varies dramatically and non-randomly throughout the year, suggesting seasonal drivers related to the life cycles or environmental conditions affecting the host and/or the commensal.

*Table 2: Monthly variations in the mean length (mm) of *Sphaeroma serratum* together with the mean density of *Jaera hopeana* per host (ratio)*

Months	Number of <i>S. serratum</i>	Mean size of <i>S. serratum</i> and standard deviation	mean number of <i>J. hopeana</i> standard deviation
August 15	73	7 ± 1.78	2.71 ± 2.35
sept-15	39	7.13 ± 2.11	5.56 ± 2.01
oct.-15	14	6.38 ± 0.88	1.71 ± 0.91
nov-15	20	$8,1 \pm 1.74$	4.35 ± 2.90
dec-15	13	6 ± 1.02	1.15 ± 0.37
Jan-16	38	7.1 ± 1.84	2.81 ± 1.69
Feb-16	31	6.8 ± 1.82	2.45 ± 2.14
March -16	53	6.61 ± 1.60	3.5 ± 3.68
April 16	58	7.05 ± 1.48	5.82 ± 4.45
May 16	65	5.86 ± 1	5.8 ± 4.89
Jun-16	57	6.6 ± 1.51	10.77 ± 5.89
Jul-16	40	7.21 ± 1.87	4.75 ± 4.58

5.2.3. The effect of seasons

Figure 9 highlights clear seasonal differences in the distribution of *Jaera* categories associated with *Sphaeroma serratum*. During autumn and summer, no undifferentiated *S. serratum* individuals were recorded as hosts. Similarly, undifferentiated *Jaera* were absent in autumn, particularly in females *S. serratum* hosts. In autumn, males of *S. serratum* represented the majority of hosts and carried 58.33% of *Jaera* individuals, with no undifferentiated *Jaera* detected. By contrast, winter, spring, and summer showed a marked shift: females of *S. serratum* became the predominant hosts, representing 78.57% in winter, 73.92% in spring, and 66,91% in summer. In these seasons, most associated *Jaera* individuals were undifferentiated. The incidence of *Jaera* was mostly associated with female

Sphaeroma, exceeding two-thirds of the cases in all seasons except autumn. In winter, Jaera incidence reached its maximum (78.57%) among female hosts, with all Jaera categories represented.

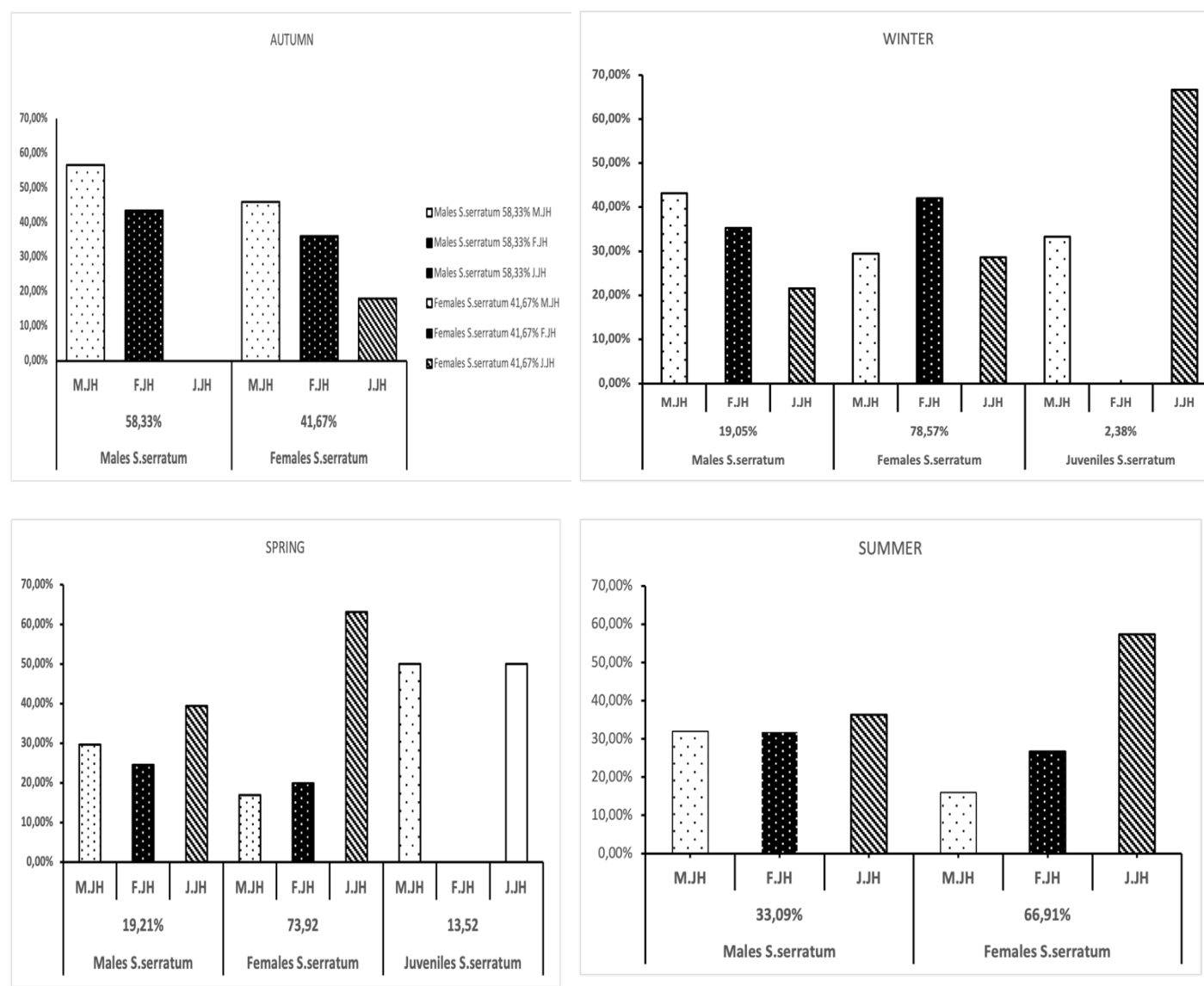


Figure 9 : The seasonal distribution of *Jeara hopeana* depending on the categories of *Sphaeroma serratum*

Discussion

Our results confirm that *Sphaeroma serratum* and its commensal *Jaera hopeana* exhibit a clearly seasonal reproductive cycle rather than continuous reproduction. A slight temporal lag was observed between the end of sexual rest and the onset of reproductive activity. Such a shift is likely driven by local climatic fluctuations, including wetter winters and warmer summers. Temperature is a well-known regulator of growth and reproduction in isopods, particularly in the Sphaeromatidae. Harvey (1969) noted that low winter temperatures inhibit the growth of *S. serratum*, which may explain the limited northern distribution of the species.

Within the genus *Jaera*, sexual dimorphism is common, though it varies among species. While males of *J. nordmunni* typically exceed females in size, the opposite trend is documented in several species of the *J. albifrons* group and in commensal forms such as *J. hopeana* and *Zais pubescens* (Wägele, 2000). In our study, *J. hopeana* females also reached larger sizes than males, consistent with patterns already known in commensal or semi-parasitic species, where female size is often linked to brood capacity.

The fecundity values observed in our material fall within the range documented for other Jaeridae and Sphaeromatidae. For example, a 1.8 mm *J. hopeana* female carried 11 eggs, a value comparable to *Iais pubescens* (6–10 eggs for females of 2.7 mm) and lower than species with larger maximum body sizes, such as *J. forsmanni*, which may produce up to 80 eggs per brood (Sjöberg, 1970). Previous studies on commensals confirm that small females typically bear fewer than 10 embryos (Haahtela & Naylor, 1965; Cooke, 1977).

Our results further show a positive correlation between female body size and egg number in both *S. serratum* and *J. hopeana*, a trend widely reported in marine and terrestrial isopods (Laifi & Medini-Bouaziz, 2021; Medini-Bouaziz et al., 2017a, 2017b; Khemaissia et al., 2016). This suggests that fecundity scaling with body size is a conserved reproductive strategy across isopods.

The commensal relationship between Sphaeromatidae and assellotes has been previously documented (Marsden, 1982). However, our study highlights a stronger seasonal structuring of this association. The incidence of *J. hopeana* on *S. serratum* varied greatly across seasons, with a marked decline in winter followed by an increase in spring—contrary to the seasonal pattern described by Marsden. This reduction in winter likely reflects higher mortality of *Jaera* at low temperatures, a phenomenon already reported for free-living forms. Since free-living *Jaera* may suffer > 50% mortality, commensal individuals may adopt modified life-history traits such as faster growth, smaller adult size, reduced lifespan, smaller broods, and balanced sex ratios, all of which enhance survival in the host environment.

The incidence of *J. hopeana* strongly depended on host characteristics, particularly host size, sex, and category. As shown earlier in the article, females of *S. serratum* hosted the majority of *Jaera* individuals in winter and spring, while in autumn, males dominated but carried fewer and less diverse *Jaera* categories. Comparable patterns were reported for *Iais pubescens*, where fluctuating host populations and vertical displacement in the intertidal zone influenced commensal density (Marsden, 1982). Similarly, individuals of *Exosphaeroma obtusum* located higher on the shore carried fewer commensals, suggesting that microhabitat and environmental stressors modulate host suitability.

Conclusion

Overall, the interaction between *S. serratum* and *J. hopeana* appears strongly shaped by seasonality, temperature, host size and sex structure, and local environmental constraints. The demographic structure of both populations—and especially the dynamic changes in host availability—drives the intensity and composition of this commensal association.

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