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Original Article

Seasonal Variability in the Genus-Family Structure of Free-Living Nematode Communities in Organic Shrimp Farming Ponds, Ca Mau Province

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Abstract: This study determined the seasonal variability of free-living nematode communities structure (genus/family level) in organic shrimp farms ponds in Tam Giang commune, Nam Can district, Ca Mau province. Based on the result of SIMPER analysis, the average similarity in nematode communities at genus level was low with 30.75% and 30.81% (in dry and rainy season, respectively). However, the average dissimilarity between seasons was considerably high with 71.75%. *Terschellingia*, *Daptonema*, and *Parodontophora* were main genera contributing to similarity/dissimilarity between seasons. At the family level, results of SIMPER analysis showed that the average similarity was low with 37.12% and 39.02% (dry and rainy, respectively). Additionally, the average dissimilarity between dry and rainy season was reasonably high with 64.06%. Specifically, four families such as Linhomoeidae, Xyalidae, Axonolaimidae, and Chromadoridae were the main families contributing to similarity/dissimilarity between seasons. Differences in sediment environmental characteristics between dry and rainy season are the reason for dissimilarity in the nematode communities structure. The high abundance of genus *Terschellingia*, *Daptonema*, *Parodontophora* may be indicative of organic enrichment conditions in shrimp pond sediment in both seasons. Nematodes with their rapid adaptation to changing environments can be used as a potential tool for bio-indicator.

Keywords: Bio-indicator, Ca Mau province, nematode communities, organic shrimp farms ponds, simper analysis.

1. Introduction

Southern Vietnam has a tropical monsoon climate which is described with two main seasons: dry season and rainy season. The dry season lasts from November to April, while the period from May to October is rainy season [1]. Nematodes are roundworms of the phylum Nematoda, as most are highly sensitive to natural and anthropogenic disturbances [2]. Thus, the

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complicated natural conditions and seasonal fluctuations in Southern Vietnam have had an enormous impact on nematode communities structure [3]. In the last few years, the effects of a seasonal factor on nematode communities have been studied at different places over the world. Heip et al. (1985) have warned that the seasonal variability on the species composition of nematodes could be very different from site to site and depending on local environmental conditions [4]. The study by Hodda and Nicholas (1986) in littoral nematodes from the Hunter estuary, New South Wales, Australia was notable that large fluctuations in the total nematode density at the various sites throughout the year [5]. Another study of Alongi (1987) in five Australian estuaries found that the nematode densities were not significantly different among estuaries, but differed seasonally (summer greater than winter) [6]. Tudorancea and Zullini (1989) studied nematode abundances in the tropical regions, reported that the abundance was highest at the end of dry season and the beginning of a small rainy season [7]. The production of meiofaunal communities in an Australia estuary during four seasons showed that the proportion of adult males and juveniles in the population and their mean size changed by season factor described by Hodda and Nicholas (1990) [8]. Beier and Traunspurger (2003) studied nematode communities in sub-mountain carbonate stream (Southwest Germany) and found that the total of nematode abundances was low during summer, autumn and winter and reached a maximum density in spring. The density of deposit- and suction-feeders similar to the variation in total nematode density was low during summer, autumn, winter, and showed the highest values in spring [9]. Similar results have been reported by Hourston et al. (2009) in Swan river estuary (West coast of Australia), nematode densities were also generally highest in spring, due to increases in the abundance of natural food (microphytobenthos) [10].

The unplanned expansion in shrimp farming in the Mekong Delta region has also had negative effects on the environment and caused devastating damage to mangrove forests [11]. A model of organic shrimp farms is developed to combat this problem. The model integrates shrimp aquaculture with mangrove protection, and thus it's sustainable development of shrimp farming in the coastal areas [12]. Nematode communities are a primary food source for the diet of shrimps [13, 14]. Thus, several studies have been performed for the ecology of nematodes in organic shrimp farm pond's sediments. Free-living nematode communities in the Tam Giang's organic shrimp farms ponds, Nam Can district, Ca Mau province were expressed by high density and diversity [11]. This characteristic of free-living nematode communities in organic shrimp farming ponds might provide a suitable natural food source for shrimps and enrich the benthic food web [15]. Furthermore, Tran et al. (2018) conducted a correlation analysis between some dominant nematode genera with the main environmental variables. Results showed that the environmental condition in dry season was separated from other seasons, salinity was the main factor responsible for the differences found between dry and other seasons. Additionally, salinity was a main environmental variable in the dry season, whereas in the trans and wet seasons were governed by Fe^{2+}, Fe^{3+}, TN, TOC, DO, pH, and depth. These environmental characteristics almost completely governed the dominant genera such as *Desmodora*, *Sabatieria*, *Terschellingia*, *Dichromadora*, *Pomponema*, *Halalaimus*, *Ptycholaimellus*, and *Sphaerotheristus* [11].

Due to complicated natural conditions in an organic shrimp farming ponds related to seasonal fluctuations, it is important to get an idea on the seasonal variability of the nematode communities structure between dry and rainy season. Therefore, our aim is to (i) identify average similarities and dissimilarities in nematode communities between dry and rainy season (at genus and family level), (ii) determine genera/families responsible for similarities and dissimilarities in both seasons.

2. Materials and Methods

2.1. Study area and sampling

The present study was carried out in March (dry season) and November (rainy season) of 2015 at eight different organic shrimp ponds distributed in Tam Giang commune, Nam Can district, Ca Mau province. Study area and sampling activities have been described in detail by Tran et al. (2018) [11].

2.2. Data analysis

An Analysis of similarities (ANOSIM) was applied for comparing the nematode communities structure (genus/family level) between dry and rainy season. Additionally, the SIMPER analysis (SIMilarity PERcentages) was used for identifying (i) average similarity and dissimilarity between dry and rainy season (at genus and family level), and (ii) the genera and families responsible for similarity and dissimilarity between both seasons. The ANOSIM and SIMPER were performed using PRIMER v6.1.6 [16].

3. Results and Discussion

3.1. Genera responsible for similarity and dissimilarity between dry and rainy season

Overall, the nematode communities in eight organic shrimp ponds, Tam Giang commune, Nam Can district, Ca Mau province consisted of 75 genera belonging to 24 families, 7 orders, in dry season. However, in rainy season the number of collected genera was relatively low, with 57 genera, 26 families, and 9 orders [11].

In dry season, results of the SIMPER analysis confirmed that the average similarity in nematode communities was low with 30.75%. Five genera such as*Terschellingia*

Daptonema, *Parodontophora*, *Ptycholaimellus*, *Pseudolella*, and *Dichromadora* were main genera contributing to similarities in dry season. More specifically, genus *Terschellingia* was the one with the most contribution (with 33.39% of total contribution) followed by *Daptonema* (18.07%),

Parodontophora (9.93%), *Ptycholaimellus* (9.45%), *Pseudolella* (5.84%), and *Dichromadora* (3.66%). In rainy season, the average similarity in nematode communities was also low with 30.81%. *Terschellingia*, *Daptonema*, and *Parodontophora* were also known as the most contribution genera (with 30.61%, 20.79%, and 11.72%, respectively). The sub- contribution genera were *Pseudolella* and *Dichromadora* (7.40% and 7.16%, respectively). Genus *Ptycholaimellus* had also contributed with a lower proportion (1.93%) than that in dry season. In both seasons, genera *Sabatieria*,

Gomphionema, *Halalaimus*, *Desmodora*, *Sphaerotheristus*, *Hopperia*, *Metadesmolaimus*, and *Eumorpholaimus* had also contributed with their percentages ranged from 1.09% to 4.13%. The percentages of the remaining genera were lower than 1.00% of the total contribution (Table 1).

Table 1. Average similarities and major nematode genera contributing to the similarity in dry/rainy season. Cut off for low contributions: 95.00% (Av.Si: Average Similarity; Con: Contribution, Cum: Cumulative)

Dry (Av.Si: 30.75%)				Rainy (Av.Si: 30.81%)			
Genera	Av.Si (%)	Con (%)	Cum (%)	Genera	Av.Si (%)	Con (%)	Cum (%)
Terschellingia	10.27	33.39	33.39	Terschellingia	9.43	30.61	30.61
Daptonema	5.56	18.07	51.46	Daptonema	6.40	20.79	51.40
Parodontophora	3.05	9.93	61.39	Parodontophora	3.61	11.72	63.11
Ptycholaimellus	2.91	9.45	70.84	Pseudolella	2.28	7.40	70.51
Pseudolella	1.79	5.84	76.67	Dichromadora	2.21	7.16	77.67
Dichromadora	1.12	3.66	80.33	Gomphionema	1.27	4.13	81.8
Sabatieria	1.01	3.28	83.61	Sphaerotheristus	1.19	3.85	85.65
Gomphionema	0.90	2.91	86.53	Halalaimus	0.81	2.64	88.29

Halalaimus	0.52	1.69	88.22	Ptycholaimellus	0.59	1.93	90.22
Desmodora	0.50	1.62	89.84	Metadesmolaimus	0.47	1.52	91.73
Sphaerotheristus	0.36	1.17	91.01	Eumorpholaimus	0.43	1.40	93.13
Hopperia	0.33	1.09	92.1	Desmodora	0.34	1.12	94.25
Theristus	0.27	0.86	92.96	Chromadorita	0.26	0.84	95.09
Metachromadora	0.26	0.86	93.82				
Linhystera	0.24	0.77	94.59				
Eumorpholaimus	0.19	0.63	95.22				

The SIMPER analysis also showed that the average dissimilarity between seasons was considerably high with 71.75%. Genus *Terschellingia* served as the key one responsible for the dissimilarity between dry and rainy season (with 18.86% of total contribution). Additionally, *Daptonema*, *Parodontophora*, *Pseudolella*, *Dichromadora*, *Ptycholaimellus*, *Gomphionema*, and *Sphaerotheristus* were also known as the sub-contribution genera (with 13.51%, 6.39%, 6.35%, 5.04%, 4.85%, 3.34%, and 4.4.4%, respectively). The contributed percentages of the remaining genera were lower than 2.00% of the total contribution (Table 2). Furthermore, the results of an ANOSIM analysis confirmed that there were significant differences in nematode communities structure (genus level) between dry and rainy season (Global R=0.095, p-value=0.007).

Table 2. Average dissimilarities and major nematode genera contributing to the dissimilarity between dry and rainy season. Cut off for low contributions: 95.00% (Av.Dis: Average Dissimilarity; Con: Contribution; Cum: Cumulative)

Average dissimilarity: 71.75%							
Genera	Av.Dis (%)	Con (%)	Cum (%)	Genera	Av.Dis (%)	Con (%)	Cum (%)
Terschellingia	13.53	18.86	18.86	Theristus	1.02	1.42	84.13
Daptonema	9.69	13.51	32.37	Marylynnia	0.85	1.19	85.31
Parodontophora	4.59	6.39	38.76	Sphaerolaimus	0.76	1.06	86.37
Pseudolella	4.56	6.35	45.11	Metachromadora	0.74	1.03	87.40
Dichromadora	3.62	5.04	50.16	Pomponema	0.62	0.87	88.27
Ptycholaimellus	3.48	4.85	55.01	Hopperia	0.61	0.85	89.12
Gomphionema	3.19	4.44	59.45	Halichoanolaimus	0.56	0.79	89.91
Sphaerotheristus	2.39	3.34	62.79	Anoplostoma	0.51	0.71	90.62
Halalaimus	2.34	3.26	66.05	Viscosia	0.50	0.69	91.31
Sabatieria	2.09	2.91	68.96	Trissonchulus	0.43	0.60	91.91
Metadesmolaimus	2.02	2.81	71.77	Paraplectonema	0.39	0.55	92.45
Desmodora	1.82	2.53	74.3	Monhystera	0.34	0.47	92.93
Eumorpholaimus	1.43	1.99	76.29	Aegialoalaimus	0.32	0.45	93.38
Eleutherolaimus	1.19	1.65	77.95	Molgolaimus	0.32	0.44	93.82
Chromadorita	1.17	1.64	79.58	Subsphaerolaimus	0.31	0.44	94.26
Leptolaimus	1.17	1.63	81.22	Microlaimus	0.30	0.42	94.67
Linhystera	1.07	1.49	82.7	Antomicron	0.26	0.36	95.03

3.2. Families responsible for similarity and dissimilarity between dry and rainy season

At the family level, in dry season, results of the SIMPER analysis showed that the average similarity in nematode communities was low with 37.12%. The most contributing families were Linhomoeidae, Xyalidae, Axonolaimidae, and Chromadoridae (23.43%, 20.78%, 15.53%, and 12.48%, respectively). Generally, the nematode communities structure at the family level did not fluctuate greatly between dry and rainy season. In rainy season, the average similarity in nematode communities was also low with 39.02%. Xyalidae, Linhomoeidae, Axonolaimidae, and Chromadoridae were also known as the four most contribution families with 26.60%, 26.32%, 13.67%, and 10.74%, respectively (Table 3).

Table 3. Average similarities and major nematode families contributing to similarity in dry/rainy season. Cut off for low contributions: 95.00% (Av.Si: Average Similarity; Con: Contribution, Cum: Cumulative)

Dary (Av.Si: 37.12%)				Rainy (Av.Si: 39.02%)			
Families	Av.Si (%)	Con (%)	Cum (%)	Families	Av.Si (5)	Con (%)	Cum (%)
Linhomoeidae	11.43	30.81	30.81	Linhomoeidae	12.25	31.39	31.39
Xyalidae	8.32	22.42	53.23	Xyalidae	11.75	30.11	61.49
Axonolaimidae	5.36	14.45	67.68	Axonolaimidae	6.83	17.51	79.01
Chromadoridae	5.12	13.8	81.48	Chromadoridae	4.16	10.66	89.67
Comesomatidae	1.76	4.74	86.22	Neotonchidae	1.28	3.29	92.95
Desmodoridae	1.26	3.39	89.61	Oxystominidae	0.89	2.28	95.23
Cyatholaimidae	0.98	2.64	92.24				
Neotonchidae	0.90	2.43	94.67				
Oxystominidae	0.63	1.70	95.37				

The average dissimilarity between dry and rainy season was fairly high with 64.06%. Specifically, Linhomoeidae and Xyalidae were known as the two most contribution families, with 22.96% and 21.87%, respectively. Families Axonolaimidae, Chromadoridae, and Neotonchidae were also responsible for those dissimilarities (ranged from 5.00% to 13.13%). The percentages of the remaining families were lower than 5.00% of the total contribution (Table 4). Results of an ANOSIM analysis also showed that there were significant differences in nematode communities' structure (family level) between dry and rainy season (Global R=0.072, p-value=0.03).

Tran et al. (2018) underlined that the environmental sediment in dry season of an organic shrimp ponds was separated from that in rainy season. Salinity was a main environmental variable in the dry season, whereas in rainy season was governed by total nitrogen (TN), total organic carbon (TOC), and dissolved oxygen (DO) [11].

Table 4. Average dissimilarities and major nematode families contributing to the dissimilarity between dry and rainy season. Cut off for low contributions: 95.00% (Av.Dis: Average Dissimilarity; Con: Contribution; Cum: Cumulative)

Average dissimilarity: 64.06%			
Families	Av.Dis (%)	Con (%)	Cum (%)
Linhomoeidae	14.71	22.96	22.96
Xyalidae	14.01	21.87	44.83

Axonolaimidae	8.41	13.13	57.96
Chromadoridae	6.70	10.46	68.42
Neotonchidae	3.20	5.00	73.43
Desmodoridae	2.70	4.21	77.64
Comesomatidae	2.68	4.18	81.82
Oxystominidae	2.42	3.77	85.59
Leptolaimidae	1.79	2.79	88.38
Cyatholaimidae	1.78	2.77	91.16
Sphaerolaimidae	1.13	1.76	92.92
Oncholaimidae	0.56	0.88	93.80
Selachinematidae	0.56	0.88	94.68
Monhysteridae	0.55	0.85	95.53

It is well known that the nematode community characteristics (density, diversity, distribution, and functional properties) can be affected by several abiotic/biotic variables such as salinity, temperature, organic matter and nitrogen, sediment grain size, oxygenation level, and food availability [17-20]. Therefore, the differences in sediment environmental characteristics between dry and rainy season are the reason for dissimilarity in the nematode communities structure. Nematodes with their rapid adaptation to changing environments can be used as a potential tool for bio-indicator. Changes in benthic faunal communities were generally detectable on high levels of taxonomic resolution such as family or order level [21]. However, in the present study, the sensitivity at the genus level resulted in higher sensitivity than at the family level. Indeed, the average dissimilarity in the genus level was higher than those in family level. Suggesting that the taxonomic rank of the genus can be considered as a good tool for environmental monitoring.

During the study period, three genera such as *Terschellingia*, *Daptonema*, and *Parodontophora* were the main genera contributing to similarity/dissimilarity between dry and rainy season. Genus *Terschellingia* is credited as indicators of pollution and organic enrichment conditions [22, 23]. Genus *Daptonema* is known to be tolerant to pollution and credited as an indicator of stressed conditions [24]. Moreover, genus *Parodontophora* is selected as indicators of a poor ecological quality status in the Mediterranean coastal ecosystems because of its well-known tolerance to pollution [25]. Genera *Terschellingia*, *Daptonema*, *Parodontophora*, and their high densities may be indicative of the pressures in shrimp pond's sediment in both seasons. Although genus *Terschellingia* had contribution with a lower proportion than those in dry season but had also a high contribution in rainy season (with 30.61%). Furthermore, genera *Daptonema* and *Parodontophora* were gaining their contribution increasing from dry to rainy season (18.07% to 20.79%, 9.93 to 11.72%, dry to rainy season respectively). Perhaps the ecological quality status of sediment in dry season was better than those in rainy season.

4. Conclusion

Therefore, it can be concluded that the seasonality in the Tam Giang's organic shrimp farms ponds, Nam Can district, Ca Mau province strongly affected the nematode communities structure at genus and family level. Differences in sediment environmental characteristics between dry and rainy season are the reason for dissimilarity in the nematode communities structure. Nematodes with their rapid adaptation to changing environments can be used as a potential tool for bio-indicator.

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