

Assessment of the ecological quality status of sediment at the organic shrimp farming ponds in Ca Mau province by applying the abundance/biomass comparison (ABC) method on nematode communities

Tran Thanh Thai, Nguyen Thi My Yen, Ngo Xuan Quang, Le Dieu Linh

Abstract—Nematode communities in the Tam Giang's organic shrimp farming ponds, Nam Can district, Ca Mau province were investigated in three seasons (March - dry, July - transfer and November - rainy season). Results showed that the average abundance (inds/10 cm²) ranged from 221.67 ± 122.08 to 2539.33 ± 1403.33 in the dry season. The transfers and rainy season also showed a high density, from 1020.00 ± 354.30 to 7254.67 ± 5454.39, 822.00 ± 1086.17 – 4608.33 ± 1302.02, respectively. Total dry biomass (µg/10 cm²) of nematode communities in Tam Giang's organic shrimp farming ponds varied from 51.11 ± 28.64 to 450.87 ± 49.53 in the dry, from 412.93 ± 291.87 to 1607.25 ± 507.42 in the transfer and ranged 49.54 ± 39.36 to 1874.09 ± 3033.16 in the rainy season. The following results were also recorded that abundance/biomass comparison (ABC) method has been used successfully for detecting the ecological quality status of sediment (EcoQ) in Tam Giang's organic shrimp farming ponds. The results indicated that unfavourable deflections (stress) in EcoQ of Tam Giang's organic shrimp farming ponds throughout the dry - transfer - rainy season. More specifically, the EcoQ of Tam Giang's organic shrimp farming ponds has been classified as lightly stressed in most seasons, except for the transfer season which has been recognized as the highest EcoQ depending on its ABC curves and W values. Although EcoQ in the Tam Giang's organic shrimp farming ponds has always been clear, information on

the main cause effected biomass between natural stress or pollution stress remains uncertain.

Index Term—Abundance/Biomass Comparison, bioindicator, ecological quality status of sediment, nematode communities, organic shrimp farms

1. INTRODUCSION

In Vietnam, the expanding shrimp farming area is an important precursor of rapid reduction of mangrove forests occurred in the last century [1]. National policies have been attempting to reduce these impacts through the development and widespread dissemination of the organic shrimp farming model. This is a new approach that preserves the critical environmental protection provided by the mangroves while also providing a sustainable basis for the shrimp farming industry. According to Vietnam's Ministry of Agriculture and Rural Development, Ca Mau province is one of the Vietnam's largest shrimp production and farming areas [2]. However, despite the biggest area of mangrove forests and organic shrimp farming, there are lack of information about the model of organic shrimp farming [3]. In the last few years, several studies have until recently referred only to survey of the physic - chemical characteristics [4, 5], plankton and meiofauna communities in the organic shrimp farming ponds (OSFP) [3, 6].

Many researches are notable in that shrimps have been described as omnivorous scavengers which feed on a variety of large quantities of organic detritus, silt, sand and sand consisted mainly of benthic organisms [7, 8]. Nematodes are

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Author: Tran Thanh Thai, Nguyen Thi My Yen, Ngo Xuan Quang- Department of Environmental Management and Technology, Institute of Tropical Biology, Vietnam Academy of Science and Technology, Le Dieu Linh - Ton Duc Thang University - thanhthai.bentrect@gmail.com

a pivotal position in freshwater and marine benthic.

2. MATERIALS AND METHODS

Study areas

The Nam Can district is a coastal area of Ca Mau province belong to the Mekong Delta region of Vietnam that covered an area of 533 km². Nam Can has been recorded as the large areas of mangrove forests. It could be one of the major reasons why the Nam Can district encompasses the largest area of organic shrimp farms [17]. Besides the big river of Cua Lon with also large areas of mangroves, Tam Giang commune (a rural commune of Nam Can district, forms a roughly 95.31 km²) created favourable conditions for the development and widespread dissemination of the model organic shrimp farms. Currently, black tiger shrimp (*Penaeus monodon*) is widely farmed in this area [4].

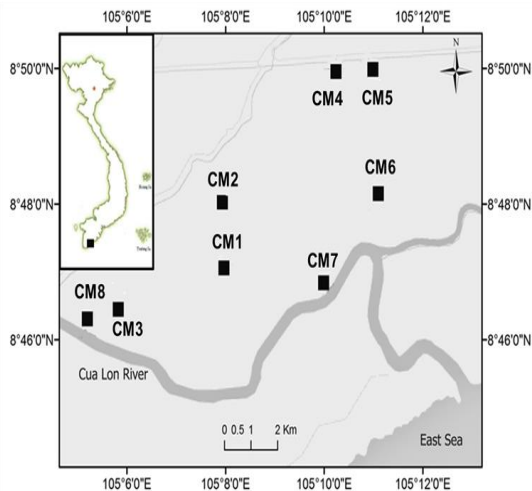


Fig. 1. Map of the sampling stations

Sampling and laboratory techniques

Nematode samples were collected by mean of 10 cm² cores, pushed into the sediment at least 10 cm depth. In each of these ponds, three replicates were collected (right, middle and left bank of pond). All samples were fixed in a 7% formaldehyde solution (heated to 60°C) and gently stirred. In the laboratory, samples were sieved through a 38 μm mesh and extracted by flotation with Ludox - TM50 (specific gravity of 1.18) [18]. Samples were stained with 3–5 mL Rose Bengal solution 1%. All individual numbers were counted

and one hundred nematode specimens were used for making slides and identification processed according to De Grisse (1969) [19].

Nematodes were identified to genus level by using the following literature: Warwick et al. (1988) [20], Zullini (2005) [21], Nguyen (2007) [22] and the NeMys online identification key [23].

Data analysis

Nematode dry biomass was calculated by measuring the maximum length (L - μm), excluding the filiform tails, and the maximal body width (W - μm) of nematodes using an image analyzer (Axiocam Zeiss). Individual nematode wet biomass (μg) was calculated using Andrassy's formula for body mass [24]: Wet biomass (μg) = L × W²/1600000, where L represents the nematode length (μm) and W the nematode width (μm). The individual dry biomass (μg) was estimated as 25% of the wet biomass [25]. Total dry biomass was then calculated by all individual genus biomass, and the total number of nematode per sample measured, and their corresponding average abundances.

The ABC curves were used to detect the EcoQ in Tam Giang's OSFP. This method involves the plotting of k - dominance curves for species abundances and species biomasses on the same graph and making a comparison of these curves forms. The species ranked in order of importance in terms of abundance or biomass on a logarithmic scale (x - axis) against percentage dominance on a cumulative scale (y - axis). The relative position of these curves has been suggested as a measure of the degree of stressed. There are three levels of environmental disturbance: Under an unstressed environment the biomass curve overlies the abundance curve for its entire length as an indication of the dominance of a few large species (k - selected species). In a highly stressed, the abundance curve overlies the biomass curve as a result of numerical dominance of a few opportunistic species with small body sizes (r - selected species). The degree and direction of the separation of these curves, which represents the area between the two curves is given by the W - statistic [26] and expressed as:

$$W = 2(pA - pB)/(S - 1)$$

In which: pA and pB are the "average species rank" for abundance and biomass and S is the

number of species. W - statistic takes values in the range (-1 to 1) with W close to 1 for equal abundances across species but biomass dominated by a single species, and W close to -1 for the converse case indicating that the biomass curve lies below the abundance curve and thus the more stressed the community and degraded the system. The ABC curves were drawn using the statistical software PRIMER VI of Plymouth Marine laboratory, UK.

Two way ANOVA test was carried out to compare the abundance and total dry biomass between seasons (dry – transfer - rainy) and between ponds (CM1 – CM8). All variables were log - transformed to normalize their distributions before analysis. All statistical analysis were performed using the software STATISTICA 7.0. P - Values < 0.05 were considered significant.

3. RESULTS AND DISCUSSION

Nematode abundance and total dry biomass

The results of present study showed that

nematode communities in Tam Giang's OSFP were characterized by high abundance through three surveys. In the dry season, the average abundance (inds/10 cm²) ranged from 221.67 ± 122.08 (CM7) to 2539.33 ± 1403.33 (CM6). The transfer and rainy season also showed a high density, from 1020.00 ± 354.30 (CM6) to 7254.67 ± 5454.39 (CM5), 822.00 ± 1086.17 (CM5) – 4608.33 ± 1302.02 (CM4), respectively (Fig. 2A). Regarding total dry biomass (µg/10cm²), in the dry season varied from 51.11 ± 28.64 to 450.87 ± 49.53, it is lower than the transfer season (ranged from 412.93 ± 291.87 to 1607.25 ± 507.42) and the rainy season (measured from 49.54 ± 39.36 – 1874.09 ± 3033.16) (Fig. 2B).

The two way ANOVA showed significant differences for pond, season and the interaction terms season * pond effect on total dry biomass at the 95% confidence level (p – pond = 0.006, p – seasons = 0.02 and p – pond * season = 0.04). However, significant differences between pond and season for nematode abundance were found (p – pond = 0.02, p – seasons = 0.005 and p – pond * season = 0.20).

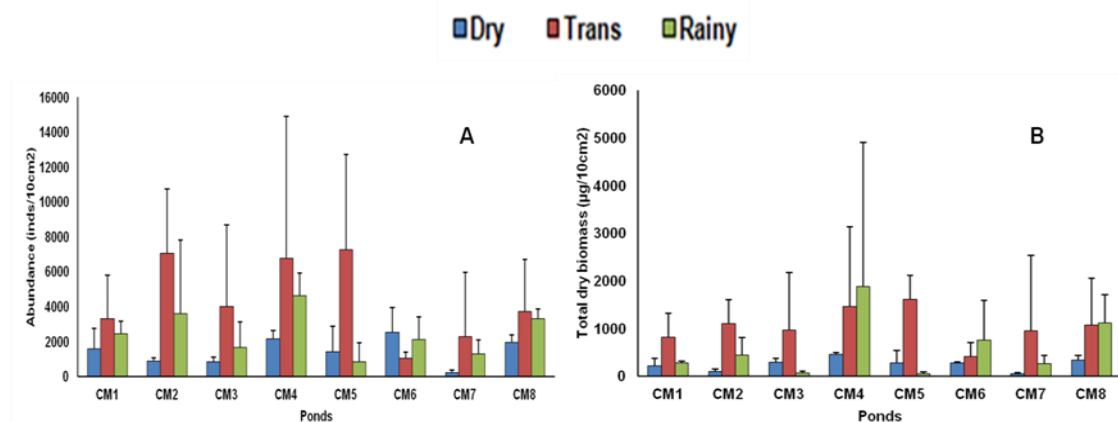


Fig. 2. The average and standard deviation for nematode abundance (A) and total dry biomass (B)

The ecological quality status of sediment was indicated by the abundance/biomass comparison method

In the dry season, the genus *Ptycholaimellus* and *Terschellingia* were known as the dominant genera. More specifically, the abundance (inds/10 cm²) of *Ptycholaimellus* was 167.32 ± 286.83 in CM1, 235.55 ± 178.28 in CM6, *Terschellingia* was 327.30 ± 189.99 in CM2, 151.67 ± 35.15 in CM4. However, they have a low biomass. For example,

in CM1 and CM6, total dry biomass (µg/10 cm²) of *Ptycholaimellus* was 23.55 ± 40.73, 19.68 ± 12.17, respectively. Hence, the ABC curves for the abundance and dry biomass generally showed stress and moderate condition in most of these ponds (Fig. 3). Stressed condition was observed mostly in the dry season, except for CM3 and CM7 were classified as moderate. Genera contributing more to the biomass in transfer season were *Pomponema* and *Sphaerolaimus* in CM1

(215.96 ± 110.05 , 211.61 ± 302.48 , respectively). In addition, *Terschellingia* was an abundant genus as well as dominated in biomass in transfer season (3249.19 ± 4603.88 inds/10 cm², 466.13 ± 688.16 $\mu\text{g}/10$ cm², respectively). Contrary to the EcoQ in the dry season, the ABC curves in the transfer season indicated unstressed condition in most of the ponds (4 out of 8). Unstressed condition was observed in CM1, CM3, CM6, CM7, while moderately stressed condition was noticed in CM2,

CM8. The ponds CM4, 5 had been classified as stressed condition (Fig. 4). In the rainy season, the ABC curves and W values showed stressed and moderately stressed condition in most of the ponds (Fig. 5) whereas unstressed condition was observed only in one pond (CM4). The genera *Terschellingia* and *Daptonema* have been recognized as the highest biomass as well as number of individuals.

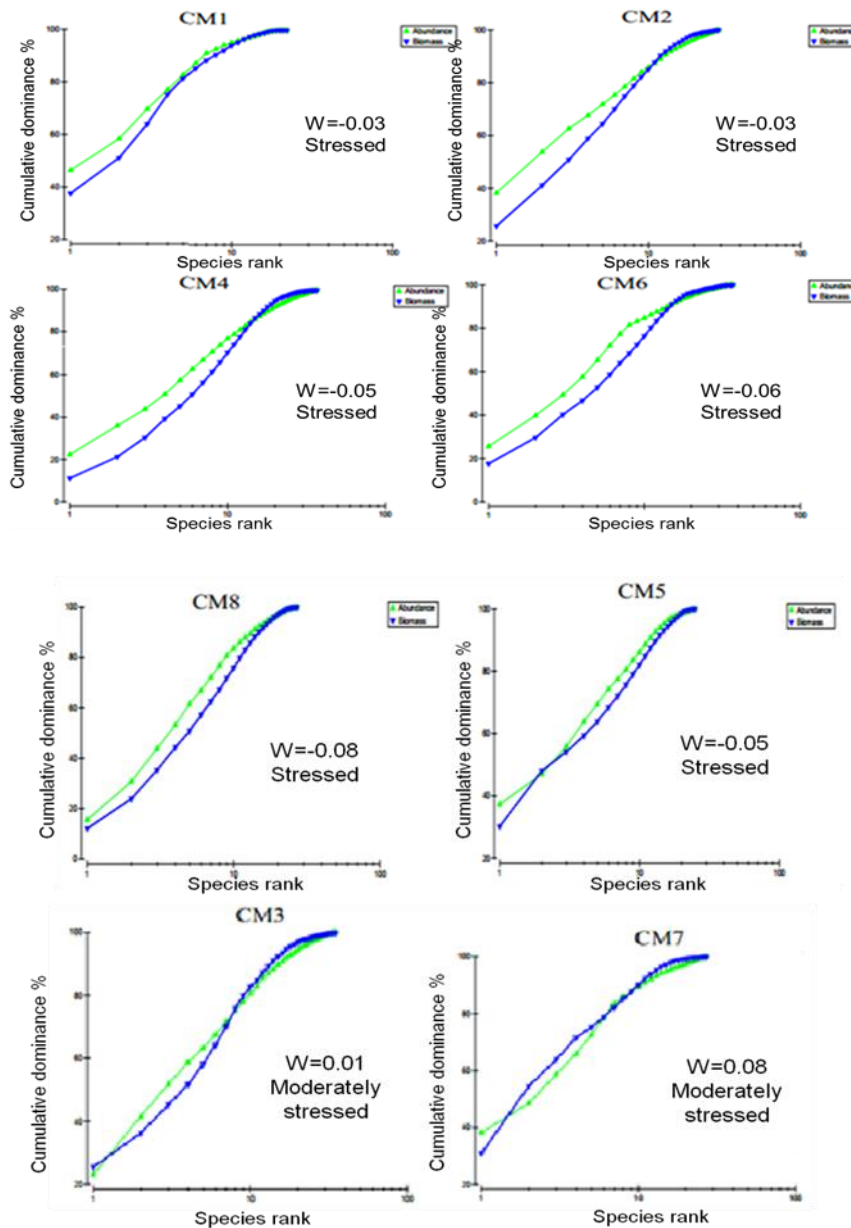


Fig. 3. The ABC curves and W values in the dry season

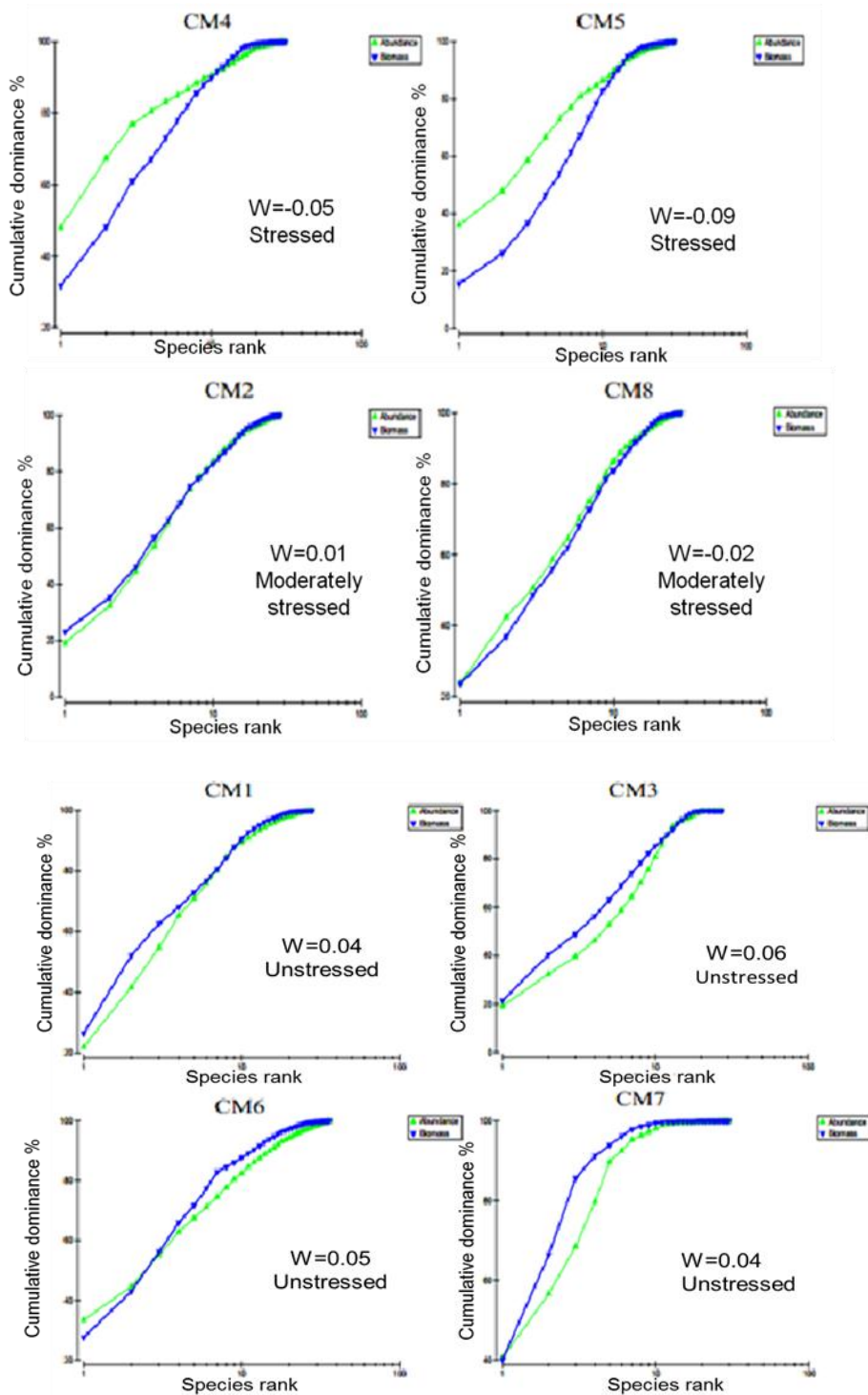


Fig. 4. The ABC curves and W values in the transfer season

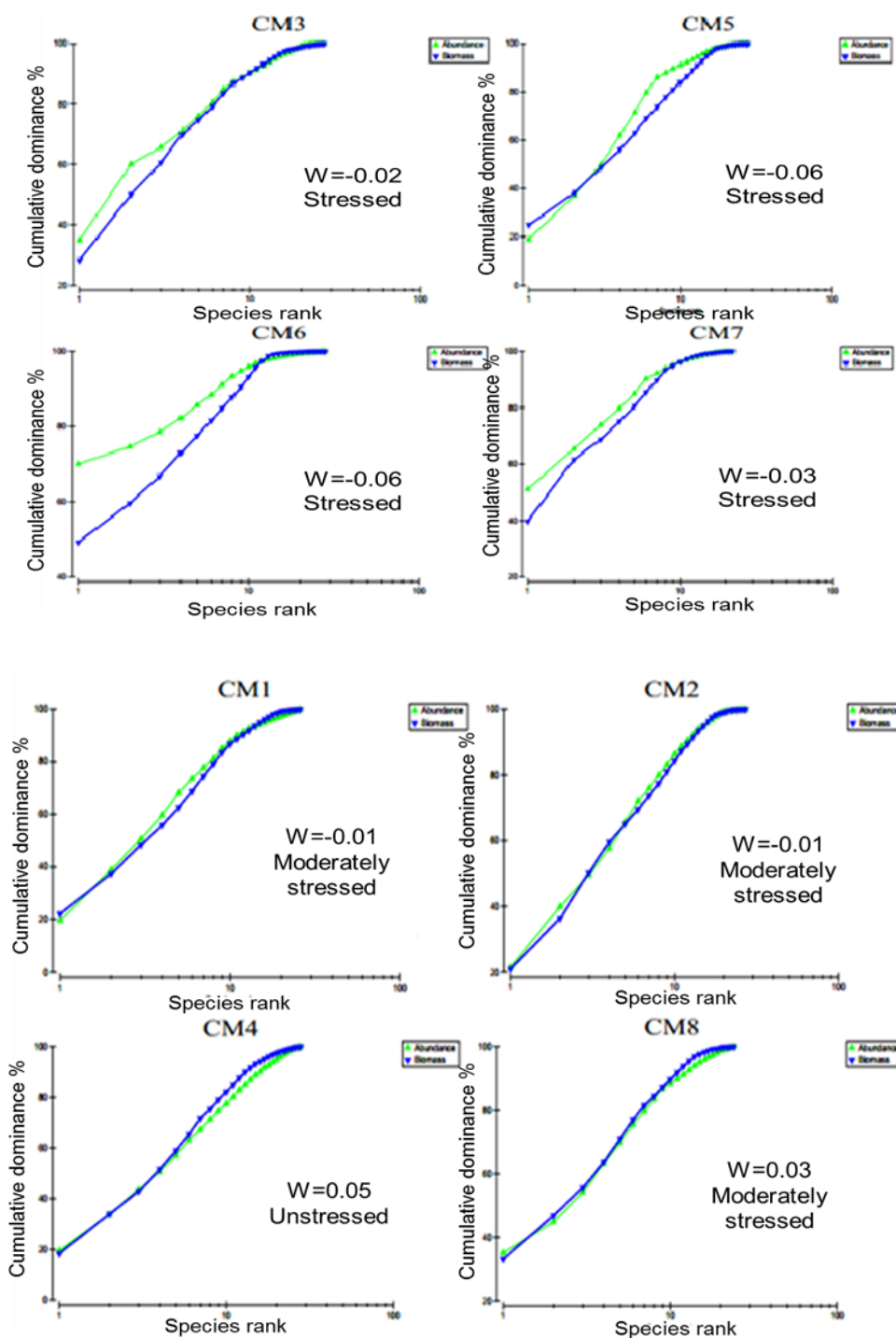


Fig. 5. The ABC curves and W values in the rainy season

In Vietnam, there are many scientific studies provided information about mangrove forest, but too few studies mentioned of the OSFP. The present study is one of the first research that use

nematode communities to detect the environmental stress on the OSFP. In general, the ABC curves and W values indicated that a lightly stressed in EcoQ in most seasons, except for the transfer

season which has been recognized as the highest environmental sediment quality. Nguyen et al. (2017) warned that the environmental characteristics in Tam Giang's OSFP may also be not quite optimal for shrimp farming, such as high percentage of TN, TOC, low pH and anaerobic condition in the sediment [4]. It could be one of the major reasons why the EcoQ in Tam Giang's OSFP was classified as lightly stressed in most seasons.

Application of the ABC method to detect the EcoQ in OSFP, Ca Mau province for classification of communities as stressed, or unstressed, is strongly influenced by the presence of these genera that dominate both the biomass and individuals curve, e.g. *Ptycholaimellus*, *Terschellingia*, *Pomponema*, *Sphaerolaimus*, and *Daptonema*. It is known that, *Terschellingia* selected as indicators of a poor ecological quality status because of their well-known tolerance to pollution [27], the genus *Daptonema* is typically found in organically rich, muddy sediment [28] and has been proposed to be representative of a community that is well adapted to stressed conditions [29]. The indicator genus *Sphaerolaimus* is again known to inhabit stressed and anoxic sediments [30]. By contrast, *Ptycholaimellus*, *Pomponema* have been recognized as the most sensitive to ecological disturbance [11].

Some limitations for the use of ABC method

Two approaches were developed for detecting the structural and functional responses of nematode communities to natural and anthropogenic disturbances: (i) the taxonomic approach such as taxonomic diversity, maturity index and trophic diversity [11, 12], and (ii) non-taxonomic approaches such as comparison of abundance/biomass curves (ABC method) were based on sound ecological principles instead of on statistical properties. The ABC curves are a sensitive indicator of natural, physical and biological disturbance as well as pollution induced disturbances [31]. These curves are used by some authors for detecting the physical disturbances and stress [32, 33, 34, 35]. However, unfortunately, it did not show the abilities to discriminate the main factors effected biomass between natural stress and pollution-induced stress [36].

Stress is a disturbance applied to a system by a stressor which is foreign to that system or which may be natural to it. Pollution is an obvious stressor [37]. Indeed, stress is an characteristic of the normal function of the ecosystems [38]. Stress is also from normal ecosystems [39] and in any cases, the physical disturbance and instability of sediments were the main factors rather than pollution in maintaining the macrobenthic communities [33]. In using ABC method, ecologist expertise will not know the cause of the disturbance, if available, because the response of ecosystems is similar to both natural environmental stress and other stress. The ABC method did not show the abilities to discriminate the main factors effected biomass between natural stress and pollution stress. Many researches have concentrated on ecosystem responses, e.g. changes in community structure (ABC method). Hence, we include the ecosystem, physiological and biochemical variables in our study, we can find main cause effected biomass between natural stress or pollution stress. In this study, the ABC curves and W values indicated that a lightly stressed in sediment environmental quality in most seasons in a year, especially in for the transfer season. The main cause may be a natural environmental stress (pH, temperature, salinity, etc.). Further research should be combined ABC method and physico-chemical values to potentially increase the precise answer of this issue.

4. CONCLUSION

These empirical data combined with the field survey ones data indicate ABC method has been used successfully for detecting EcoQ in Tam Giang's OSFP, Ca Mau province. The results showed that a lightly stressed EcoQ in most seasons, especially in the transfer season which has been recognized as the highest EcoQ. However, ABC curves, used as a method for detecting disturbance effects without prior knowledge of the site, is certainly restricted and needs further investigation. No single method of analysis is likely to produce stress classifications without unacceptable misclassifications. The ecological stress, from any source, is best measured by multiple methods or analyses with different assumptions.

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Đánh giá chất lượng môi trường sinh thái nền đáy trong các ao nuôi tôm sinh thái ở tỉnh Cà Mau bằng áp dụng phương pháp ABC (Abundance/Biomass Comparison) lên quần xã tuyến trùng

Trần Thành Thái^{1,2}, Nguyễn Thị Mỹ Yên¹, Ngô Xuân Quảng¹, Lê Diệu Linh³

¹Viện Sinh học Nhiệt đới, Viện Hàn lâm Khoa học và Công nghệ Việt Nam, ²Trường Đại học Khoa học Tự nhiên, ĐHQG-HCM,

³Trường Đại học Tôn Đức Thắng

Tác giả liên hệ: thanhthai.bentrect@gmail.com

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Tóm tắt—Quần xã tuyến trùng tại 8 ao nuôi tôm sinh thái tại xã Tam Giang, huyện Năm Căn, tỉnh Cà Mau được khảo sát trong 3 mùa (tháng 3 – mùa khô, tháng 7 – chuyển mùa và tháng 11 – mùa mưa). Kết quả cho thấy mật độ trung bình của quần xã (cá thể/10 cm²) dao động từ 221,67 ± 122,08 đến 2539,33 ± 1403,33 trong mùa khô. Chuyển mùa và mùa mưa cũng ghi nhận mật độ cao (1020,00 ± 354,30 đến 7254,67 ± 5454 và 39, 822,00 ± 1086,17 – 4608,33 ± 1302,02, tương ứng). Tổng sinh khối khô trung bình (µg/10 cm²) của quần xã tuyến trùng trong các ao tôm từ 51,11 ± 28,64 đến 450,87 ± 49,53 ở mùa khô, từ 412,93 ± 291,87 đến 1607,25 ± 507,42 ở chuyển mùa và từ 49,54 ± 39,36 đến 1874,09 ± 3033,16 trong mùa mưa. Phương pháp ABC (Abundance/Biomass Comparison) đã được áp dụng thành công trong

đánh giá chất lượng môi trường sinh thái nền đáy trong 8 ao tôm sinh thái. Kết quả ghi nhận hầu hết các ao trong 3 mùa khảo sát có hệ sinh thái nền đáy đang bị xáo trộn nhẹ (stressed). Tuy nhiên, chuyển mùa có chất lượng nền đáy tốt nhất trong 3 mùa khảo sát. Mặc dù kết quả đánh giá được hiện trạng sinh thái nền đáy ở các ao tôm nhưng nguyên nhân gây ra sự xáo trộn đó do điều kiện tự nhiên tác động hay do ô nhiễm còn chưa được sáng tỏ.

Từ khóa—Ao tôm sinh thái, chất lượng sinh thái nền đáy, chỉ thị sinh học, quần xã tuyến trùng, so sánh sinh khối/mật độ