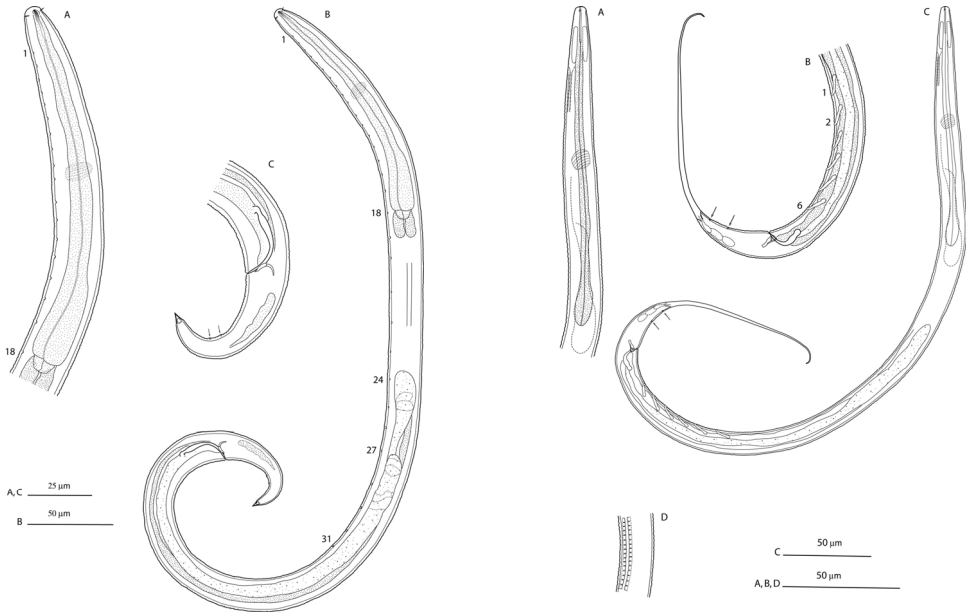
Meiobenthos with special reference to free-living marine nematodes as bioindicators for different mangrove types in Can Gio Biosphere Reserve, Vietnam



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ABSTRACT

In 2000, Can Gio mangrove became the first Biosphere Reserve of Vietnam with a total area of 75,740 ha. The major habitat types are rehabilitated mangrove (23,028 ha, *Rhizophora apiculata* with 96.7%), and naturally regenerating mangrove (7,829 ha).

Hypothesis of the study is that rehabilitated monoculture mangrove forest cohorts and natural forests differ in their vegetation and physical properties such as topography, sedimentary patterns, hydrography, in such that benthic community structure and system function is impacted.

Objective of this work is to study meiobenthic community structures with special reference to nematodes in rehabilitated monoculture and natural regenerated mangrove forests, and to use them as bioindicators for different mangrove types in Can Gio Biosphere Reserve.

Therefore, the major activities are: (i) To investigate and compare total meiobenthic community structures in rehabilitated monoculture and natural regenerated mangrove forests in the dry and rainy seasons. (ii) To compare nematode community structures in rehabilitated monoculture and natural regenerated mangrove forests in the dry and rainy seasons, including: definition of species compositions, age structures, trophic structures, diversity indexes, analyze community structures by graphical/distribution plots such as k-dominance curve and by multivariate statistical methods such as cluster analysis, multi-dimensional scaling (MDS), analysis of similarities (ANOSIM) and similarities percentage procedure (SIMPER)

Meiobenthic communities were investigated along three tidal creeks. In each creek, samples were taken within a mud flat (Mud) site and at 3 different types of mangrove from the mouth to the upper reaches of the creek: natural *Avicennia* (Avi) forest; natural mixed forest of *Avicennia* and *Rhizophora* (Mix) and rehabilitated *Rhizophora* (Rhi) forest during the rainy season 2004 and both the dry and rainy season of 2005.

Meiobenthic composition mainly included nematodes, copepods, nauplii, foraminifera, polychaetes, oligochaetes, kinorhynchs, acari, ostracods, and others less abundant group (bivalves, gastropods, insect larvae, turbellaria, nemertinea).

In three creeks, meiobenthic densities were highest in Khe Nhan Creek (2440 ind/10cm^2), lowest in Nang Hai Creek (1303 ind/10 cm^2) and in the middle in Rach Oc Creek (2158 ind/10 cm^2). Meiobenthic densities in Mudflat and Mixed forests were higher than in *Avicennia* forests or *Rhizophora* forests.

Nematodes were the most abundant meiobenthic group at all stations. Nematode percent contribution to total meiofauna was highest in Khe Nhan Creek (91.1%), and lower in Nang Hai Creek (88.0%) and Rach Oc Creek (87.1%). Nematode percent contribution to total meiofauna in Mixed forests and Mudflat sites was higher than in *Avicennia* and *Rhizophora* forests. In Nang Hai Creek, however, nematode percentages were the lowest in Mudflat site (65.9%). Copepods were the second most abundant group, with highest densities in Nang Hai Creek (4.7%), and density peaks at the Mudflat site of this creek (117 ind/10cm^2). Foraminifera were second most abundant in Khe Nhan and Rach Oc Creeks, with highest percentages in *Rhizophora* forest. Meiobenthic density in the dry season was higher than in the rainy season. Nematode and copepod densities increased, while nauplii and foraminifera reduced in the dry season.

Nematode community had high diversity, including 214 putative species, belonging to 92 genera, 36 families, and 10 orders. The family Leptolaimidae had 27 species belonging to 6 genera. Genus *Leptolaimoides* previously contained 5 known species, the present study contributing to 5 new species *L. tropicus* sp. nov., *L. cangioensis* sp. nov., *L. mangrovi* sp. nov., *L. clavicaudatus* sp. nov. and *L. hexatubolosus* sp. nov..

Genus *Deontolaimus* had a typical single species, the present study contributing to 2 new species *D. mangrovi* sp. nov. and *D. pseudopapillatus* sp. nov..

In the dry season, 200 putative species were recorded, belonging to 89 genera, 34 families and 10 orders. 17 families with abundance higher than 1% represented 87.8% of total nematode individuals, most important families were Linhomoeidae, Xyalidae, Comesomatidae. Most abundant species were *Theristus* sp1, *Hopperia* sp1, *Paracomesoma* sp2, *Terschellingia* sp3, *Terschellingia* sp4, *Parodontophora* sp1, and *Dichromadora* sp1. In the rainy season, the nematode community included 205 species, belonging to 90 genera, 36 families and 10 orders. 19 families with the abundance higher than 1% occupied 85% of total nematode individuals. The most important families were Xyalidae, Linhomoeudae, Comesomatidae. Between seasons, the number of individuals of Linhomoeidae, Chromadoridae, Oxystominidae reduced drastically from dry season to rainy season. On the other hand, individuals of Criconematidae and Leptolaimidae increased from dry season to rainy season. The most abundant species in the rainy season were *Paracomesoma* sp2, *Hopperia* sp1, *Terschellingia* sp3, *Terschellingia* sp4, *Dichromadora* sp1, *Theristus* sp1 and *Haliplectus* sp1. Between two seasons *Theristus* sp1 reduced from the first position in dry season to the sixth position in rainy season, *Hopperia* sp1 and *Paracomesoma* sp2 changed a little.

Age composition showed that juveniles were most abundant in all sites in both seasons. Highest abundance of juveniles was found in the Mudflat site, and male/female ratios increased from Mudflat site to *Avicennia* forest to Mixed forest and *Rhizophora* forest.

Trophic structure showed that non-selective deposit feeders (1B) and epistratum feeders (2A) were dominant in Mudflat sites, while selective deposit feeders (1A) were dominant in *Avicennia* forests, Mixed forests, and *Rhizophora* forest. In addition, predators and phytoparasitic nematodes in *Rhizophora* forests were also higher than at all other sites.

Nematode diversity indexes were generally high. Shannon-Wiener diversity indexes H' ranged from 1.9 to 3.7, evenness J from 0.6-0.9 through out all stations. Diversity was higher in *Avicennia* and Mixed forests than in Mudflat and *Rhizophora* forests. In both the dry and rainy seasons, the diversity in Mudflat areas was mainly reduced due to 2 dominant species: *Theristus* sp1 and *Paracomesoma* sp2 and in the rainy season in *Rhizophora* forests by the phytoparasitic nematode *Criconemella* sp1.

Base on composition and abundance of the nematode community, sample stations clustered into 3 main groups: Group 1 included all stations of the Mudflat site, three subtidal stations of *Avicennia* forest, Mixed forest and *Rhizophora* forest; Group 2 contained intertidal stations of *Avicennia* forest and Mixed forest; Group 3 included intertidal stations of *Rhizophora* forest. The separation was clearer in the dry season than in the rainy season.

Most important typifying species in Mudflat site were *Theristus* sp1*, Paracomesoma* sp2*, Pseudolella* sp1 and *Hopperia* sp1. In *Avicennia* and Mixed forest, most important typifying species were *Terschellingia* sp3, *Terschellingia* sp4, *Dichromadora* sp1, *Ptycholaimellus* sp1, *Astomonema* sp1 and *Pseudochromadora* sp1. In *Rhizophora* forest, the most important typifying species were *Hopperia* sp1, *Sphaerolaimus* sp3 *Anoplostoma* sp1, *Haliplectus* sp3, *Dichromadora* sp1 and *Criconemella* sp1.

Above results showed that meiobenthos and nematode community structure varied in different types of mangrove in both the dry and rainy seasons. This variation can be used to separate naturally regenerated forest and rehabilitated forests, as well as forest types and mudflat sites in Can Gio Biosphere Reserve. The most important characteristics to be considered are: (i) densities of total meiobenthos, nematodes, foraminifera; (ii) nematode trophic structure; (iii) nematode diversity indexes (iv) nematode assemblage based on multivariate analysis.

ZUSAMMENFASSUNG

Im Jahre 2000 wurde in den Can Gio Mangroven das erste Biospheren Reservat Vietnams eingerichtet. Es hat eine Größe von 75740 ha. Die größten Anteile am Habitat haben aufgeforsteten Mangroven (23028 ha, 96.7% *Rhizophora apiculata*) und durch natürliche Prozesse regenerierte Abschnitte (7829 ha).

Der Ausgangspunkt dieser Untersuchung ist die Annahme, dass Mangroven aus gleichzeitig angepflanzten Monokulturen und natürlich gewachsene Wälder sich in ihrer Vegetation und ihren Umweltbedingungen wie Topographie, Sedimentablagerungen und Hydrographie in einer Art und Weise unterscheiden, dass dadurch die Zusammensetzung und Lebensweise der Meiobenthos Populationen beeinflusst werden.

Das Ziel dieser Arbeit ist es Meiobenthos Populationen, unter besonderer Berücksichtigung von Nematoden, in aufgeforsteten Monokulturen und natürlich regenerierten Mangroven Wäldern zu untersuchen, und diese als Biomarker für unterschiedliche Mangroventypen im Can Gio Biospheren Reservat zu nutzen.

Aus diesem Grund sind die Hauptaktivitäten:

(i) Untersuchung und Vergleich der Struktur der Gesamt Meiobenthos Population in aufgeforsteten Monokulturen und natürlich regenerierten Mangroven Wäldern während der Trocken- und Regenzeit. Die Hauptgruppen sind: Nematoden, Copepoden, Nauplii, Foraminifera, Polychaeten, Oligochaeten, Kinorhynchen, Acari, Ostracoden

(ii) Der Vergleich der Struktur von Nematoden Populationen in aufgeforsteten Monokulturen und natürlich regenerierten Mangroven Wäldern während der Trocken- und Regenzeit, unter Berücksichtigung von: Beschreibung von Artenzusammensetzung, Altersstruktur, Nahrungsgewohnheiten, Diversitäts Indexen, Analyse der Artenzusammensetzung anhand graphischer Darstellung wie k-Dominanz Kuven und multivariaten statistischen methoden wie die Cluster- Analysis, Multi-Dimensional Scaling (MDS), analysis of similarities (ANOSIM) und similarities percentage procedure (SIMPER)

Meiobenthos Population wurden entlang dreier Priele untersucht. In jedem Priel wurden Proben innerhalb des Watts (Mud) und in drei verschiedenen Arten von Mangrovenwald genommen. Diese waren (von der Mündung bis zum Oberlauf des Priels): natürlicher *Avicennia* (Avi) Wald, natürlich gemischter *Avicennia* und *Rhizophora* (Mix) Wald, sowie angepflanzter *Rhizophora* (Rhi) Wald. Alle Stellen wurden sowohl während der Trocken- als auch während der Regenzeit 2005 beprobt.

Die Artenzusammensetzung des Meiobenthos bestand hauptsächlich aus Nematoden, Copepoden, Nauplii, Foraminifera, Polychaeten, Oligochaeten, Kinorhynchen, Acari, Ostracoden und anderen weniger abundanten Gruppen (Bivalven, Gastropoden, Insektenlarven, Turbellaria, Nemertinea)

Im Vergleich der drei untersuchten Priele zeigte sich, dass die Bevölkerungsdichte des Meiobenthos im Khe Nhan Priel am höchsten, im Nang Hai Creek am niedrigsten und im Rach Oc Priel dazwischen liegend war. Die Bevölkerungsdichte in natürlichen gemischten Wälder war höher als in den *Avicennia* oder *Rhizophora* dominierten Wäldern.

Nematoden waren an allen Stationen die meiobenthische Gruppe mit der höchsten Abundanz. Der höchste prozentuale Anteil an der gesamten vorhandenen Meiofauna wurde für Nematoden im Khe Nhan Priel gemessen. In den Nang Hai and Rach Oc

Prielen war der Anteil geringer. Der prozentuale Anteil an Nematoden in der gesamten Meiofauna war in natürlichen gemischten Wäldern und im Watt höher als in den *Avicennia* oder *Rhizophora* dominierten Wäldern. Innerhalb des Nang Hai Priels jedoch, war der prozentuale Anteil der Nematoden im Watt am niedrigsten. Copepoden hatten die zweit höchste Abundanz im Meiobenthos, mit höchsten Bevölkerungsdichten im Nang Hai Priel, vor allem in dessen vorgelagertem Watt. Foraminifera hatte die zweit höchste Abundanz in den Khe Nhan und Rach Oc Prielen und zeigte die höchsten prozentualen Anteile an der gesamten vorhandenen Meiofauna in den angepflanzten *Rhizophora* Wäldern. Bevölkerungsdichte der Meiofauna war in der Trockenzeit höher als in der Regenzeit. Für Nematoden und Copepoden nahm die Bevölkerungsdichte in der Trockenzeit zu, während sie bei Nauplii und Foraminifera abnahm.

Die Nematodengemeinschaft zeigte sich als sehr divers, da 214 putative Arten, aus 92 Gattungen, 36 Familien und 10 Ordnungen identifiziert werden konnten. Die Familie Leptolaimidae war mit 27 Arten aus 6 Gattungen vertreten. Die Gattung *Leptolaimoides* bestand bisher aus fünf bekannten Arten, der diese Studie fünf weitere Arten hinzufügt: *L. tropicus* sp. nov., *L. cangioensis* sp. nov., *L. mangrovi* sp. nov., *L. clavicaudatus* sp. nov. und *L. hexatubolosus* sp. Nov. Auch der Gattung *Deontolaimus*, bisher nur aus einer Art bestehend, konnten durch diese Studie zwei neue Arten hinzu gefügt werden: *D. mangrovi* sp. nov. und *D. pseudopapillatus* sp. nov..

In der Trockenzeit konnten in der Nematodengemeinschaft 200 putative Arten, aus 89 Gattungen, 34 Familien und 10 Ordnungen verzeichnet werden. Die Gesamtheit der vorhandenen Nematoden Population setzte sich zu 87,8% aus 17 Familien zusammen, für die alle eine Abundanz von mehr als 1% festgestellt werden konnte. Die wichtigsten Familien waren die Linhomoeidae, Xyalidae und die Comesomatidae. Arten mit der höchsten gesamten Abundanz waren *Theristus* sp1, *Hopperia* sp1, *Paracomesoma* sp2, *Terschellingia* sp3, *Terschellingia* sp4, *Parodontophora* sp1 und *Dichromadora* sp1. In der Regenzeit konnten in der Nematodengemeinschaft 205 putative Arten, aus 90 Gattungen, 36 Familien und 10 Ordnungen verzeichnet werden. Die Gesamtheit der vorhandenen Nematoden Population setzte sich zu 85% aus 19 Familien zusammen, für die alle eine Abundanz von mehr als 1% festgestellt werden konnte. Die wichtigsten Familien waren die Xyalidae, Linhomoeudae und die Comesomatidae. Von der Trockenzeit zur Regenzeit nahm der Anzahl der Individuen, aus den Familien Linhomoeidae, Chromadoridae und Oxystominidae, drastisch ab. Andererseits nahm die Anzahl der Individuen aus den Familien Criconematidae and Leptolaimidae von der Trockenzeit zur Regenzeit zu Arten mit der höchsten gesamten Abundanz waren *Paracomesoma* sp2, *Hopperia* sp1, *Terschellingia* sp3, *Terschellingia* sp4, *Dichromadora* sp1, *Theristus* sp1 und *Haliplectus* sp1. *Theristus* sp1 wurde während Trockenzeit mit der höchsten Abundanz verzeichnet, die aber in der Regenzeit auf den sechsten Platz absank. Die Abundanz von *Hopperia* sp1 und *Paracomesoma* sp2 veränderte sich nur wenig.

Die Altersgruppenzusammensetzung der Nematodengemeinschaft zeigte das juvenile Nematoden an allen Probenpunkten und zu beiden Jahreszeiten die höchste Abundanz hatten. Die höchste Abundanz wurde für diese Gruppe im Watt festgestellt. Das Geschlechterverhältnis vergrößerte sich vom Watt aus zum *Avicennia* Wald, zum gemischten Wald und hin zu dem *Rhizophora* Wald.

Die trophische Struktur zeigte eine Dominanz von nicht-selektiven Ablagerungsfressern (1B) und Epistratfressern (2A) im Watt, in *Avicennia* Wäldern und gemischtem Wald, während *Rhizophora* Wälder von selektiven Ablagerungsfressern dominiert wurden,

und wo auch Raub- und Pytoparasitische Nematoden in den größten Zahlen anzutreffen waren.

Der errechnete Diversitätsindex für Nematoden waren durchgehen hoch. Der Shannon-Wiener Diversitäts Index ergab H'-Werte zwischen 1.9 und 3.7 und Evenness J-Werte zwischen 0,6 und 0,9 für alle Stationen. Die Diversität war höher in *Avicennia* und gemischten Wäldern, als in *Rhizophora* Wälder und dem vorgelagerten Watt. In der Regenzeit wurde die Diversität im Watt hauptsächlich durch die Verringerung zwei dominanter Arten ausgelöst, *Theristus* sp1 and *Paracomesoma* sp2, währen dies in *Rhizophora* Wälder durch die phytoparasitische Nematode *Criconemella* sp1 verzeichnet wurde.

Auf der Zusammensetzung und der relativen Abundanzen in der Nematodengemeinschaft basierend, konnten drei Hauptgruppen geformt werden: Gruppe 1 beinhaltet alle Stationen im Watt, drei subtidale Stationen in *Avicennia* Wäldern, die gemischten und *Rhizophora* Wälder; Gruppe 2 beinhaltet intertidale Stationen in *Avicennia* und gemischten Wäldern; Gruppe 3 beinhaltet intertidale Stationen in *Rhizophora* Wäldern. Diese Aufteilung war in der Regenzeit klarer zu erkennen.

Die wichtigsten für das Watt typifizierenden Arten waren *Theristus* sp1*, Paracomesoma* sp2*, Pseudolella* sp1 und *Hopperia* sp1. In *Avicennia* und gemischten Wäldern waren diese Arten: *Terschellingia* sp3, *Terschellingia* sp4, *Dichromadora* sp1, *Ptycholaimellus* sp1, and *Pseudochromadora* sp1. In *Rhizophora* Wäldern wurde diese Rolle von *Hopperia* sp1, *Sphaerolaimus* sp3 *Anoplostoma* sp1, *Haliplectus* sp3 und *Dichromadora* sp1 gefüllt.

Die oben dargestellten Ergebnisse zeigen, dass dass sowohl der gesamte Meiobenthos, so wie auch die Nematodengemeinschaft in verschiedenen Wäldern über beide Jahreszeit variierten und diese Variation verwendet werden kann, um zwischen natürlichen gemischten und angepflanzten Wäldern differenzieren zu können, sowie auch zwischen dem Watt und verschiedenen Wald Typen im Can Gio Biospheren Reservat. Faktoren mit der höchsten Ausagekraft in diesem Kontext waren: (i) Bevölkerungsdichte des gesamten Meiobenthos, der Nematoden und von Foraminifera; (ii) Die trophische Struktur der Nematodengemeinschaft; (iii) Diversitätsindex für Nematoden; (iv) Multivariate Analyse der Nematodengemeinschaft.

TÓM TẮT

Rừng ngập mặn Cần Giờ được công nhận là Khu dự trữ Sinh quyển đầu tiên của Việt Nam vào năm 2000 với tổng diện tích 75.740 ha. Thảm thực vật ở đây chủ yếu là rừng trồng lại chiếm 23.028 ha, trong đó đước đôi *Rhizophora apiculata* chiếm 96,7%, và một phần nhỏ 7.829 ha là rừng tái sinh tự nhiên.

Giả thiết của đề tài đặt ra là rừng ngập mặn trồng lại với chỉ một loài duy nhất là đước đôi và rừng tái sinh tự nhiên khác nhau về cấu trúc của thảm thực vật, các đặc điểm vật lý của môi trường như địa mạo, trầm tích, thủy văn, tất cả những điều này đã tác động đến cấu trúc quần xã động vật đáy và tác động đến chức năng của hệ sinh thái.

Mục đích của đề tài là nghiên cứu cấu trúc quần xã động vật đáy cỡ trung (sau đây gọi tắt là động vật đáy) đặc biệt quan tâm đến nhóm tuyến trùng sống tự do trong rừng ngập mặn trồng lại và rừng tái sinh tự nhiên và sử dụng chúng như những chỉ thị sinh học để phân biệt các kiểu rừng ngập mặn ở Khu dự trữ Sinh quyển Cần Giờ.

Các yêu cầu chính đặt ra là: (i) Điều tra và so sánh cấu trúc quần xã động vật đáy ở rừng ngập mặn trồng lại và rừng tái sinh tự nhiên ở mùa khô và mùa mưa; (ii) So sánh cấu trúc quần xã tuyến trùng ở rừng ngập mặn trồng lại và rừng tái sinh tự nhiên ở mùa khô và mùa mưa, bao gồm: nghiên cứu thành phần loài, cấu trúc tuổi, các nhóm dinh dưỡng, các chỉ số đa dạng sinh học, phân tích cấu trúc quần xã bằng đường cong ưu thế 'k-dominance curve' và phương pháp phân tích đa biến (multivariate analysis) cụ thể như 'cluster analysis', 'multi-dimensional scaling' (MDS), 'analysis of similarities' (ANOSIM) và 'similarities percentage procedure' (SIMPER).

Quần xã động vật đáy được nghiên cứu dọc theo ba rạch triều. Ở mỗi con rạch, mẫu được thu ở khu vực bãi bùn (Mud) và tại ba kiểu rừng ngập mặn khác nhau từ cửa rạch đến bên trong lần lượt là: rừng mắm tái sinh tự nhiên *Avicennia* (Avi); rừng hỗn giao mắm và đước tái sinh tự nhiên (Mix) và rừng đước trồng *Rhizophora* (Rhi) trong mùa mưa 2004, mùa khô và mưa 2005.

Thành phần động vật đáy bao gồm các nhóm chủ yếu là tuyến trùng, giáp xác chân chèo, thiếu trùng giáp xác, trùng lỗ, giun nhiều tơ, giun ít tơ, kinorhynchs, acari, ostracods, và một số nhóm ít gặp khác (hai mảnh, chân bụng, ấu trùng côn trùng, turbellaria, nemertinea).

Kết quả cho thấy, trong ba rạch ngập triều mật độ động vật đáy cao nhất ở Khe Nhàn (2440 con/10cm^2), thấp nhất ở Nàng Hai (1303 con/10 cm^2) và trung bình ở Rạch Ốc (2158 con/10 cm^2). Mật độ động vật đáy ở bãi bùn và rừng hỗn giao cao hơn ở rừng mắm và rừng đước.

Tuyến trùng là nhóm đông đảo nhất ở tất cả các điểm thu mẫu. Tỷ lệ tuyến trùng cao nhất ở Khe Nhàn (91,1%), thấp hơn ở Nàng Hai (88,0%) và Rạch Ốc (87,1%). Tỷ lệ tuyến trùng ở rừng hỗn giao và bãi bùn cao hơn ở rừng mắm và rừng đước. Nhưng ở Nàng Hai, tỷ lệ tuyến trùng thấp nhất ở bãi bùn (65,9%). Giáp xác chân chèo là nhóm đông đảo thứ hai ở Nàng Hai (4,7%) và mật độ đạt cao nhất trong ba rạch nghiên cứu, đặc biệt ở bãi bùn (117 con/10cm^2). Trùng lỗ là nhóm đông đảo thứ hai ở Khe Nhàn và Rạch Ốc, tỷ lệ cao nhất luôn đạt được tại rừng đước. Mật độ động vật đáy ở mùa khô cao hơn mùa mưa. Mật độ tuyến trùng và giáp xác chân chèo tăng lên, trong khi mật độ thiếu trùng giáp xác và trùng lỗ giảm đi trong mùa khô.

Quần xã tuyến trùng có sự đa dạng rất cao bao gồm 214 loài, thuộc 92 giống, 36 họ, 10 bộ. Trong đó họ Leptolaimidae có 27 loài, thuộc 6 giống. Giống *Leptolaimoides* có năm loài đã biết, nghiên cứu này đóng góp mô tả thêm năm loài mới là *L. tropicus* sp. nov., *L. cangioensis* sp. nov., *L. mangrovi* sp. nov., *L. clavicaudatus* sp. nov. và *L. hexatubulosus* sp. nov.. Giống *Deontolaimus* có một loài đơn duy nhất *D. papillatus*,

nghiên cứu này đóng góp vào việc mô tả thêm hai loài mới *D. mangrovi* sp. nov. và *D. pseudopapillatus* sp. nov..

Trong mùa khô, quần xã tuyến trùng có 200 loài, thuộc 89 giống, 34 họ và 10 bộ. 17 họ cùng với tỷ lệ cá thể lớn hơn 1% chiếm 87,8% tổng số cá thể, các họ quan trọng nhất là Linhomoeidae, Xyalidae, Comesomatidae. Các loài có số lượng lớn nhất là *Theristus* sp1, *Hopperia* sp1, *Paracomesoma* sp2, *Terschellingia* sp3, *Terschellingia* sp4, *Parodontophora* sp1, và *Dichromadora* sp1. Trong mùa mưa, quần xã tuyến trùng bao gồm 205 loài, thuộc 90 giống, 36 họ và 10 bộ. 19 họ với số lượng cá thể lớn hơn 1% chiếm 85% tổng số cá thể tuyến trùng, các họ quan trọng nhất là Xyalidae, Linhomoeudae, Comesomatidae. So sánh giữa hai mùa, số lượng cá thể của Linhomoeidae, Chromadoridae, Oxystominidae giảm đi khá nhiều từ mùa khô sang mùa mưa. Mặt khác, số lượng cá thể của Criconematidae và Leptolaimidae tăng lên từ mùa khô đến mùa mưa. Các loài chiếm số lượng lớn trong mùa mưa là *Paracomesoma* sp2, *Hopperia* sp1, *Terschellingia* sp3, *Terschellingia* sp4, *Dichromadora* sp1, *Theristus* sp1 và *Haliplectus* sp1. Giữa hai mùa *Theristus* sp1 giảm từ vị trí thứ nhất trong mùa khô xuống vị trí thứ sáu trong mùa mưa, *Hopperia* sp1 và *Paracomesoma* sp2 gần như không đổi.

Cấu trúc tuổi của tuyến trùng cho thấy, tỷ lệ ấu trùng là đông đảo nhất ở tất cả các điểm thu mẫu trong cả hai mùa khô và mưa. Tỷ lệ ấu trùng cao nhất ở bãi bùn. Tỷ lệ đực/cái có xu hướng tăng dần từ khu vực rừng mắm đến rừng hỗn giao và rừng đước.

Các nhóm dinh dưỡng của tuyến trùng cho thấy nhóm 1B (non-selective deposit feeders) và 2A (epistrate feeders) là nổi bật ở vị trí bãi bùn, ở rừng mắm và rừng hỗn giao chiếm số đông là nhóm 1A (selective deposit feeders), ở rừng đước nhóm 1A cũng chiếm tỷ lệ lớn nhất, nhưng ngoài ra nhóm 2B (predators/omnivores) và tuyến trùng ký sinh thực vật có tỷ lệ cao nhất so với các khu vực nghiên cứu khác.

Các chỉ số đa dạng của tuyến trùng nhìn chung khá cao. Chỉ số đa dạng Shannon-Wiener H’ biến thiên trong khoảng 1,9 đến 3,7, chỉ số đồng đều J' từ 0,6 đến 0,9 trên tất cả các điểm. Chỉ số đa dạng ở rừng mắm và hỗn giao nhìn chung cao hơn ở bãi bùn và rừng đước. Chỉ số đa dạng giảm đi ở khu vực bãi bùn chủ yếu do sự có mặt đông đảo của hai loài *Theristus* sp1 và *Paracomesoma* sp2. Còn ở rừng đước chỉ số đa dạng giảm đi trong mùa mưa bởi sự có mặt của loài *Criconemella* sp1.

Dựa trên thành phần và số lượng cá thể của các loài tuyến trùng, qua phân tích thống kê đa biến, các điểm thu mẫu có thể được chia thành ba nhóm chính : Nhóm 1 bao gồm các điểm ở bãi bùn và ba điểm dưới triều của rừng mắm, hỗn giao và rừng đước; Nhóm 2 bao gồm các điểm giữa triều của rừng mắm và hỗn giao; Nhóm 3 bao gồm các điểm giữa triều của rừng đước. Sự phân biệt này trong mùa khô là rõ nét hơn trong mùa mưa.

Một số loài quan trọng và tiêu biểu của khu vực bãi bùn là *Theristus* sp1*, Paracomesoma* sp2*, Pseudolella* sp1 và *Hopperia* sp1. Ở rừng mắm và hỗn giao, một số loài tiêu biểu nhất là *Terschellingia* sp3, *Terschellingia* sp4, *Dichromadora* sp1, *Ptycholaimellus* sp1, *Astomonema* sp1 và *Pseudochromadora* sp1. Ở rừng đước, một số loài tiêu biểu là *Hopperia* sp1, *Sphaerolaimus* sp3, *Anoplostoma* sp1, *Haliplectus* sp3, *Dichromadora* sp1 và *Criconemella* sp1.

Kết quả trên đây cho thấy cấu trúc quần xã động vật đáy và tuyến trùng khác nhau giữa các kiểu rừng ngập mặn trong cả mùa khô và mùa mưa. Chúng có thể được sử dụng để phân biệt rừng ngập mặn trồng lại và rừng tái sinh tự nhiên, cũng như các kiểu rừng và khu vực bãi bùn ở Khu dự trữ sinh quyển Cần Giờ. Những đặc điểm cần quan tâm là: (i) mật độ động vật đáy tổng số, mật độ tuyến trùng , mật độ trùng lỗ; (ii) các nhóm dinh dưỡng của tuyến trùng; (iii) các chỉ số đa dạng của tuyến trùng (iv) số lượng và thành phần loài tuyến trùng qua phân tích đa biến.

1 INTRODUCTION

1.1 Statement of the problem

Mangrove forests occupy the large area in the intertidal zone of tropical and subtropical coastlines. Presently in the world, mangrove areas cover approximately from 14 to 30 million ha, with an average of about 17 million ha, of which about half lies in the Asia-Pacific region and the rest about equally distributed in Africa (25%) and the Americas (25%) (Lacerda 2001).

According to Saenger *et al.* (1983), the economic value of mangroves lies in the direct and indirect products obtainable from mangrove resources. Direct products consist of various wood products and related materials such as tan-bark and fodder while indirect products include fish, crustaceans, shellfish and honey.

Mangroves provide physical protection for communities in low lying coastal areas, more importantly, they are believed to play a major role in supporting tropical estuarine and coastal food web (Alongi & Christoffersen 1992), by providing a major source of organic material and acting as nursery grounds and habitats for commercially important fish species (Robertson & Duke 1987, Pinto & Punchihewa 1996).

The need for fast economic development has led many countries to massively destroy their mangrove forests. As Robertson & Alongi (1992) suggested, around 10,000 km^2 of mangrove forest are annually lost worldwide. Loss of mangroves through human activity has been documented in many parts of the world. As an example of the rate of disappearance of mangrove areas in Brazil, Saenger *et al.* (1983) estimated that mangroves covered an area of approximately 2.5 million ha. 10 years later, the estimated geographical area covered by mangroves was 1.4 million ha, 56% smaller (Kjerfve & Lacerda 1993).

However, increasing awareness of the true value of mangrove ecosystems has led to renewed efforts to protect and restore them. More recently, mangrove restoration or rehabilitation has been initiated successfully in various parts on the world (Field 1996).

In order to consider the rehabilitation of mangrove ecosystems it is necessary to define the term clearly. "The rehabilitation of an ecosystem be defined as the act of partially or, more rarely, fully replacing structural or functional characteristics of an ecosystem that have been diminished or lost, or the substitution of alternative qualities or characteristics than those originally present with proviso that they have more social, economic or ecological value than existed in the disturbed or degraded state. Likewise it has been agreed that restoration of an ecosystem is the act of bringing an ecosystem back into, as nearly as possible, its original condition. Restoration is seen as a special case of rehabilitation" (Field 1998).

"Rehabilitation denotes an activity, including restoration and habitat creation, which converts a degraded system to a stable alternative" (Stevenson *et al.* 1999). Unfortunately, mangrove rehabilitation has often been carried out simply by planting mangrove seedlings without adequate site assessment, or subsequent evaluation of the success of planting at the ecosystem level (Field 1996). Moreover, for economic reasons, mangrove reforestation efforts are often limited to only one or two tree species (Gan 1995). This raises obvious questions regarding habitat change and reduced ecological function in mangrove plantations compare to natural mixed

species mangrove forests. Biodiversity is widely regarded to be important in maintaining genetic richness, ecological functioning and the resilience of ecosystem (Schultze & Mooney 1993, Heywood 1995).

Mangrove in Vietnam occupied an area of appropriately 400,000 ha, 250,000 ha lie in the south (Maurand 1943). Throughout two Vietnam wars and excessive exploitation, deforestation for agriculture and shrimp ponds, mangrove area reduced drastically. At present, the mangrove areas are about 154,300 ha (Le Duc Tuan 1998).

According to Phan Nguyen Hong (1991), based on geographical characteristics, field surveys and remote sensing data, mangrove vegetation in Vietnam can be divided into 4 main zones from the north to the south. Can Gio mangrove lays in the zone IV on the coast of southern Vietnam, with favourable ecological conditions for the extensive development of mangroves. According to Chu Quang Can (1972), before the war Can Gio covered approximately 40,000 ha, with *Rhizophora apiculata* as the dominant species. During the second war from 1962 to 1971, 57 % of Can Gio forest were sprayed by different herbicides such as orange mixture (2,4-D and 2,4,5-T), white mixture (2,4-D and picloram) and blue mixture (sodium dimethylarsenate and cacodylic acid) (Ross 1975). 104,939 ha forest, corresponding to 36% of the total mangrove forest in the South of Vietnam was destroyed (Lang 1974). Since the end of the Second Indochina War (1975) the total area of mangrove forest has further changed, as a large area has been transformed into agriculture, aquaculture and buildings.

Efforts to rehabilitate Can Gio mangrove were started in 1978. *Rhizophora apiculata* was chosen for planting because of its fast growing nature that would allow the restoration of the forest cover at the fastest rate. In addition, it is the tree with the highest commercial value. Since 1984, other tree species, such as *Intsia bijuga, Ceriops tagal, C. decandra, Lumnitzera racemosa, Xylocarpus granatum, Thespesia populnea* were planted on higher land to recover the barren land at higher altitudes (Le Duc Tuan *et al.* 2002).

In 2000, Can Gio was designated as the first Man and Biosphere Reserve of Vietnam, with a total area of 75,740 ha. The major habitat types found at Can Gio are plantation mangrove, of which there is about 23,028 ha (*Rhizophora apiculata* with 96.7%), and naturally regenerating mangrove, of which there is about 7,829 ha (Vien Ngoc Nam 2007). It represents the largest rehabilitated mangrove area in Vietnam (Aksornkoae 1993).

Mangrove rehabilitation has changed the soil's properties thanks to the sediment formed by litter fall with the help of large quantities of fine, fibrous root matter. These muds have the highest concentration of organic carbon and nitrogen (Alongi & Christoffersen 1992). This has directly influenced the distribution of benthos. Phan Nguyen Hong *et al.* (1996) and Do Duc Nhuong (2000) have carried out preliminary studies on benthos communities in the area of Can Gio mangrove forest, however, without taking into consideration forest structure (rehabilitated vs natural forest) and age. On the other hand, the effects of mangrove rehabilitation associated meiobenthic communities have never been assessed in the area. The present study is interested in the impacts of habitat change (rehabilitated vs natural forest) on composition, abundance, and diversity of meiobenthos at different tidal levels, as well as different seasons. The received information will be valuable for monitoring the ecological development of mangrove rehabilitation in Can Gio area in particular, and contribute to management and sustainable exploitation of mangrove forest resources in the world in general.

1.2 Meiobenthos and disturbance assessment

1.2.1 Meiobenthos as bioindicators of habitat change

Meiobenthos are mobile, sometimes also hapto-sessile animals, smaller than macrobenthos, but large than microbenthos. The size boundaries of meiobenthos are based on the standardized mesh width of a 500 μm (1000 μm) sieve as upper and 42 μm (63 μm) as lower limit: all fauna passing the coarse sieve, but are retained by the fine sieve, are considered meiobenthos (Giere 1993).

Nematodes usually dominate all meiobenthos samples both in abundance and biomass as they represent the most frequent metazoans. All free-living marine nematodes have meiobenthic size. In meiobenthos samples, 90-95% of individuals and 50-90% of biomass are usually made up by this group (Herman *et al.* 1985). The whole phylum currently contains approximately 20,000 species, among them about 4,000 to 5,000 free-living marine species have been described (Giere 1993).

"Bioindicators are organisms (or groups of organisms) that characterize special conditions of an ecosystem, and indicate natural modifications, or induced modifications" (New 1995). Some species may contribute disproportionately to the structure and dynamics of the ecosystem. The identification of these species may provide an indicator of ecosystem health, and an early warning system to implement intensive conservation efforts in advance of a collapse (Paine 1966, Chapin 1998, 2000).

Many organisms can be used as bioindicators for different kinds of disturbance such as bacteria, phytoplankton, zooplankton, invertebrates, fish… Benthic fauna have been found to vary greatly in sensitivity to various type of pollution. Their species and communities have often been regarded as good indicators, especially for organic pollution (Cairns & Dickson 1971). While the information about meiofauna responses to pollutions is not much, meiofauna have certain inherent advantages over macrofauna in the determination of the effects of biological pollutants at the community level. Heip (1980), Hicks (1991) and Warwick (1993) pointed out undisputable advantages in meiofauna over macrofauna for studying in polluted areas:

+ High abundance and diversity allow for conclusions on changes in species composition in small areas, even in “poor” biotops where macrofauna is often very scarce or exterminated.
+ Meiobenthic animals generally lack of a planktonic phase and are more consistently exposed to the local pollution accumulated in the sediment.
+ Short generation cycles and rapid growth allow for easier answers on possibly noxious impacts, especially since the usually more sensitive reproductive and juveniles stages can be regularly included in the assessments, even in the short term investigations.
+ Meiofauna reacts more promptly and drastically than macrofauna to the pollution. Meiofauna is relatively insensitive to mechanical disturbance and destabilization of the sediment and able to differentiate between impairment by mechanical and chemical actions.
+ Small samples and convenient, inexpensive sampling, easily transporting the whole, unextracted sample back to the lab reduces the time in the field, bulk fixation of the complete sample allows convenient timing of evaluation.

But the problems of pollution studies with meiofauna should not be concealed:

- Microscopic animals are not readily distinguishable by layman. It is difficult to convince the public that their role may be of equal importance in the ecosystem as the often familiar macrofauna.
- In order to cope with high temporal and spatial heterogeneity, frequent sampling along a dense station grid is required for reliable documentation of trends.
- The rather complicated identification of meiofauna requires a high expertise and high standard optical equipment.

Although meiobenthos have some disadvantages, the use of meiofauna in pollution monitoring studies started decades ago and at present their potential was assumed to be quite high. Marine nematodes were thought to be an ecological importance and sensitive bioindicators of pollution because they are very diverse taxonomically and occur everywhere, usually in great numbers and often exceeding other taxa by orders of magnitude (Croll & Mathew 1977, Platt *et al.* 1984). In part, there were problems with nematode identification. However, there are valuable illustrated keys at present to simplify the identification of free-living nematodes (Platt & Warwick 1983, 1988, Warwick *et al.* 1998). In addition, there are strong indications that pollution effects are detectable at even higher taxonomic levels (Warwick 1988b). It has further been observed that to be of value in a pollution assessment context it may not be necessary to work at the species level (Warwick 1988b, Heip *et al.* 1988).

1.2.2 Methods for the assessment of disturbance using meiobenthos

According to Raffaelli & Mason (1981), Nematode/Copepod ratio could be used for assessing organic pollution. Most nematodes linked to the short, detrital/bacterial based food chain. In the case of organic enrichment their number will increase rapidly. In contrast, harpaticoids are mainly microalgal-based and oxygen sensitive members of the food web. They will react negatively to an increase in the organic load. The divergent ecological character of nematodes and copepods for assessing the impact of pollution is by simply calculating the nematode/copepod ratio. Although they realized that this N/C ratio would shift depending on variations in the grain size distribution, they contended that if this trend were to be generalized for all sandy eulittoral coasts: a value >100 would indicate organic pollution. However, this attractive simple parameter produced much debate.

Most meiofauna studies showed that pollution entails marked changes in diversity (Moore & Bett 1989). Hence, diversity indices are calculated in many pertinent meiofauna studies, although the validity and meaning of diversity as an indicator of ecological disturbance are much debated. There is no general valid answer which are the predominant factors structuring a meiobenthic assemblage and determining its diversity. The Shannon-Wiener diversity index (H') is perhaps currently the most popular diversity index with marine biologists. This incorporates both the species richness and equitability component. Species richness is often given simply as the total number of species (S), which is obviously very dependent on sample size (the bigger the sample, the more species there are likely to be). More commonly, Margalef's index (d) is used, which also incorporates the total number of individuals and is a measure of the number of species present for the given number of individuals. Equitability expresses how evenly the individuals are distributed among the different species, and is often termed evenness. Pielou' evenness index (J) is most commonly used (Clarke & Warwick 1994).

Lambshead *et al.* (1983) introduced ecology to an apparently easily applicable method to assess stress through pollution, the "k-dominance curves". K-dominance curves are essentially a means of graphically representing the two component aspects of diversity, namely the total number of species (species richness) and how evenly the individuals are apportioned among the species (evenness). By plotting the k-dominance curves of two or more assemblages together, we have a means of assessing differences in diversity at a glance. From this, we can suggest a description of intrinsic diversity: one assemblage is more diverse than another if the k-dominance of one is less than or equal to the other for all values of k from one to whatever is the smaller total number of species.

Perhaps the biologically most meaningful method of linking community data to an environmental variable such as pollutional impact is Multi-Dimensional Scaling (MDS) (Field *et al.* 1982). Although its computational basis is fairly complex, it yields an easy-to-conceive graphic document, a "map" of sample similarities influenced by environmental variables. Its sensitivity and its general applicability have been proven in numerous examples both for macro and meiobenthos, and both for abundance and biomass values (Warwick 1993). Moreover, MDS configurations based on taxonomically higher ranks than species resulted in an essentially similar pattern (species, genus or family). Hence, this method represents a valuable tool revealing the impact of an environmental variable, even in cases where mere diversity assessment could not give a significant answer (Warwick 1988a).

In summarizing articles, Warwick & Clarke (1991), Clarke (1993) and Warwick (1993) evaluated methods for assessing changes in community structure. Applying these methods to a range of studies, they used meiobenthos data in direct comparison with macrobenthos studies and discriminated between:

1. Univariate methods where relative abundances of various species are reduced to a single index. The appropriate statistical test is a classical ANOVA, the most frequently used method within this category is the Shannon Wiener diversity index H'.

2. Graphic/distributional methods where relative abundance (or biomass) of species is plotted as a curve. The typical example is the k-dominance curve.

3. Multivariate methods of classification and ordination which compare faunal communities considering both their specific identity and their (relative) quantitative importance. These latter methods are exemplified in techniques such as the multi-dimensional scaling ordination (MDS).

1.2.3 Meiobenthos studies in mangroves

Gerlach (1958) described some nematode species on the northeast coast of Brazil. His publication could be the first publication on the meiofauna in mangroves. Later then, Por (1984) registered the occurrence of some harpacticoid copepods in a mangrove in the southeast of Brazil. Recently, Netto & Gallucci (2003) gave an account of the meiofauna, particularly nematodes, and the infaunal macrobenthos in a pristine mangrove forest of South Brazil. In Cuba, investigations of the meiobenthos in mangrove were carried out by Lalana-Rueda & Gosselck (1986), Armenteros *et al.* (2006).

In Africa, Dye (1983a, b) studied composition and seasonal fluctuations of meiofauna and vertical and horizontal distribution of meiofauna in mangrove sediments in Transkei, Southern Africa. Then, Vanhove *et al.* (1992) published a paper on meiobenthic communities of five mangrove vegetation types in Gazi Bay, Kenya.

Ólafsson (1995) investigated meiobenthos with emphasis on free-living marine nematodes in mangrove areas in Zanzibar, south eastern Africa. In 2000, Ólafsson *et al.* published research of influences of spring tide inundation on meiobenthos of hypersaline tropical mangrove sediment. Recently, the first study on ecology of meiofauna in mangroves of the Red Sea was presented by Khalil (2001).

More studies on meiobenthos were conducted in the mangrove areas of Australia. Decraemer & Coomans (1978) had one of the first publications on the nematodes in mangroves along Australian coast. Then, a series of studies about ecological aspects of meiobenthos from composition, abundance to influences of different factors to meiofaunal communities in tropical, subtropical and temperate mangroves were done by Hodda & Nicholas (1985), Alongi (1987a, b, 1989, 1990), Nicholas *et al.* (1991).

Research on mangrove meiobenthos in Asia was mainly carried out along different mangrove forests adjacent to the Bay of Bengal in India (Sultan Ali *et al.* 1983, Chinnadurai & Fernando 2007), Malaysian mangroves (Krishnamurthy *et al.* 1984, Sasekumar 1994, Gee & Somerfield 1997, Somerfield *et al.* 1998), and subtropical mangrove in Hongkong (Zhou 2001)

In Vietnam, there are only a few studies concerning meiobenthos including nematodes in the mangroves. These initial studies were only concentrated on identification of free-living nematodes without taking the meiobenthic community structure, the surrounding forest structure (rehabilitated vs natural forest) and mangrove age into consideration (Nguyen Vu Thanh & Doan Canh 2000, Gagarin & Nguyen Vu Thanh 2004, Nguyen Vu Thanh & Gagarin 2004, Nguyen Thi Thu, Nguyen Vu Thanh, Gagarin 2004, Nguyen Vu Thanh, Lai Phu Hoang, Gagarin 2005, Gagarin & Nguyen Vu Thanh 2006a, b).

1.3 Focus and objectives

The present study is part of the joint German-Vietnamese research project 'Ecosystem functioning of rehabilitated versus natural mangroves in the Can Gio Reserve, Vietnam'. The research goal is to achieve a better understanding of the differences in ecosystem functioning between rehabilitated and natural mangroves in Can Gio Biosphere Reserve, Vietnam. The results will be used by the affiliated subprojects to answer the question on the fate of nutrients in a mangrove dominated land-ocean interaction zone in South Vietnam.

Mangrove rehabilitation has changed the soil's properties thanks to the sediment formed by litter fall with the help of large quantities of fine, fibrous root matter. This mud had the high concentration of organic carbon and nitrogen and directly influenced the distribution of benthos (Alongi & Christoffersen 1992).

Hypothesis of the study is that rehabilitated monoculture mangrove forest cohorts and natural forests differ in their vegetation and physical properties such as topography, sedimentary patterns, and hydrography, in such that benthic community structure and system function are impacted

The objective of this work is to study meiobenthic community structures with special reference to nematodes in rehabilitated monoculture and natural regenerated mangrove forests, and to use them as bioindicators for different mangrove types in Can Gio Biosphere Reserve.

Therefore, the major activities are:

- To investigate and compare total meiobenthic community structures in rehabilitated monoculture and natural regenerated mangrove forests in both dry and rainy seasons. Main groups under investigation are: nematodes, copepods, polychaetes, oligochaetes, foraminifera, kinorhynchs, acari, and ostracods.
- To compare nematode community structures in rehabilitated monoculture and natural regenerated mangrove forests in the dry and rainy season,, including: definition of species compositions, age structures, trophic structures, diversity indexes such as number of species (S), Margalef species richness (d), Pielou' evenness index (J), Shannon-Wiener diversity index (H'), and to analyze community structures by graphical/distribution plots such as k-dominance curve and by multivariate statistical methods such as cluster analysis, multi-dimensional scaling (MDS), analysis of similarities (ANOSIM) and similarities percentage procedure (SIMPER).

2 MATERIALS AND METHODS

2.1 Study area

2.1.1 Location

The study was carried out in Can Gio Mangrove Biosphere Reserve, located about 65 km south of Ho Chi Minh City with latitude: 10°22'14''-10°40'09'' and longitude: 106°46'12''-107°00'59''. The area is delimited by the following waterways: Soai Rap River, Vam Sat River, Rach Don Channel, An Nghia Canal, Long Tau River, Tac Roi Canal, Dong Tranh River, Cai Mep River and the South China Sea. From north to south the area is 28 km long, and 30 km wide from east to west (Le Duc Tuan *et al.* 2002).

2.1.2 Natural conditions and vegetation

Topographically, the Can Gio mangrove forest forms a basin. This formation has a minimum altitude ranging from 0-1.5 m, situated in the north-eastern sector of the forest with downward inclines from the east, south and west. Giong Chua Mountain is the highest point in the forest with a maximum altitude of 10.1 m.

Can Gio mangrove forest developed from a comparatively recent brackish swamp, as the alluvium from Sai Gon and Dong Nai Rivers created the soil foundations. The development of such a mangrove forest is dependent on high precipitation and a high density of rivers interweaving the area, providing a rich and plentiful supply of alluvium in combination with clay alluvial deposition, vitriolic processes, and a brackish water-table. Can Gio soil types are somewhat limiting for human use. The deeper soil layer are as yet, highly uncompacted, thus unable to provide solid foundations, contain high contents of various sulphur oxides, which are detrimental in agriculture, and a high salt content.

The climate of Can Gio mangrove forest in general is characterized by high humidity and temperatures. There are two seasons and the area is affected by equatorial monsoons. Rainy season is from May to October and dry season is from November to April.

Precipitation in Can Gio is the lowest in the Ho Chi Minh City area, with an average range of 1,300-1,400 mm per annum. Data about rainfall in 2005 is shown in Figure 1.

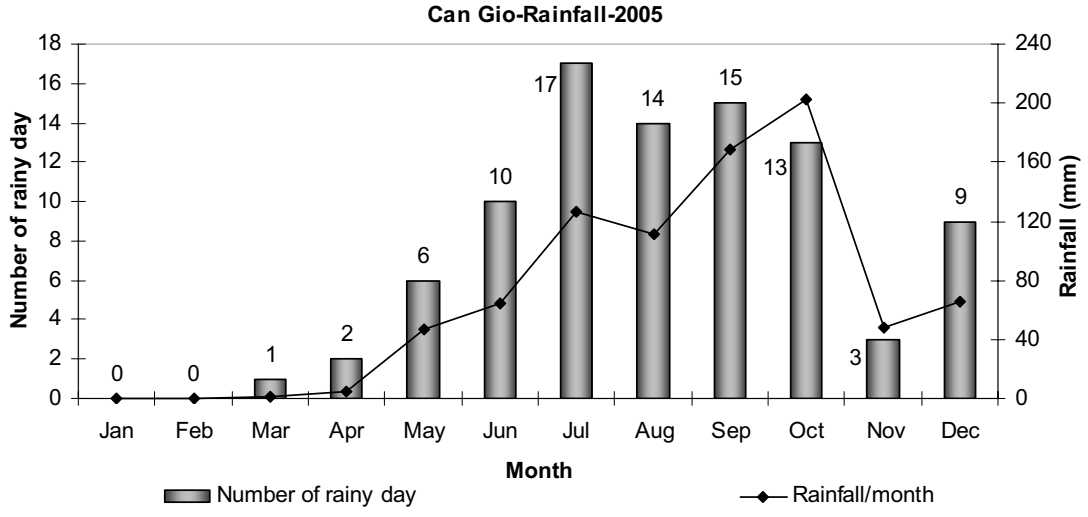

Figure 1. Rainfall in 2005 in Can Gio. Source: Southern Meteorological Department.

The daily temperature amplitude is 5-7°C, but less than 4°C over a month. The monthly average temperatures are highest from March to May, and lowest from December to January. The yearly average temperature is 25.8°C.

The daily average radiation is always above 300 cal/cm^2/day. The maximum monthly average occurs in March, with 14.2 Kcal/cm^2/month, and the minimum monthly average is in November with 10.2 Kcal/cm^2/month. There is a noticeable decline, particularly between the periods from September to December, in the monthly amounts of radiation, from 14Kcal/cm^2/month to 10 Kcal/cm^2/month.

There are two main wind directions: between May and October, during the rainy season, there is a south-southwesterly wind, which is at its strongest during July and August; between November and April, during the dry season, north-northeasterly wind blows, which is at its strongest in February and March.

The humidity in Can Gio is about 4%-8% higher than in other areas of Ho Chi Minh City. During the rainy season, humidity ranges from 79-83%, with a maximum of 83% in September. In the dry season, humidity ranges from 74-77%, with a minimum of 74% in April.

The average extent of evaporation is 4 mm/day, and 120.4 mm/month. Evaporation is highest in June (173.2 mm/month) and at its lowest in September (83.4 mm/month).

Can Gio has a complex and convoluted network of rivers. Freshwater sources originate from the Sai Gon and Dong Nai Rivers, emptying out via the main branches Long Tau and Soai Rap and also via subordinate braches such as the Thi Vai. There is a considerable mixing of saline and fresh water at the two main estuaries: Dong Tranh bay and Ganh Rai bay. Rivers cover an area of 31.76% of the total area of Can Gio District.

The Can Gio mangrove forest lies in a zone with a bi-diurnal tidal regime (two ebb and flow tides per day). Tidal amplitudes range from about 2 m at mean tide to 4 m during spring tides. It has been observed that the two daily high and low tides differ in height. Maximum tidal amplitudes, in the region of 4.0-4.2 m, are the highest observed in the whole of Vietnam. High tides reach their maximum between September and January, at 3.6-4.1 m in the southern region and 2.8-3.3 m in the northern region of Can Gio. In Can Gio, the maximum tidal high occurs in October or November, and the minimum in April or May. Between the 29th and 3rd day of the month (lunar calendar), and between the 14th and 18th day of the month, the whole of the Can Gio forest is flooded at high tide (twice a day). On the 8th and 25th day of the month the low tide is at its minimum.

According to data collected between 1977 and 2000, river and coastal water is most saline during high tides and least saline during low tides. Fluctuations in salinity correlate directly with the combined effect of tidal regime and the currents of the Sai Gon and Dong Nai rivers. Around the month of April, marine water is more dominant in sea-river interactions such that the marine water penetrates further inland, thereby increasing salinity levels in the forest. The reverse is true during the month of September and October, when the river plays a more dominant role in sea-river interactions, depressing salinity levels as marine waters are washed out to the sea. The introduction of the Tri An hydroelectric enterprise has effected the salinity of the Can Gio region considerably. In the dry season, salinity has decreased compared to levels measured in April prior to 1993. At Nha Be (inland), where in 1993 the salinity was 4-9 ppt in April, today it is only 4 ppt; and further south at Tam Thon Hiep (near the sea),

only 18 ppt. In the rainy season, however, salinity has increased, due to the controlled outlet of water from Tri An. The forms of the Soai Rap and Long Tau river differ, thus the rivers are affected to different extents by the tidal regime. As the Soai Rap River has a shallow cross-section, the tidal impact of the South China Sea is less than on the deeper Long Tau River, hence its salinity is lower (Le Duc Tuan *et al.* 2002).

In terms of global mangrove distribution, Vietnam lies in the area that has the richest assemblage of species. According to Phan Nguyen Hong (1999) and Nguyen Boi Quynh (1997), floral species in Can Gio total 128 species, belonging to 80 genera and 47 families. Included in this figure are 33 true mangrove species (19 genera, 15 families), 42 associated mangrove species (36 genera, 24 families), and immigrant species. Some typical species in Can Gio are *Rhizophora apiculata, R. mucronata, Avicennia alba, A. officinalis, A. marina, Bruguiera gymnorrhiza, B. parviflora, Sonneratia alba, S. ovata, S. caseolaris, Ceriops sp, Kandelia candel, Aegiceras corniculatum, Lumnitzera racemosa, Acrostichum aureum, Thespesia populnea,* and *Hibicus tiliaceus*.

2.2 Sampling and data collection

2.2.1 Sampling times and sites/stations

In the rainy season of 2004, meiobenthic communities were investigated in 3 tidal creeks Nang Hai (NH), Khe Nhan (KH) and Rach Oc (RO) in the Can Gio Forestry Park area (Figure 2). These creeks flow in nearly right angle direction to Dong Tranh River. Along the creek from the mouth to the upper reaches, representatives of natural and rehabilitated mangrove forests are settled. On the bank of Dong Tranh River and the mouths of the creeks are natural forests with abundance of *Avicennia alba*. The upper reaches of the creeks are characterized by rehabilitated forests of the single species, *Rhizophora apiculata* (planted in 1978-1982). Between these two forest types, mixed forests of planted and naturally settled mangroves have evolved. The main species here include *Avicennia alba*, *Rhizophora apiculata*, and others such as *Excoecaria agallocha*, *Xylocarpus* spp, *Aegyceras* spp, *Lumnitzera* spp (Figure 2).

In each creek, four sites were selected in range of mangrove forests including mud flat site (Mud) and 3 types of mangroves sites: natural *Avicennia* forest (Avi), natural mixed forest (Mix), and rehabilitated *Rhizophora* forest (Rhi). The samples were collected from both banks of the creek “a” and “b” at 3 intertidal stations: low water tide (1), middle water tide (2), high water tide (3); and a station at shallow water subtidal zone “c”. In the mud flat (Mud) of each creek, 4 stations were sampled. Therefore in each creek, 18 intertidal stations on both banks, 3 stations at shallow water subtidal zone and 4 stations at mud flat were sampled. 3 replicates were taken at each station (Figure 2).

In both the dry and rainy seasons 2005, samples were taken in Rach Oc Creek at the same sites/stations in the rainy season 2004.

2.2.2 Sampling, extraction and preparation of permanent slides

Samples were taken by hand corer of 40 cm length and area of 10 cm^2 (diameter = 3.5 cm). Sediment was collected to a depth of 10 cm at each sampling station These were preserved in 5 % neutralized formalin heated up to the point of 60-70°C.

Some hydrological parameters of the water were measured such as temperature (T), pH, salinity (NaCl), electric conductivity (EC), dissolved oxygen (DO), turbidity (Tu) at the time of the sampling procedure by the TOA (Model WQC-22A).

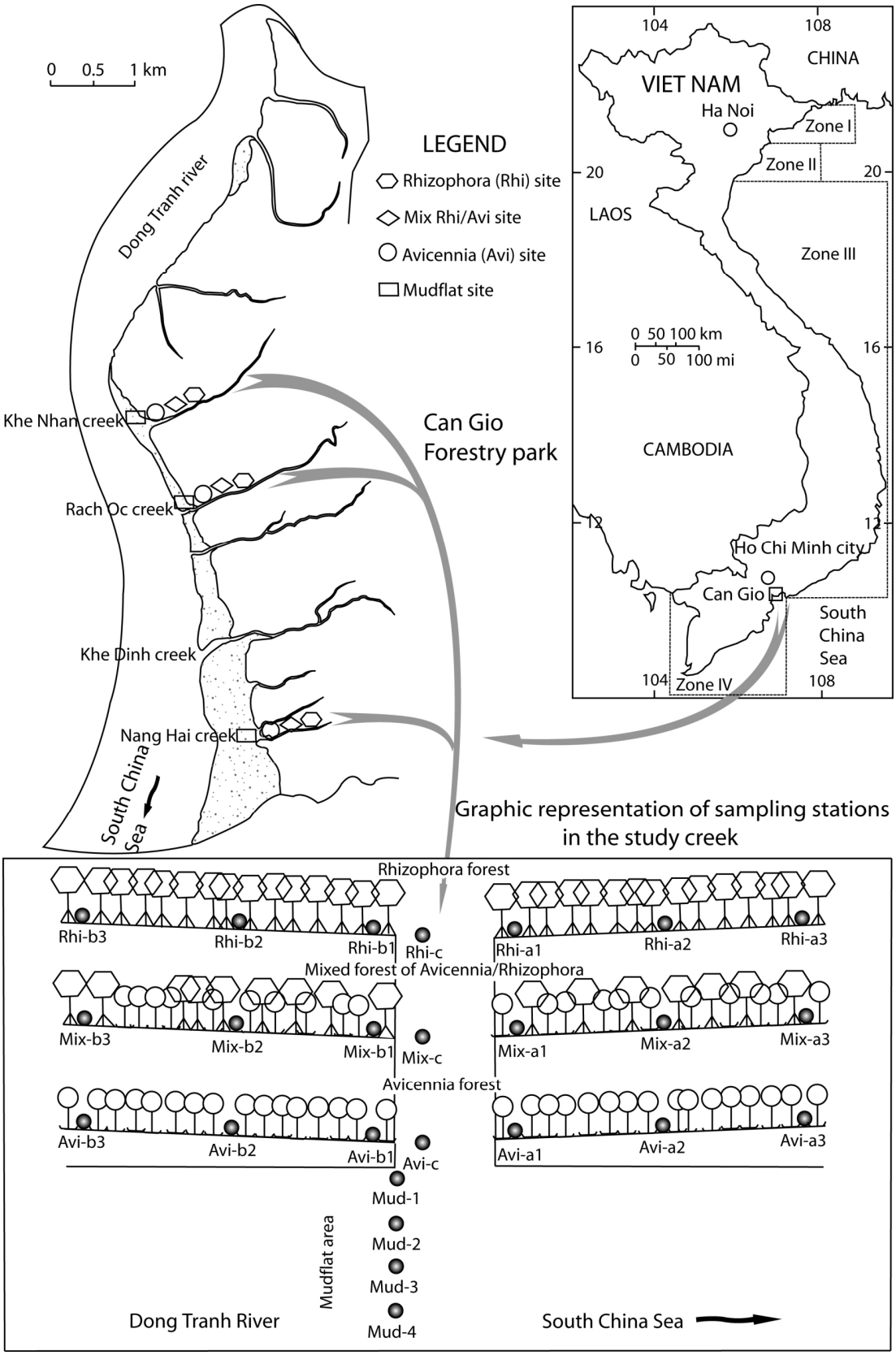

Figure 2. Map of mangrove zones in Vietnam and sampling sites/stations in Can Gio Mangrove Biosphere Reserve

Extraction of meiobenthos content was executed in two steps: (i) decantation of the total sample and (ii) centrifugation of residue (Heip *et al.* 1985). Decantation is designed to eliminate heavy fraction in the sample, such as shells, gravel, or coarse sand. To perform this process, a sample was put into a 5 litres bucket and stirred with strong tap water and poured through a 1 mm sieve into another bucket to exclude large materials. After that, sediment was stirred again, allowed to settle for about 10 seconds and the water content was poured into another bucket. The procedure was repeated 5-10 times for each sample until the supernatant water was clear. Then sample was poured through a 40 μm sieve and collected into tubes for centrifugation with LUDOX solution with the specific gravity of 1.18, relying on the assumption that the mean gravity of marine nematodes is 1.13 (Jonge & Bouwmann 1977). The conditions for centrifugation were as follows: time span of 10 min and speed of 3000 rpm. The procedure was repeated three times for each sample. After each centrifugation session, supernatant was rinsed with tap water on a 40 μm sieve to get rid of LUDOX and then collected into receptacles with FAA solution (20 ml 96% ethanol, 6 ml formalin, 1 ml glacial acetic acid, 40 ml distilled water).

To subsample nematode species in a sample, about 200 nematodes (or all if lower numbers occurred) were picked out randomly and transferred to a cavity block filled with solution I (1% glycerin, 20% ethanol, 79% distilled water). The cavity block was then placed in a desiccator containing excess of 96% ethanol and keep at 40°C for at least 1 day. After that the cavity block was removed form the desiccator and solution II (5% glycerin, 95% ethanol) was added. A cover glass partly closed the cavity block that was kept at 40°C to evaporate all ethanol. The solution II was added into the cavity block 3-4 times every two hours, until all ethanol had evaporated. After that the nematodes were immediately ready for mounting. If mounting had to be delayed, the cavity block was placed in the desiccator with dry silica gel or calcium chloride. The nematodes were placed in a small drop of anhydrous glycerin surrounded by a wax ring on the slide. The cover slip was gently placed on to the wax ring, just touching the top of the glycerin drop. Then the slides were heated gradually until wax melted and sealed the glycerin drop in. At this point the slides were ready for nematode identification under a light microscope.

In order to increase the visibility of meiobenthos, entire samples were stained with 1% solution of Rose Bengal for at least 24 hrs before counting

2.2.3 Data collection

The extracted meiobenthos were categorized into different higher taxonomic groups (nematodes, polychaetes, copepods,...) under a stereomicroscope based on works of Higgins & Thiel (1988) and Giere (1993). To estimate the meiobenthic abundance, nematodes and other meiobenthic taxa, the sample was taken subsamples by dilution and counted in a 10×10 square grid using specially designed counting trays. Final counts were expressed in numbers of specimens per 10 cm^2 of entire sample.

Nematode taxonomic classification was carried out according to De Ley & Blaxter (2002) for family level identification and Lorenzen (1994) for genus level identification.

For determining nematode genera/species, the manuals Free-living Marine Nematodes Part I (Platt & Warwick 1983), Free-living Marine Nematodes Part II (Platt & Warwick 1988) and Free-living Marine Nematodes Part III (Warwick *et al.* 1998) were used together with other literatures.

Drawings and measurements were made with the aid of a drawing tube (camera lucida) attached to a Zeiss Axioskop microscope.

Abbreviation used in species description

L	length
a	body length divided by maximum body diameter
b	body length divided by oesophagus length
c	body length divided by tail length
c'	tail length divided by anal body diameter
V	position of vulva as percentage of body length from anterior
hd	head diameter
cbd	corresponding body diameter
abd	anal body diameter
spi	spicule length measured on the chord
sup	supplement number
R_1-R_3	rings of cephalic setation

2.3 Data analysis

Univariate measures were statistically tested using SPSS 13.0 software package. Differences of meiobenthic densities and biodiversity indexes between sites/stations were tested using one-way analysis of variance (ANOVA), based on lg(x+1) transformed data. If the data was not normally distributed, a non-parametric Kruskal-Wallis test was used instead. The assumptions were tested by Levene's test of normal distribution within a group, homogeneity of means and mean independent of variance. Differences of meiobenthic densities and biodiversity indexes at each station between rainy and dry seasons were tested using Paired-sample T test (parametric test) or Two related samples Wilcoxon test (non-parametric test). Correlation between meiobenthos densities and abiotic factors were also analyzed by SPSS 13.0 software.

Diversity of nematode communities was calculated by the indices of Shannon-Wiener diversity (H'), Margalef's species richness (d), Pielou's evenness (J') using the software PRIMER 5 (Plymouth Rountines In Multivariate Ecological Research) (Clarke & Warwick 1994). K-dominance curve for nematode species, an alternative diversity ordering technique, uses plotting rank and the cumulative proportions. In the graph, one can compare several assemblages at once. The curve located at higher position is lower in diversity meanwhile the lowest position curve is the most diverse compared with the upper curve.

Cluster analysis and multidimentional scaling ordination (MDS), based on Bray-Curtis similarities of square root transformed abundance data, were performed by PRIMER 5. Formal significant test for differences between sites/stations were calculated using the analysis of similarities (ANOSIM). Species contributing to dissimilarities between sites/stations were investigated using the similarities percentage procedure (SIMPER).

3 RESULTS

3.1 Abiotic factors

Some hydrological factors were measured at the time of sampling. Temperatures varied little from 27.3°C to 30.7°C at different stations, creeks and between seasons. Dissolved oxygen index (DO) varied among stations and seasons. In all three creeks, DO tended to reduce from *Rhizophora* sites(2.7-5.0 mg/l) to *Avicennia* sites (2.1-4.5 mg/l). pH index was nearly similar at all three study creeks Nang Hai, Khe Nhan and Rach Oc in the rainy season 2004 (7.0-7.2). In the dry season 2005, pH was a little higher than in the rainy season 2004 and the rainy season 2005. But pH also tended to decrease from *Rhizophora* sites to *Avicennia* sites in all three creeks and the lowest value was 6.4 found at the *Avicennia* sites of Rach Oc creek in the rainy season 2004 (Appendix, Table A1).

The result of salinity showed that salinity increased from *Rhizophora* sites to *Avicennia* sites. Comparison of salinity measurements between two seasons showed that salinity increased considerably from the rainy season 2004 (11.4-12.6‰) to the dry season 2005 (32.4-33.1‰). Then, salinity decreased again in the rainy season 2005 (21.5-21.7‰), but it remained higher than in the rainy season 2004 (Table A1).

In the rainy and dry seasons 2005, turbidity index (Tu) also increased from *Rhizophora* sites to *Avicennia* sites. The index recorded the highest value in Rach Oc creek in the rainy season 2004. The data recorded in the dry season were in reverse order so that Tu decreased from *Rhizophora* sites to the *Avicennia* sites (Table A1).

3.2 Meiobenthos

3.2.1 Meiobenthic composition in three creeks

Preliminary investigation of meiobenthos in Can Gio Biosphere Reserve was carried out in three creeks Nang Hai, Khe Nhan and Rach Oc in the rainy season of 2004. Meiobenthic composition mainly included nematodes, copepods, nauplii, foraminifera, polychaetes, oligochaetes, kinorhynchs, acari, ostracods, and others less abundant group (bivalves, gastropods, insect larvae, turbellaria, nemertinea)

In the rainy season 2004, average meiobenthic density in Khe Nhan Creek was 2440 ind/10 cm^2, higher than in Rach Oc Creek (2158 ind/10 cm^2) and Nang Hai Creek with only 1303 ind/ 10cm^2. Among sites in Khe Nhan Creek, meiobenthic density in Mixed sites was the highest with 3171 ind/10 cm^2, while meiobenthic density in the Mudflat site of Nang Hai Creek was the lowest with only 732 ind/10 cm^2. In general, meiobenthic density was reduced from Mixed sites to *Rhizophora* sites to *Avicennia* sites, to the lowest density in Mudflat sites in Khe Nhan and Nang Hai Creeks. On the other hand, Rach Oc Creek differed from the other two creeks since the meiobenthic density in the Mudflat site was higher than in *Rhizophora* and *Avicennia* sites, though meiobenthic density was here also highest in Mixed sites, (Table A2, A3, A4).

The nematode group was the assemblage with the highest density in the meiobenthic community. In Khe Nhan Creek, average nematode percentile contribution to total meifauna was 91.1%, higher than in Nang Hai Creek. In Mixed sites, nematode assemblages contributed the highest percentage (93.0%), followed by 91.2% in *Avicennia* sites, 91.6% in Mudflat sites, and lowest with 88.3% in the area of *Rhizophora* sites. (Table A2).

In Nang Hai Creek, result from the rainy season 2004 showed that average nematode

percentile contribution to total meiofauna was 88.0%. The highest values were reached in Mixed sites with 91.8%, followed by 89.6% in *Rhizophora* sites, 88.1%, in *Avicennia* sites and 65.9% in the Mudflat site. (Table A3).

In Rach Oc, there was average of 87.1% nematodes in total meiobenthic density. The highest percentage was 94.2% in the Mudflat site, decreasing to 89.1% in Mixed sites, 83.4% in *Rhizophora* sites, and the lowest 82.7% in *Avicennia* sites. (Table A4).

In general, during the rainy season 2004 nematode percentile contribution to total meiofauna was high in Mixed sites of Nang Hai and Khe Nhan creeks and in the Mudflat site of Rach Oc creek. Nematode density was highest in Mixed sites, lowest in *Avicennia* sites, with the exception of Nang Hai creek, where lowest densities were found in the Mudflat site.

Data collected in the rainy season 2004 showed that copepods were the third most abundant group in Khe Nhan Creek. Copepod percentile contribution was the highest (3.1%) in the Mudflat site, in comparison with other sites (2.5%, 2.4%, and 2.1% in *Rhizophora*, Mixed, and *Avicennia* sites, respectively). Average density of copepods in Khe Nhan Creek was 59 ind/10 cm^2, and the highest density was found in Mixed sites with 77 ind/10 cm^2 (Table A2).

Copepods occupied the position of the second most abundant group in Nang Hai creek, with an average of 4.7% of total meiobenthos. In Mudflat sites copepods represented 15.9% of the total meiofauna, followed by 4.8% in *Avicennia* sites, 3.6% in *Rhizophora* sites, and lowest value of 2.9% in Mixed sites. The density of copepods in Nang Hai Creek was also the highest of all three creeks, with an average density of 61 ind/10 cm^2, especially in Mudflat site, where average density totaled 117 ind/10 cm^2 (Table A3).

In Rach Oc Creek, nauplii were found to be the third most abundant group. On average, they represent 3.9% of total meiobenthos, equivalent to an average density of 85 ind/10 cm^2. Copepods were the fourth most abundant group in this creek with a density of 69 ind/10 cm^2 and average percentile contribution of 3.2% of total meiobenthos. Average density of copepods was the highest at Mixed sites with 92 ind/10 cm^2 (Table A4).

Result from the rainy season 2004 showed that foraminifera had fairly high densities in all three creeks. Foraminifera were the second most abundant group in Khe Nhan and Rach Oc creeks with average densities of 81 and 101 ind/10 cm^2, respectively. In both creeks, percentile contributions of foraminifera were the highest in the *Rhizophora* sites, with 6.3% (150 ind/10 cm^2) in Khe Nhan Creek and 11.3% (237 ind/10 cm^2) in Rach Oc Creek. (Table A2, A4)

In Nang Hai Creek, foraminifera were less densely distributed than in Khe Nhan and Rach Oc Creeks, but were still the third most abundant group in the creek. Here too, the highest density of foraminifera was found in *Rhizophora* sites with an average of 62 ind/10 cm^2, representing 3.7% of total meiobenthos (Table A3).

3.2.2 Changes in meiobenthic abundance in Rach Oc Creek

In the year 2005, changes of meiobenthos were intensively investigated in Rach Oc Creek in both the dry and rainy seasons.

3.2.2.1 Total meiobenthos

In the dry season of 2005, average meiobenthic density was 2803 ind/10 cm^2, a drastic increase of approximately 30% in comparison with densities found during the rainy

season of 2004. Increased density most dominant in Mixed and Mudflat sites, with 3129 and 3420 ind/10 cm^2 (average density increased by 43-48%) (Table A5). Density of meiobenthos in Mudflat sites was significantly higher than in *Rhizophora* and *Avicennia* sites ($P<0.05$) (Figure 3A). On the other hand, meiobenthic density in Mixed sites was higher than in *Rhizophora* and *Avicennia* sites, but not significantly different among *Rhizophora*, Mixed and *Avicennia* sites ($P>0.05$) (Figure 3A). Among Mudflat stations, meiobenthic density in station Mud-4 was significantly higher than in Mud-2 and Mud-3 ($P<0.05$). Density in Mud-1 was significantly higher than in Mud-2 ($P<0.05$), but not significantly different than in stations Mud-4 and Mud-3 ($P>0.05$) (Figure 4A). In *Avicennia* sites, density in Avi-a1 was significantly higher than Avi-a3 ($P<0.05$). In addition, density at station Avi-b1 was also significantly higher than at station Avi-b2 and Avi-b3 ($P<0.05$). At the subtidal station Avi-c, density was significantly lower than at all other stations ($P<0.05$) (Figure 4B). Between stations at Mixed sites, there was no significant difference between intertidal stations, but subtidal station Mix-c was also significantly lower than other intertidal stations ($P<0.05$) (Figure 4C). At *Rhizophora* sites, density of meiobenthos at station Rhi-a1 was significantly higher than station Rhi-a2 and Rhi-a3 ($P<0.05$), while station Rhi-b1 was generally higher, but not significantly so, than stations Rhi-b2 and Rhi-b3 ($P>0.05$). One exception is that meiobenthic density at the station Rhi-c was significantly higher than at the stations Rhi-a2 and Rhi-a3 ($P<0.05$) (Figure 4D).

Meiobenthic density in the rainy season 2005, with an average 1630 ind/10 cm^2, was decreased by 42% of 2803 ind/10 cm^2 in the dry season. The highest density reduction was recorded at *Avicennia* sites with a 53% decrease from the average density in the dry season. Results showed that average densities at *Avicennia* sites during the rainy season were as low as 1118 ind/10 cm^2 (Table A6). Assessment of meiobenthos at 4 sites during the rainy season 2005 showed that densities in Mudflats and Mixed sites were significantly higher than at *Rhizophora* and *Avicennia* sites ($P<0.05$) (Figure 3A). Between stations at Mudflat sites, meiobenthic density showed no significant difference ($P>0.05$) (Figure 4A). At *Avicennia* sites, Avi-b1 was significantly higher than all other stations and the subtidal station Avi-c was significantly lower than all others ($P<0.05$) (Figure 4B). In Mixed sites, between intertidal stations, Mix-b2 was significantly higher than Mix-b3, though there was no significant difference with other intertidal sites. Change between intertidal and subtidal stations was significant ($P<0.05$) (Figure 4C). In *Rhizophora* areas, densities in Rhi-a1 and Rhi-b1 were significantly higher than in Rhi-b2 and Rhi-b3 ($P<0.05$), but not significantly different to Rhi-a2 and Rhi-a3 ($P>0.05$) (Figure 4D).

Changes of meiobenthic density from the dry season to the rainy season proved significant at all sites. Densities of meiobenthos in the dry season was significantly higher than in the rainy season ($P<0.05$) (Figure 3A). At Mudflat sites, significant difference between seasons was in station Mud-4 ($P<0.05$) (Figure 4A). At other sites, significant differences between seasons were in stations Avi-a1 and Avi-b1 (*Avicennia* sites), stations Mix-a1, Mix-a2 and Mix-c (Mixed sites), and stations Rhi-b2, Rhi-b3 and Rhi-c (*Rhizophora* sites) ($P<0.05$) (Figure 4B, 4C, 4D).

3.2.2.2 Nematodes

Results showed that nematode percent contribution to total meiofauna increased from 87.1% in the dry season of 2004, to 90.6% in the dry season of 2005. The highest percentage of nematodes was registered at Mudflat sites with 94.3%. However, the lowest percentage recorded was not at *Avicennia* sites, but at *Rhizophora* sites. On the other

hand, when comparing with nematode density in the rainy season 2004, nematode density in the dry season 2005 increased 35%, reached average 2539 ind/10 cm^2, mainly in *Avicennia* and Mudflat sites (Table A5). The density of nematodes at Mudflat sites was significantly higher than in *Avicennia* and *Rhizophora* sites (P<0.05). Density in Mixed sites was higher than at *Rhizophora* and *Avicennia* sites, and lower than at Mudflat sites, however the variance was not significant among sites (P>0.05) (Figure 3B).

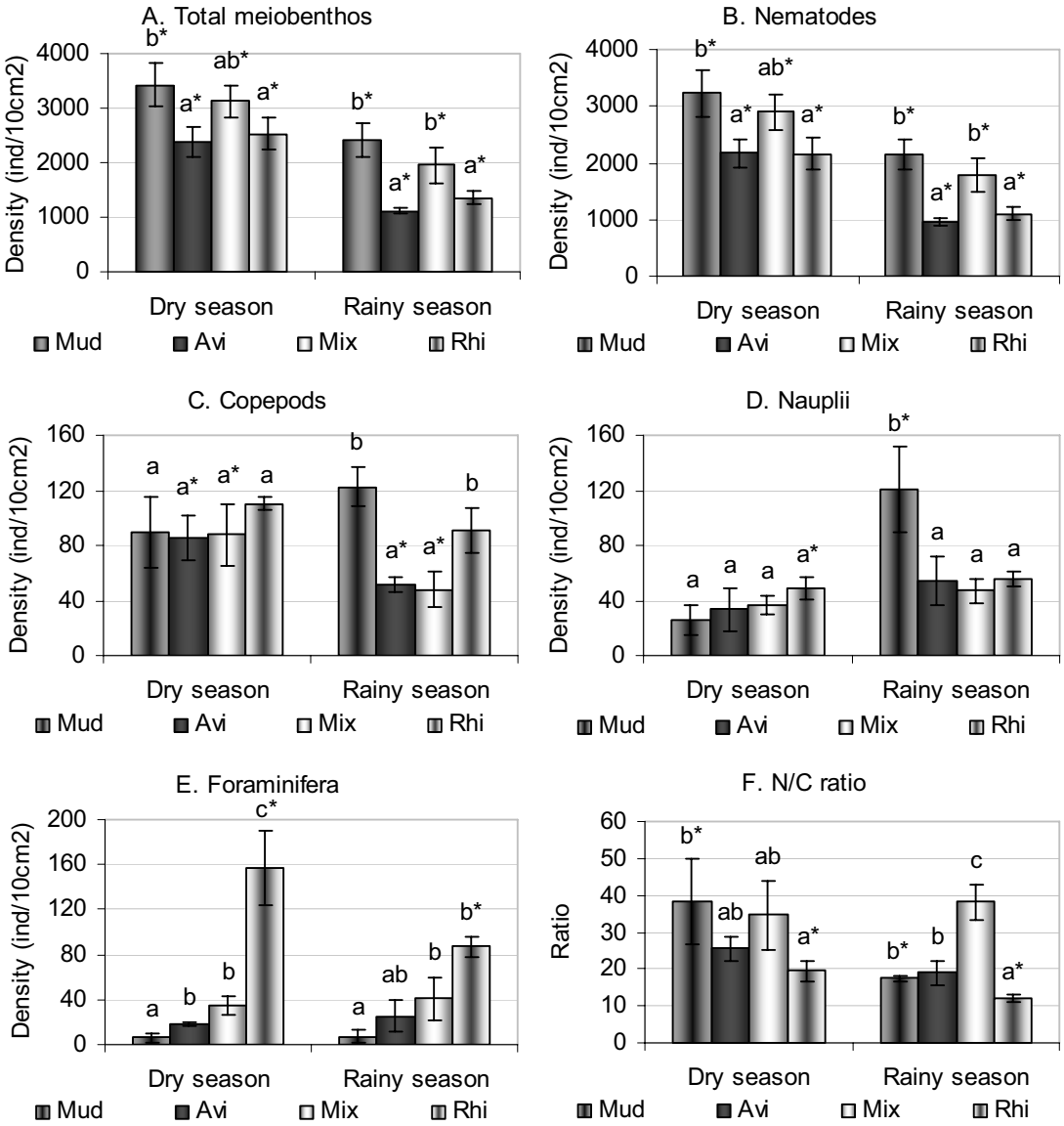

Figure 3. Densities (mean ± sd) of meiobenthos (A), major benthic groups (B, C, D, E) and N/C ratio (F) in the dry and rainy seasons

For each season, columns with the same letter were not significantly different among sites (ANOVA, P>0.05)
At the same sites, columns with the star (*) were significantly different between two seasons (T-test, P<0.05)

Within stations, there was no significant difference of nematode density between stations in Mudflat sites (P>0.05) (Figure 4E). In *Avicennia* sites, the density at Avi-a1 was significantly higher than in Avi-a2 and Avi-a3. In the opposite bank of the creek, Avi-b1 was also significantly higher than Avi-b2 and Avi-b3 (P<0.05). The density at subtidal station Avi-c was significantly lower than at all other intertidal stations (P<0.05) (Figure 4F). In Mixed sites, there was no significant difference between intertidal stations (P>0.05) (Figure 4G). However, the subtidal station Mix-c

density was significantly lower than other intertidal stations (P<0.05). When comparing densities at *Rhizophora* sites, the density at stations Rhi-a1, Rhi-b1, Rhi-c were significantly higher than at stations Rhi-a2, Rhi-a3. Density at stations Rhi-b2 and Rhi-b3 was lower than at station Rhi-b1, though the difference was not significant (P>0.05) (Figure 4H).

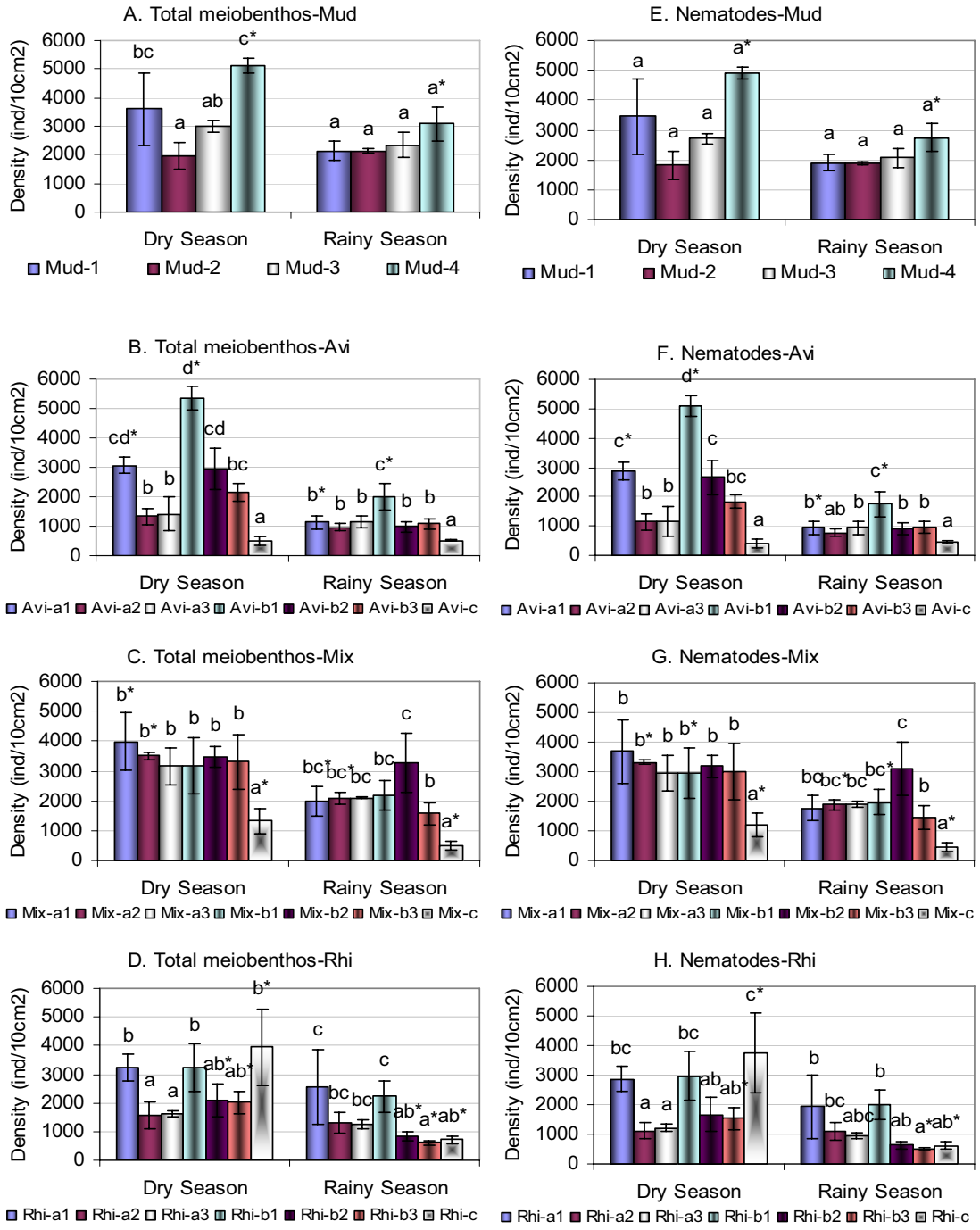

Figure 4. Densities (mean ± sd) of total meiobenthos at the Mud (A), Avi (B), Mix (C) Rhi (D) and nematodes in the Mud (E), Avi (F), Mix (G), Rhi (H) at different stations in the dry and rainy seasons

For each season, columns with the same letter were not significantly different among stations (ANOVA, P>0.05)
At the same sites, columns with the star (*) were significantly different between two seasons (T-test, P<0.05)

Nematode density was also investigated in the rainy season 2005. Results showed that

nematode percentage in meiofauna decreased in comparison with the dry season 2005 and equivalent with the rainy season 2004 was 87.2% of the total meiobenthos (Table A6). In addition, percentages at different forests sites varied. Percentages were the highest at Mixed sites and lowest at *Rhizophora* sites. Nematode density was reduced drastically by about 44% in comparison to the dry season 2005. Average nematode density was only 1421 ind/10 cm^2 in the rainy season 2005 (Table A6). Between 4 sites, densities at Mudflat and Mixed sites were significantly higher than at *Rhizophora* and *Avicennia* sites ($P<0.05$) (Figure 3B). At Mudflat sites, there was no significant difference between stations ($P>0.05$) (Figure 4E). At *Avicennia* sites, nematode density at Avi-b1 was significantly higher than at all others ($P<0.05$), Avi-c was significantly lower than all others, except Avi-a2 (Figure 4F). Between stations at Mixed site, subtidal station Mix-c was significantly lower than all other stations, Mix-b2 was not significantly different from Mix-a1, Mix-a2, Mix-a3, and Mix-b1 ($P>0.05$), but significantly different from stations Mix-b3 ($P<0.05$) (Figure 4G). At *Rhizophora* sites, Rhi-a1 and Rhi-b1 were significantly higher than Rhi-b2, Rhi-b3 and Rhi-c ($P<0.05$), but not significantly different from Rhi-a2 and Rhi-a3 ($P>0.05$) (Figure 4H).

Between the dry season and the rainy season in 2005, the difference of nematode density was significant for all 4 sites ($P<0.05$) (Figure 3B). At Mudflat sites, differences seen between the two seasons were significant at station Mud-4. At *Avicennia* sites, significant differences between the two seasons were seen at stations Avi-a1 and Avi-b1. At Mixed sites, seasonal differences were significant at Mix-a2, Mix-b1 and Mix-c. At *Rhizophora* sites, differences between dry and rainy seasons were significant at stations Rhi-b3 and Rhi-c ($P<0.05$) (Figure 4E, 4F, 4G, 4H).

3.2.2.3 Copepods and nauplii

In the dry season of 2005, result in Rach Oc Creek showed that copepod abundance increased to be the second most abundant group with an average density of 94 ind/10 cm^2, representing 3.3% of the total meiobenthos. Copepods were most dense at *Rhizophora* sites (110 ind/10 cm^2) and contributed the highest percentage (4.4% of total meiobenthos) in Rach Oc Creek. During the dry season, comparison of copepod density between 4 sites, yielded no significant differences ($P>0.05$) (Figure 3C).

Nauplii were the 4th most abundant group, with an average of 1.3% of total meiobenthos. At *Rhizophora* sites, nauplii density was the highest with 49 ind/10 cm^2 and showed the highest abundance (1.9% of total meiobenthos). However there was not significant difference among different sites ($P>0.05$) (Figure 3D).

In the rainy season of 2005, copepods in Rach Oc Creek remained in the second abundant group, but density reduced to an average of 73 ind/10 cm^2. However, copepod percentage continued at a level of 4.5% of total investigated meiobenthos. Among sites, density was the highest in the area of the Mudflat site with an average of 122 ind/10 cm^2 (Table A6). Densities in Mudflat and *Rhizophora* sites were significantly higher than in *Avicennia* and *Rhizophora* sites ($P<0.05$) (Figure 3C).

In the rainy season, nauplii were the third most abundant group with 63 ind/10 cm^2, occupying 3.9% of total meiobenthos. The highest nauplii density was found at Mudflat sites, with 121 ind/10 cm^2 (5% of total meiobenthos). In addition, density at Mudflat sites was significantly higher than at other sites ($P<0.05$) (Figure 3D).

Differences in copepod densities between dry and rainy seasons was significant at *Avicennia* and Mixed sites ($P<0.05$) (Figure 3C). On the other hand, nauplii density had a significant difference at Mudflat site ($P<0.05$) (Figure 3D).

3.2.2.4 Foraminifera

During the dry season 2005, investigation in Rach Oc Creek showed a drastic decrease of foraminifera density from an average density of 101 ind/10 cm^2 in the rainy season 2004 to 60 ind/10 cm^2 (dry season 2005). However, they were still the third most abundant group with an average percentage of 2.1% of total meiobenthos. The highest densities were maintained in the areas of *Rhizophora* sites with 157 ind/10 cm^2 (6.2% of total meiobenthos at this site). Among 4 sites, foraminifera density at *Rhizophora* sites was significantly higher than at other sites, density at the Mudflat site was significantly lower than the other sites, and *Avicennia* and Mixed sites showed no significant difference ($P>0.05$) (Figure 3E).

In the rainy season 2005, results in Rach Oc Creek showed a continuous density reduction of foraminifera to an average of 44 ind/10 cm^2, occupying 2.7% of total meiobenthos, placing them as the third most abundant group. However, foraminifera density was highest at *Rhizophora* sites with an average of 87 ind/10 cm^2, producing a high level average percentage of 6.4% of the total meiobenthos. In the rainy season, foraminifera densities at *Rhizophora* and Mixed sites were significantly higher than at Mudflat sites, however there was no significant difference among the 3 forest types *Avicennia*, Mixed and *Rhizophora*.

Between the two seasons, changes were significant at *Rhizophora* sites (dry season higher than rainy season) ($P<0.05$) (Figure 3E).

3.2.2.5 Other less abundant groups

Some other groups such as polychaetes, oligochaetes, acari and ostracods were less abundant, usually less than 1% of total meiobenthos, but also showed their variations in different types of mangrove.

In general, polychaete density decreased from Mudflat sites to *Rhizophora* sites in the dry season. Differences between *Rhizophora* sites and other sites was significant ($P<0.05$). In the rainy season, oligochaete density changed a little, exception being at *Rhizophora* sites, where density was significantly higher than in the dry season ($P<0.05$). However there was no significant difference among the 4 sites in the rainy season ($P>0.05$) (Figure 5A).

Oligochaete densities in the dry season changed among the 4 sites, but this difference was not significant ($P>0.05$). The same result was obtained in the rainy season. Comparison between seasons showed that there was also no significant difference in the density of oligochaetes ($P>0.05$) (Figure 5B).

Concerning acari densities, Figure 5C shows that the overall density at Mudflat sites was lowest and significantly different from the other three forest sites in the dry season ($P<0.05$). In the rainy season, the density was not significantly different between sites ($P>0.05$). The significant difference between seasons was at Mudflat and *Rhizophora* sites ($P<0.05$).

Ostracods in the dry season showed significantly higher densities at Mudflat and *Avicennia* sites than at Mixed site ($P<0.05$). But in rainy season, ostracod density reduced at all sites and there was no significant difference between sites ($P>0.05$). Comparison between seasons showed that ostracod densities at Mudflat, *Avicennia* and *Rhizophora* sites in dry season were significantly higher than at the same sites in

rainy season (P<0.05). At Mixed sites changes between seasons were not significant (P>0.05) (Figure 5D).

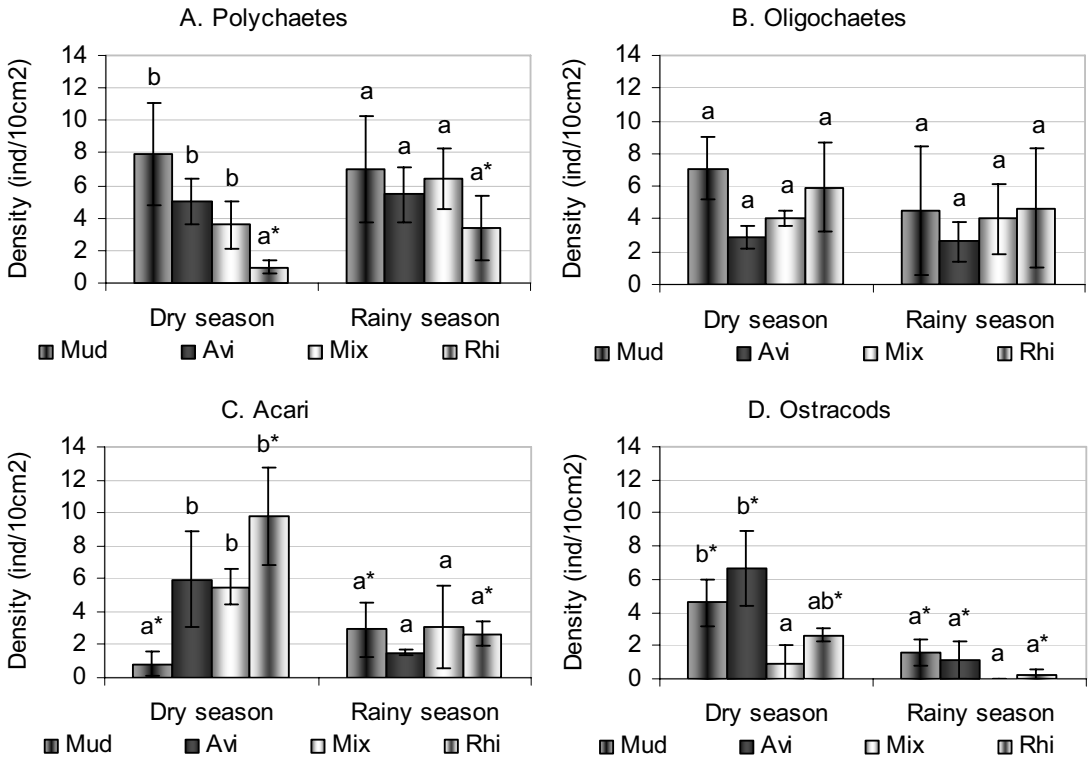

Figure 5. Densities (mean ± sd) of less abundant groups Oligochaetes (A), Polichaetes (B), Acari (C) and Ostracods (D) in dry and rainy seasons

For each season, columns with the same letter were not significantly different among sites (ANOVA, P>0.05)
At the same sites, columns with the star (*) were significantly different between two seasons (T-test, P<0.05)

3.2.2.6 Variation of the nematode/copepod ratio (N/C ratio)

Variation of N/C ratio was estimated for both the dry and rainy seasons. In dry season, nematode/copepod ratio was the highest at Mudflat sites and lowest at *Rhizophora* sites. Difference of N/C ratio between these sites was significant (P<0.05). In the rainy season, N/C ratios decreased at Mudflat, *Avicennia* and *Rhizophora* sites, but increased at Mixed sites. Change of N/C ratio in Mixed sites was significantly higher than at Mudflat, *Avicennia* and *Rhizophora* sites. N/C ratios in *Rhizophora* sites were significantly lower than in Mudflat and *Avicennia* sites (P<0.05) (Figure 3F).

Between the dry and rainy season, N/C ratio varied significantly in Mudflat and *Rhizophora* sites (P<0.05) (Figure 3F).

3.2.3 Correlation with abiotic factors

The Table 1 shows a significant positive correlation between the abundance of total meiobenthos, nematodes, and copepods and water temperature (T°C) (P<0.05; P<0.01)). N/C ratio also produced a positive correlation with water temperature (P<0.05). In addition, total meiobenthos and nematode density was significantly positively correlated with pH (P<0.05). Polychaetes had significant positive correlation with dissolved oxygen in the water (DO) (P<0.01). The abundances of meiobenthos or major meiobenthic groups were not significantly correlated with salinity (NaCl) or turbidity (Tu). Other meiobenthic groups, such as nauplii,

foraminifera, and oligochaetes did not show a significant correlation with temperature, dissolved oxygen , pH, salinity, or turbidity in this study.

Table 1. Correlations (r-value) between the abundance of total meiobenthos, individual meiobenthic groups, and the nematode/copepod ratio (N/C) and some physical variables at the sampling stations (the data correlations are based on samples from the dry and rainy season 2005)

Variable	T (°C)	DO (mg/l)	pH	NaCl (‰)	Tu (mg/l)
Total meiobenthos	0.964**	-0.238	0.833*	0.601	-0.259
Nematodes	0.962**	-0.233	0.827*	0.592	-0.244
Copepods	0.847*	-0.363	0.749	0.638	-0.341
Nauplii	0.625	0.041	0.378	0.206	-0.007
Foraminifera	0.426	0.513	0.256	-0.103	-0.047
Polychaetes	-0.332	0.942**	-0.556	-0.807	0.414
Oligochaetes	0.388	0.636	0.014	-0.370	0.583
N/C ratio	0.892*	0.038	0.733	0.361	-0.020

Values with one star (*) are significant at $P<0.05$
Values with two stars (**) are significant at $P<0.01$

3.3 Nematode assemblage

3.3.1 Taxonomy

3.3.1.1 List of species

The nematode community in Rach Oc Creek was investigated for both the dry and rainy season 2005. General results showed a total of 214 putative species, belonging to 92 genera, 36 families, and 10 orders (Table A7).

Number of the nematode taxa in Can Gio mangrove forest is very abundance. However, here we only mention and discuss an example of family Leptolaimidae, and two its genera *Leptolaimoides* and *Deontolaimus*. Family Leptolaimidae is one of the families with fairly high abundance and especially appearance of several new species.

3.3.1.2 Family Leptolaimidae Örley, 1880

Diagnosis. Leptolaimids comprise a heterogeneous group of genera with rather few characters in common, but typically have: cuticle striated, never punctated, the striation usually not coarse but widely spaced, six anterior cephalic sensilla usually minute; four posterior cephalic sensilla setiform; amphids never multispiral; buccal cavity often tubular or small, rarely with teeth; oesophagous usually with posterior bulb; males almost always with conspicuous well-cuticularised tubular precloacal supplements, test usually pair and opposed; ovaries usually paired and always reflexes.

3 subfamilies in Leptolaimidae: Leptolaiminae Örley, 1880; Anonchinae Andrassy, 1973 and Camacolaiminae Micoletzky, 1924. There are currently no available criteria by which to divide the Leptolaimidae into holophyletic subfamilies.

Subfamily Leptolaiminae Örley, 1880

List of known genera

1. *Alaimella* Cobb, 1920
2. *Anomonema* Hopper, 1963
3. ***Antomicron**** Cobb,1920
4. *Aphanolaimus* De Man, 1880
5. *Bathyonchus* Kreis, 1936
6. *Caribplectus* Andrássy, 1973
7. *Cricolaimus* Southern, 1914
8. *Cynura* Cobb, 1920
9. *Dagda* Southern, 1914
10. *Diodontolaimus* Southern, 1914
11. *Halaphanolaimus* Southern, 1914
12. ***Leptolaimoides**** Vitiello, 1971
13. ***Leptolaimus**** De Man, 1876
14. *Leptoplectonema* Cooman & Raski, 1991
15. *Listia* Blome, 1982
16. *Pakira* Yeates, 1967
17. *Paraphanolaimus* Nicoletzky, 1923
18. *Paraplectonema* Strand, 1934
19. *Plectolaimus* Inglis, 1966
20. *Stephanolaimus* Ditlevsen, 1914

***** Genus present in this study ****** Genus described to species

Genus *Leptolaimoides* Vitiello, 1971

Diagnosis. Cuticucles striated. Six papilla. Four cephalic setae. Buccal cavity tubular. Amphids elongate and oval. Lateral field presents. Gubernaculum with apophisis. Precloacal supplements tubular present or absent. Tail conical with postcloacal setae.

List of known species

1. *L. thermastris* Lorenzen, 1966 (type species)
2. *L. asiaticus* Gagarin & Nguyen Vu Thanh, 2005
3. *L. haploopis* Jensen, 1978
4. *L. punctatus* Yong Huang and Zhinan Zhang, 2006
5. *L. tubulosus* Vitiello, 1971

The present work contributed to describe 5 new species of *Leptolaimoides*.

***Leptolaimoides tropicus* sp. nov.** (Figure 6. A-F)

Etymology. The specific name refers to the type locality in the tropics.

Morphometric data. ♂$_1$ (holotype): L = 605 µm; a = 55.7; b = 7.1; c = 6.2; c' = 12.2; Spicules 10 µm on the chord. ♂$_2$: L = 509 µm; a = 54.0; b = 7.2; c = 6.2; c′ = 11.3; Spicules 11 µm on the chord. ♀$_1$: L = 589 µm; a = 47.8; b = 7.0; c = 5.4; c′ = 13.6; V = 40%. ♀$_2$: L = 544 µm; a = 44.1; b = 6.4; c = 6.6; c' = 9.5; V = 42%.

Description

Males (mainly referring to holotype). Body very slender, tapering to the ends. Body length 605 µm, maximum diameter 11 µm. Cuticle finely annulated with a lateral field beginning just posterior to the amphids and visible to the end of the conical region of the tail. Head with four minute cephalic setae (R_3), sensillae of R_1, and R_2, not visible. Amphids long oval (12 times longer than wide), 23 µm long (9.4 hd) and 2 µm wide (0.7 hd), and located at 9 µm (3.8 hd) from anterior end. Buccal cavity tubular and narrow, merging imperceptibly with oesophagus lining. Oesophagus cylindrical, only weakly enlarged at posterior end. Ventral gland or its exit pore not seen. Testes single directed anteriorly located on the left side of intestine. Spicules (1.3 abd) slender, regularly bent, weakly cuticularised, proximally with knobbed capitulum. Gubernaculum with straight dorso-caudal apophysis (3.6 µm). Precloacal supplements absent. Tail 97 µm long (12.2 abd), conical in 28-30% of its length, then narrowing to a filiform posterior end. There are two minute postcloacal setae. First one located at 1.5 abd from cloaca. The second one near the beginning of narrowing part of tail (1.5-1.6 abd after first one).Three serial caudal glands.

Females (paratypes). Similar to males in general appearance. Body slender and tapering to the end as in the males. Cuticle annulate with lateral field from the amphids to the end of the conical region of the tail. The maximum diameter (12 µm) is wider than in the males. Amphids located at nearly the same position as in male. Amphids somewhat shorter than in male. Ovaries opposed and reflexed. The anterior ovary on the right side of the intestine and the posterior ovary on the left side of intestine. Vulva at 40-42% of body length. Tail conical in approximately 30% and narrowing as in the males. Tubular structures (supplements) never seen in females.

Remarks

The new species resembles *L. thermastris* Lorenzen, 1966 and *L. haploopis* Jensen, 1978 in the absence of precloacal supplements.

It differs from *L. thermastris* in the body size (605 µm vs 350-380 µm) and in having longer amphids (19-23 µm vs 8-12 µm). Further, *L. tropicus* is also distinguished from *L. thermastris* by shorter spicules (10-11 µm vs 13 µm) and the more anterior location of the vulva (V = 40-42 % vs V = 43-46 %).

The new species differs from *L. haploopis* Jensen, 1978 by the smaller body size (605 µm vs 770 µm), shorter spicules (11-12 µm vs 16 µm) and shorter amphids (19-23 µm vs 30 µm).

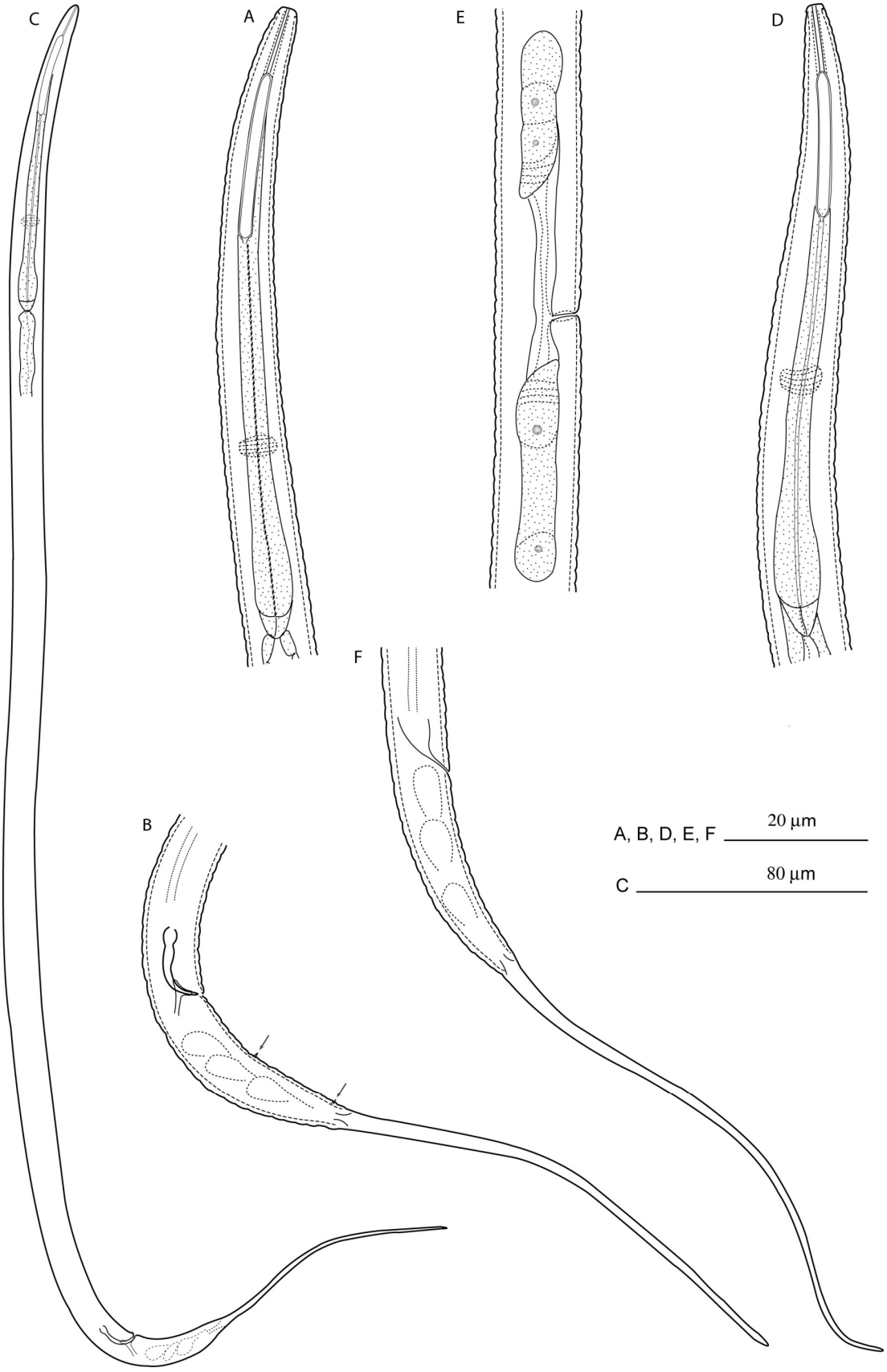

Figure 6. *Leptolaimoides tropicus* sp. nov., A-C, male, holotype: A, head region; B, tail region and spicular apparatus; C, total view. D-F, female, paratype: D, head region; E, vulva region; F, tail region

***Leptolaimoides cangioensis* sp. nov.** (Figure 7. A-F)

Etymology. The specific name refers to the sampling location in the Can Gio Biosphere Reserve, Vietnam.

Morphometric data. ♂$_1$ (holotype): L = 416 µm; a = 41.0; b = 5.7; c = 5.9; c′ = 7.8; Spicules 9 µm on the chord. ♂$_2$: L = 451 µm; a = 44.4; b = 6.3; c = 5.8; c′ = 9.0; Spicules 9 µm on the chord. ♂$_3$: L = 393 µm; a = 38.7; b = 6.2; c = 5.1; c' = 8.9; Spicules 9 µm on the chord. ♂$_4$: L = 360 µm; a = 38.2; b = 5.8; c = 5.4; c′ = 9.0; Spicules 10 µm on the chord. ♀$_1$: L = 341 µm; a = 31.3; b = 5.6; c = 6.5; c′ = 8.0; V = 52 %. ♀$_2$: L = 307 µm; a = 26.5; b = 4.9; c = 4.0; c' = 10.5; V = 45 %; ♀$_3$: L = 442 µm; a = 38.1; b = 6.2; c = 5.7; c' = 10.1; V = 43 %.

Description

Males (mainly referring to holotype). Body slender, maximum diameter 10 µm. Cuticle striated. Lateral field with two longitudinal dotted lines from posterior of the amphids to the end of the conical region of the tail. Head with four minute cephalic setae (R_3), sensillae of R_1, and R_2, not visible. Amphids short, oval, 5 µm long (2 hd) and 1.4 µm wide (0.6 hd), and located at 8 µm (3 hd) from anterior body end. Buccal cavity tubular and narrow, length 16 µm (6.4 hd). Oesophagus cylindrical, weakly enlarged at end. Spicules slender, ventrally curved, 9 µm on the chord. Gubernaculum strong with a caudal apophysis straight then bent to dorsal side, length 6 µm. Two tubular, equally sized, precloacal supplements, 6 µm long. Tail 70 µm long (7.8 abd), conical in 34% of its length, then narrowing to be filiform. Two tiny postcloacal setae present. First one located at 0.6 abd from cloaca. The second one at 1 abd posterior to the first one. Three serial caudal glands in the conical part of the tail.

Females (paratypes). Similar to male in most features. Average body length 363 µm, slightly smaller then average male length. But the maximum diameter is wider than in males (average 11 µm vs 10µm). Amphids the same size as in the male but one paratype female showed amphids of 5.4 µm length and 1.7 width, larger then in males. Ovaries, opposed and reflexed. Anterior ovary on the right and posterior ovary on the left side of intestine. Vulva at 43-51% of body length. Tail length (8-10.5 abd), conical then narrowing to be filiform and the filiform portion appearing to be set off by a slight constriction.

Remarks

In the genus *Leptolaimoides* only *L. cangioensis* sp. nov. is characterized by the presence of two precloacal supplements in the male. Moreover, it also differs from known species in having the shortest amphids (4-6 µm), in the original structure of spicules and gubernaculum with apophysis right and then bent to dorsal side. Two tubular equally sized precloacal supplements, 5-7 µm long. Tail 67-78 µm long, conical in 34% of its length, then narrowing to be filiform and in the female the filiform portion appearing to be set off by a slight constriction.

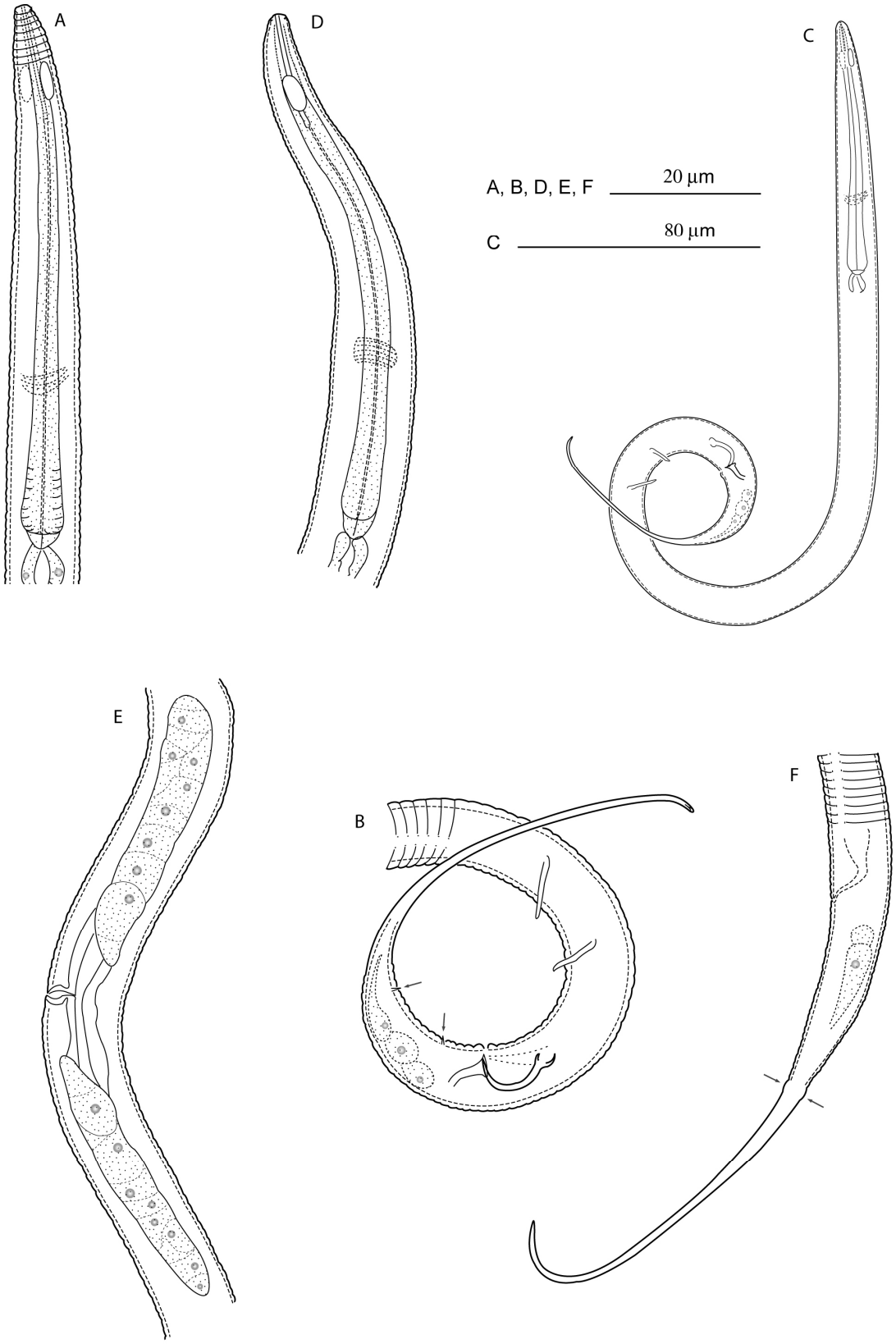

Figure 7. *Leptolaimoides cangioensis* sp. nov., A-C, male, holotype: A, head region; B, tail region and spicular apparatus; C, total view. D-F, female, paratype: D, head region; E, vulva region; F, tail region

***Leptolaimoides mangrovi* sp. nov.** (Figure 8. A-F)

Etymology. The specific name refers to the sampling location in mangrove forest.

Morphometric data. ♂$_1$ (holotype): L = 458 µm; a = 40.8; b = 5.7; c = 5.8; c' = 8.7; Spicules 11 µm on the chord. ♂$_2$: L = 391 µm; a = 37.2; b = 6.4; c = 6.0; c′ = 7.5; Spicules 11 µm on the chord. ♂$_3$: L = 343 µm; a = 30.5; b = 5.0; c = 6.3; c′ = 7.5; Spicules 11 µm on the chord. ♂$_4$: L = 361 µm; a = 29.3; b = 5.1; c = 4.4; c′ = 9.3; Spicules 12 µm on the chord.♀$_1$: L = 458 µm; a = 43.6; b = 6.9; c = 5.4; c′ = 10.5; V = 46 %. ♀$_2$: L = 463 µm; a = 36.5; b = 7.1; c = 6.3; c' = 9.2; V = 50 %. ♀$_3$: L = 402 µm; a = 31.7; b = 6.1; c = 4.9; c' = 8.4; V = 56 %.

Description

Males (mainly referring to holotype). Body slender, maximum diameter 11 µm. Cuticle very finely annulated with lateral field from posterior end of amphids to anterior to the narrowing part of tail. Head with four very minute cephalic setae (R_3), sensillae of R_1, and R_2, not visible. Amphids long oval, 13 µm long (5.1 hd) and 2 µm wide (0.9 hd), and located at 8 µm (3.1 hd) from anterior body end. Buccal cavity tubular, narrow. Oesophagus cylindrical and weakly enlarged at posterior end. Spicules strongly cuticularised, distally curved ventral, proximally with knobbed capitulum, 11 µm measuring on the chord. Gubernaculum large with straight caudal apophysis 5 µm long. Three tubular, equally sized, precloacal supplements of simple structure, each 4 µm long, first one at 15 µm from cloaca, second one at 7 µm from first one, last one at 11 µm from second one. Tail 79 µm long (8.7 abd), conical in 30% of its length, then gradually narrowing to end in a pointed (acute) tip. Two tiny postcloacal setae. First one located near the middle of conical part of the tail (1 abd from cloaca). The second one at 0.5 abd after the first one. Number and arrangement of caudal glands not clearly discernable due to size of specimens.

Females (paratypes). Similar to male in most features. Body size 402-463 µm, maximum diameter 10-13 µm, being slightly bigger than the males. Amphids same as in males, in the same position from anterior end as in males. Ovaries opposed and reflexed. Anterior ovary on the right, posterior one on the left of intestine. Vulva at 46-56 % of total body length.

Remarks

L. mangrovi sp. nov. resembles *L. asiaticus* Gagarin, Nguyen Vu Thanh, 2005, but it differs from *L. asiaticus* in having shorter amphids (10-14 µm vs 17-18 µm) and in the further anterior location of the amphids (6-8 µm from anterior end of body vs 11 µm). It differs also in the smaller size of the spicules (11-12 µm vs 15-16 µm) and shorter supplements (4-7 µm vs 7-8 µm).

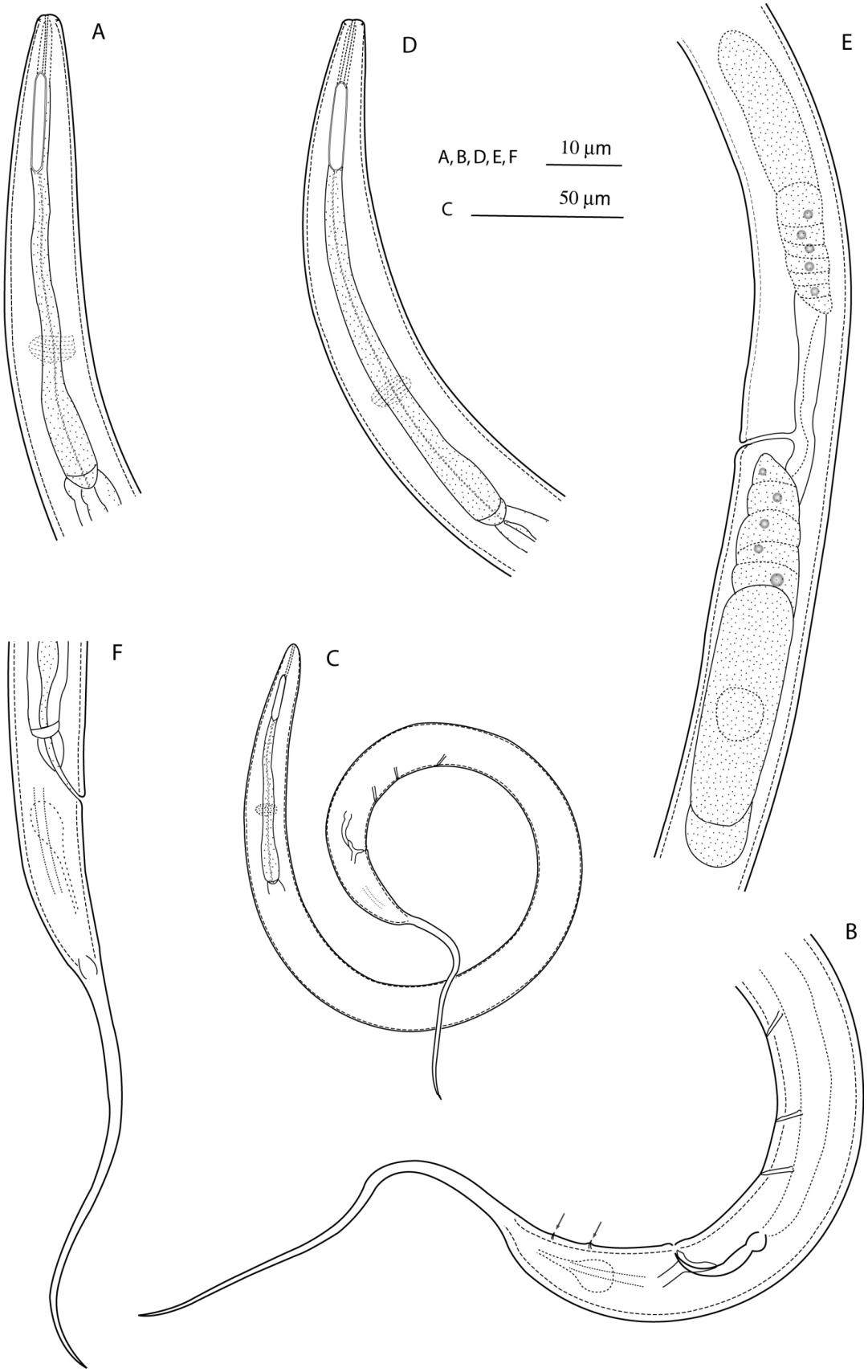

Figure 8. *Leptolaimoides mangrovi* sp. nov., A-C, male, holotype: A, head region; B, tail region and spicular apparatus; C, total view. D-F, female, paratype: D, head region; E, vulva region; F, tail region

***Leptolaimoides clavicaudatus* sp. nov.** (Figure 9. A-D)

Etymology. The specific name refers to the club-shaped (claviform) terminal part of the tail.

Morphometric data. ♂$_1$ (holotype): L = 213 µm; a = 23.5; b = 4.1; c = 4.5; c' = 6.5; Spicules 9 µm on the chord. ♀$_1$: L = 384 µm; a = 37.8; b = 6.0; c = 7.9; c′ = 6.7; V = 49 %.

Description

Males (holotype). Body small, comparatively stocky, maximum diameter 9 µm. Cuticle very fine annulated. Lateral fields not seen. Four minute cephalic setae (R_3) not clear, sensillae of R_1, and R_2, not visible. Amphids long oval, 10 µm long (5.4 head diameter) and 1 µm wide (0.8 hd), and located at 4 µm (2.4 hd) from anterior body end. Buccal cavity tubular, narrow. Oesophagus cylindrical, weakly enlarging to a posterior bulb-like end. Testes single directed anteriorly on the left side of intestine. Spicules slender, distally curved ventral, measuring 9 µm on the chord. Gubernaculum with straight caudal apophysis 4 µm long. Four tubular, equally sized, precloacal supplements, 7 µm long, with rounded cephalisations proximally, first one at 16 µm from cloaca, others at 13-14 µm from previous one. Tail 47 µm long (6.5 abd), conical in 65% of its length, then narrowing to be cylindrical, ending in a club-shaped terminal portion. Three caudal glands with common spinneret. Two tiny postcloacal setae in the conical part of the tail. First one located at 2.1 abd from cloaca. The second one at 1.1 abd posterior to first one.

Females (paratypes). Similar to male in most characters. Body size nearly being double that of males, though maximum diameter is only slightly wider than in the male (10 µm vs 9 µm). Amphids smaller (9 µm vs 10 µm) and located further behind anterior end than in the male (7 µm vs 4 µm). Ovaries opposed and reflexed. Anterior ovary on the right, posterior one on the left of intestine. Tail conical in approximately 57 %, then cylindrical and ending in a club-shaped terminal portion. Vulva at 49 % of body length. Situation of the caudal glands not clearly visible.

Remarks

Within the genus *L. clavicaudatus* sp. nov. is characterized by the presence of four precloacal supplements in the male. It is close to *L. punctatus*, but differs from this species in absence of two longitudinal rows of dots and in smallest size of body (213-384 µm vs 615-692 µm in *L. punctatus*), it also differs from that by having a small length of the spicules (8.7 µm vs 17 µm) and smaller length of the amphids (9.8 µm vs 19-23 µm). Moreover, it also differs from all known being the smallest one (213 µm), by shorter spicules (9 µm) and a shorter tail (47 µm) with a club-shaped terminal portion.

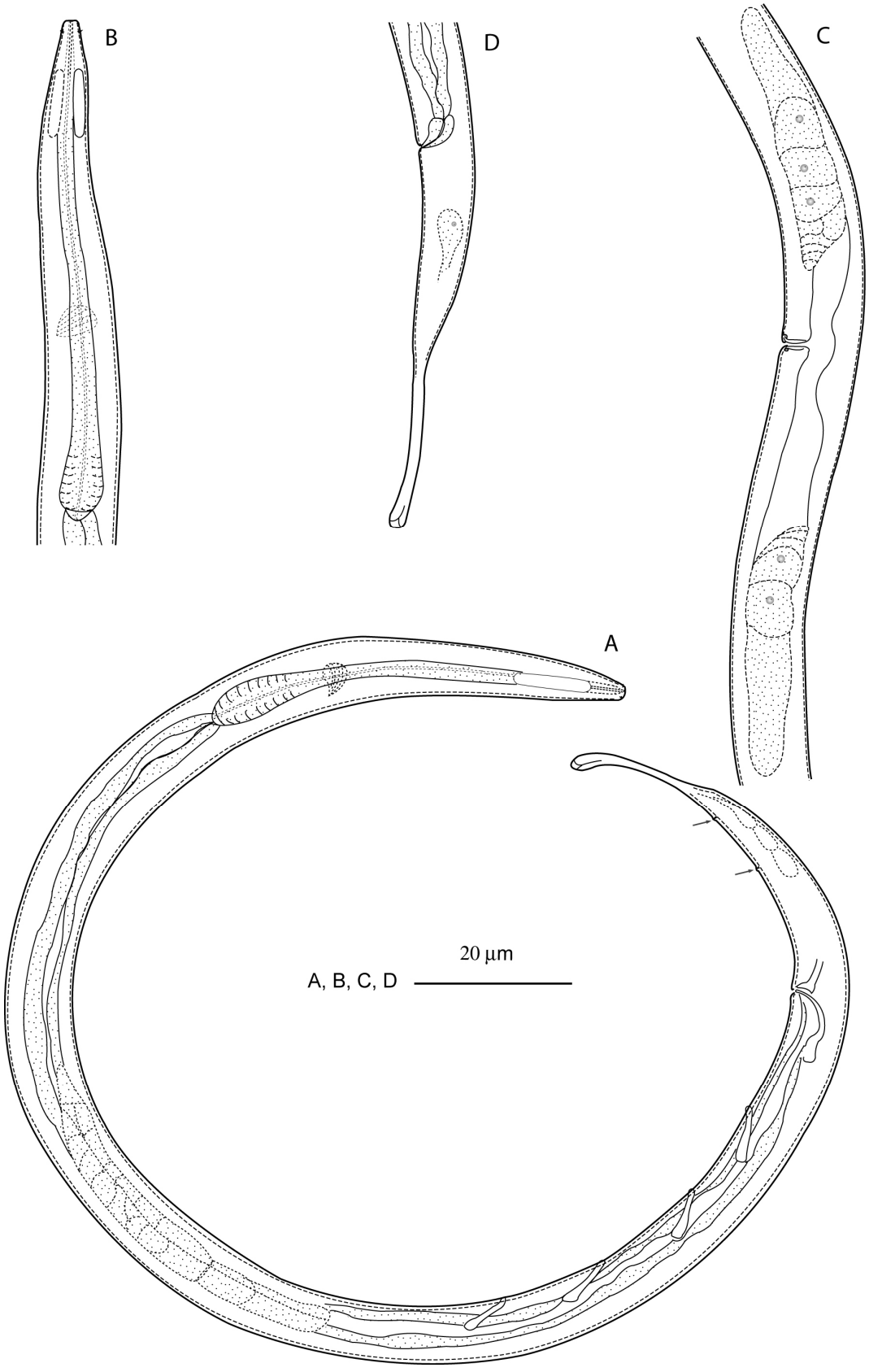

Figure 9. *Leptolaimoides clavicaudatus* sp. nov., A, male, holotype, total view. B-E, female, paratype: B, head region; C, vulva region; D, tail region

***Leptolaimoides hexatubulosus* sp. nov.** (Figure 10. A-D)

Etymology. The specific name refers to the six tubular precloacal supplements of the male.

Morphometric data. ♂$_1$ (holotype): L = 529 μm; a = 37.0; b = 3.9; c = 4.1; c' = 10.9; Spicules 12 μm on the chord.

Description

Males (holotype). Body slender, tapering to the ends. Body length 529 μm, maximum diameter 14 μm. Cuticle annulated and created the lateral field with 2 longitudinal ridges immediately posterior to the amphids, visible to the end of the conical region of the tail (Figure 10D). Head with four minute cephalic setae (R_3), sensillae of R_1, and R_2, not visible. Amphids long oval (8 times longer than wide), 16 μm long (3 hd) and 2 μm wide (0.4 hd), and located at 8 μm (1.5 hd) from anterior end. Buccal cavity tubular and narrow with length 15 μm. Oesophagus cylindrical enlarged at posterior end. Cervical gland detected but the excretory pore invisible. Testes single directed anteriorly located on the left side of intestine. Spicules strong cuticularised, 12 μm on the chord (1 abd), regularly bent, proximally with knobbed capitulum. Gubernaculum with dorso-caudal apophysis (6 μm). 6 tubular precloacal supplements with length 9 μm. Distance between them is normally 9 μm, except the distance between supplement 1 and 2 is 12 μm. The distance from supplement 6 to cloaca is 18 μm. Tail 127 μm long (10.9 abd), conical in 28% of its length, then narrowing to a filiform posterior end. There are two minute postcloacal setae. First one located at 1.4 abd from cloaca. The second one near the beginning of narrowing part of tail (0.75 abd after first one). Three serial caudal glands.

Females. There are no females detected.

Remarks

Within the genus *L. hexatubulosus* sp. nov. is characterized by the presence of six precloacal supplements in the male. In addition, it has a more complicated lateral field with 2 longitudinal ridges in comparison with other *Leptolaimoides* species.

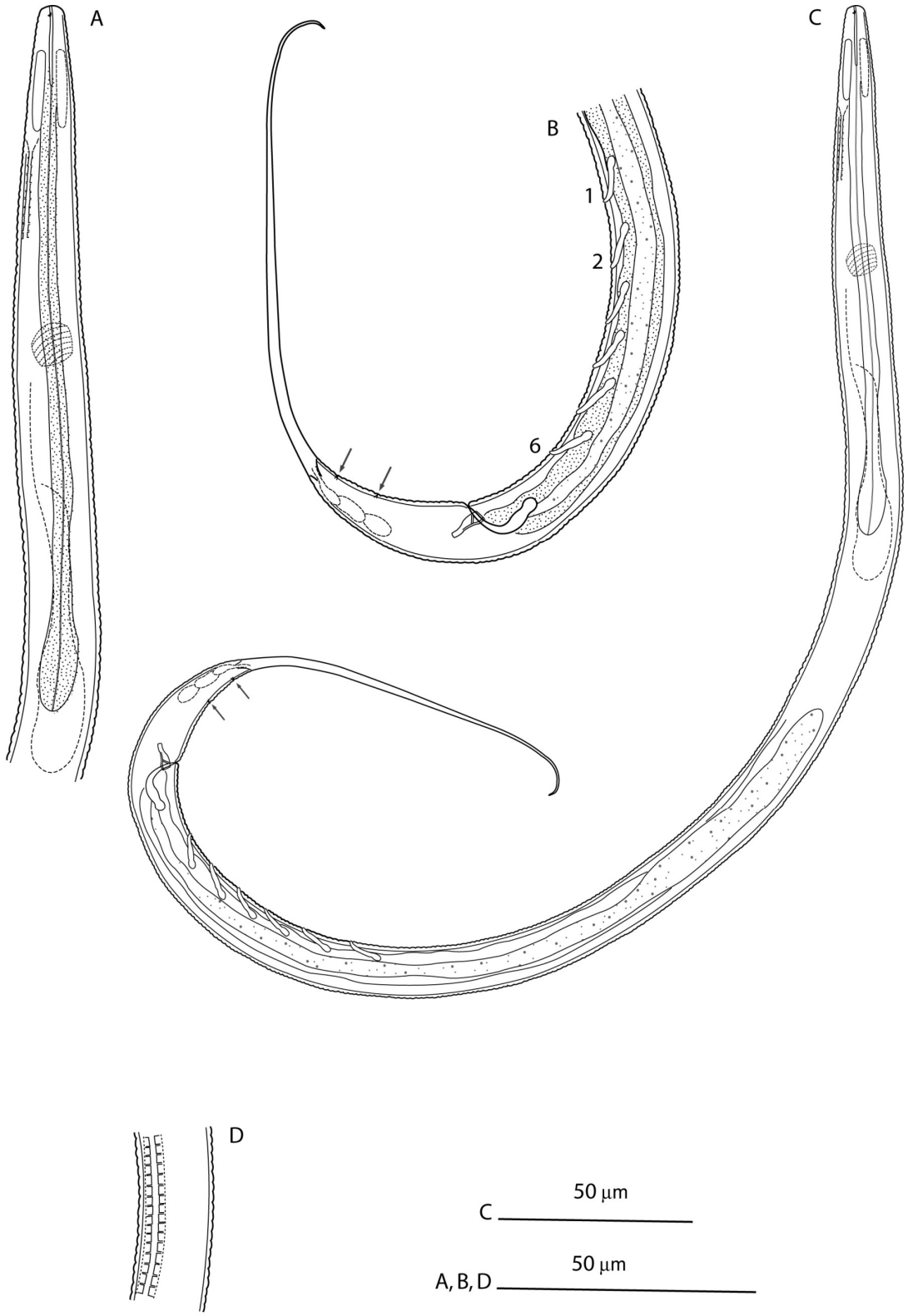

Figure 10. *Leptolaimoides hexatubulosus* sp. nov., A, male head, B, cloacal and tail region, C, total view. D, lateral field at midbody

Key to the species of the genus *Leptolaimoides*

1(6). Supplements in males absent
2(3). Small nematodes: L = 350 μm;
spicules = 13 μm…… *L. thermastris* Lorenzen, 1966
3(2). Large nematodes, body length more than 500 μm.
4(5). Body length 770 μm; amphid length 30 μm;
spicules16 μm ..... *L. haploopis* Jensen, 1978
5(4). Body length ≤ 600 μm; amphid length 19-23 μm;
spicules 10-11 μm.....…..…….. *L. tropicus* sp. nov.
6(1). Supplements in males present
7(8). Male with 6 supplements..... *L. hexatubulosus* sp. nov.
8(7). Male with 2-4 supplements
9(12). Males with 4 supplements.
10(11). Body length 615-692 μm; amphid length 19-23 μm;
body with two longitudinal rows of enlarged dots…*L. punctatus* Yong Huang & Zhinan Zhang, 2006
11(10). Body length 213-384 μm; amphids length 9.8 μm; body without two longitudinal rows of enlarged dots……..……*L. clavicaudatus* sp. nov.
12(9). Males with 2-3 supplements
13(14). Males with 2 supplements…….....…… *L. cangioensis* sp.nov.
14(13). Males with 3 supplements
15(16). Large nematodes, body length > 500 μm; amphid length 21 μm; spicules length 13 μm; supplement length 11 μm..……*L. tubulosus* Vitiello, 1971
16(15). Smaller nematodes, body length < 500 μm.
17(18). Body length 343-458 μm; amphid length 10-14 μm;
spicules length 11-12 μm; supplement length 4-7 μm……*L. mangrovi* sp. nov.
18(17). Body length 445-473 μm; amphid length 17-18 μm;
spicules length 15-16 μm;
supplement length 7-8 μm……. *asiaticus* Gagarin & Nguyen Vu Thanh, 2005

Subfamily Camacolaiminae Micoletzky, 1924

Diagnosis. The Camacolaiminae always have amphids which are ventrally-spiral with one loop; they always lie between the posterior 4 cephalic sensilla or may even be anterior to them. There is usually a buccal cavity spear which is inserted in the dorsal wall of the buccal cavity. The pharynx usually has a glandular swelling at the end. Cuticle is usually striated and is seldom smooth. Some of the males have pre-cloacal tubules.

List of known genera

1. *Anguinoides* Chitwood, 1936
2. *Camacolaimoides* De Coninck and Stekhoven, 1933
3. ***Camacolaimus**** De Man, 1889
4. ***Deontolaimus**** De Man, 1880
5. *Eontolaimus* Furstenberg & Vincx, 1988
6. *Ionema* Cobb, 1920
7. *Nemella* Cobb, 1920
8. *Neurella* Cobb, 1920
9. ***Onchium**** Cobb, 1920
10. *Procamacolaimus* Gerlach, 1954

***** Genus present in this study ****** Genus described to species

Genus *Deontolaimus* De Man, 1880

List of known species:

1. *D. papillatus* De Man, 1880 (type and single species)

The present work contributes to describe 2 new species in *Deontolaimus*.

***Deontolaimus mangrovi* sp. nov.** (Figure 11, A-E; Figure 12, A-D)

Etymology. The specific name refers to the sampling location in mangrove forest.

Morphometric data. (holotype) ♂$_1$: L = 523 µm; a = 28.8; b = 4.5; c = 5.5; c' = 7.3; spi 20 µm; sup = 47

Paratype, ♂$_2$: L = 729 µm; a = 50.3; b = 5.7; c = 7.3; c′ = 8.4; spi = 26 µm; sup = 49. ♂$_3$: L = 631 µm; a = 41.4; b = 5.3; c = 6.7; c′ = 7.6; spi = 20 µm; sup not clear. ♂$_4$: L = 757 µm; a = 49.7; b = 6.0; c = 7.3; c′ = 9.0; spi = 24 µm; sup not clear. ♂$_5$: L = 766 µm; a = 48; b = 5.7; c = 8.0; c′ = 7.8; spi = 22 µm; sup = 38. ♂$_6$: L = 685 µm; a = 45.0; b = 5.5; c = 7.2; c′ = 8.2; spi = 25 µm; sup = 49. ♂$_7$: L = 617 µm; a = 40.5; b = 4.8; c = 7.7; c′ = 6.5; spi = 20 µm; sup = 34. ♂$_8$: L = 664 µm; a = 45.8; b = 5.0; c = 6.6; c′ = 8.6; spi = 21 µm; sup = 32. ♂$_9$: L = 478 µm; a = 31.4; b = 3.9; c = 6.3; c′ = 6.1; spi = 21 µm; sup = 34.

♀$_1$: L = 907 µm; a = 34.7; b = 4.6; c = 9.1; c′ = 6.0; V = 46%. ♀$_2$: L = 874 µm; a = 43.0; b = 4.5; c = 9.5; c' = 7.5; V = 52%. ♀$_3$: L = 904 µm; a = 47.9; b = 6.5; c = 7.4; c' = 10.5; V = 43%. ♀$_4$: L = 921 µm; a = 51.8; b = 4.7; c = 7.8; c' = 10.2; V = 46%. ♀$_5$: L = 752 µm; a = 37.1; b = 3.8; c = 9.2; c' = 6.6; V = 46%. ♀$_6$: L = 856 µm; a = 40.7; b = 5.8; c = 7.7; c' = 8.5; V = 44%.

Description

Male. Body length 650 µm (478-766 µm). Maximum diameter 15 µm (14-16 µm). Cuticle fine annulate with longitudinal unstriated band from just posterior to the amphids and visible to the end of the conical region of the tail. Four cephalic setae very minute and difficult to detect, six anterior sensilla not visible. Amphids a simple spiral of one turn situated well forward between the cephalic setae, 2-3 µm (0.5-0.6 hd). Buccal cavity with a long stylet like tooth, length 19 µm (3.3 hd). Oesophagous cylindrical, enlarged about one third posterior into an elongate bulb. Testes pair, outstretched and located in the left side of intestine. Spicules ventrally curve, 22 µm measured along the chord. Gubernaculum with caudal apophysis. 32-49 simple precloacal supplements cup shaped. The number and arrangement of supplements varying from different individuals. The specimens with 32-34 supplements, 26-27 supplements located frequently from anterior oesophagus region to the middle body, 6-8 remaining supplements located in the precloacal region, among them 4 supplements create a subgroup present near the precloaca (Figure 11C). Other specimens with 47-49 supplements, 42-44 supplements in the anterior group, only 5 supplements in the precloacal region and 3 supplements in the subgroup nearest cloaca (Figure 11E). However, number of supplements from the anterior part of oesophagus to the cadia always is 17-19 supplements (Figure 11A, 11B). Tail 93 µm long (7.7 abd), conical in 25-30% of its length, then narrowing and elongated.

Female. Similar to male in most features. Body length 869µm (752-920 µm), much longer than in male. Maximum diameter 21, a little wider than male width. Ovaries paired, opposed and reflexed. Vulva at 46% (43-52%) of body length.

Remarks

The new species differs from *D. papillatus* in shape of tail: conical then elongated and end without pointed tip vs conical with pointed tip strongly cuticularised.

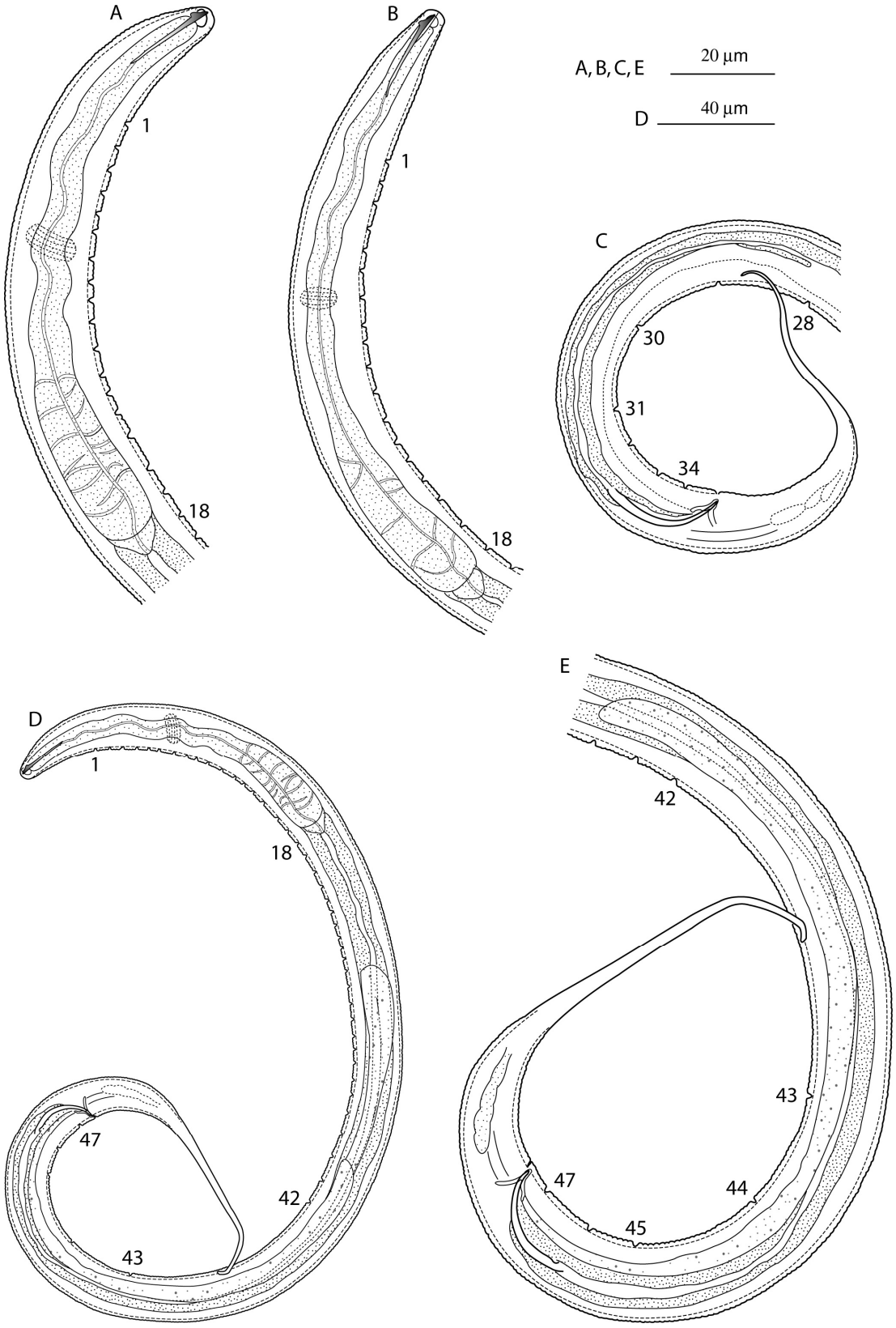

Figure 11. *Deontolaimus mangrovi* sp. nov. Male. A, Anterior end of male1; B, Anterior end of male2; C, Tail of male2; D, Entire male1; E, Posterior testis and tail region of male1

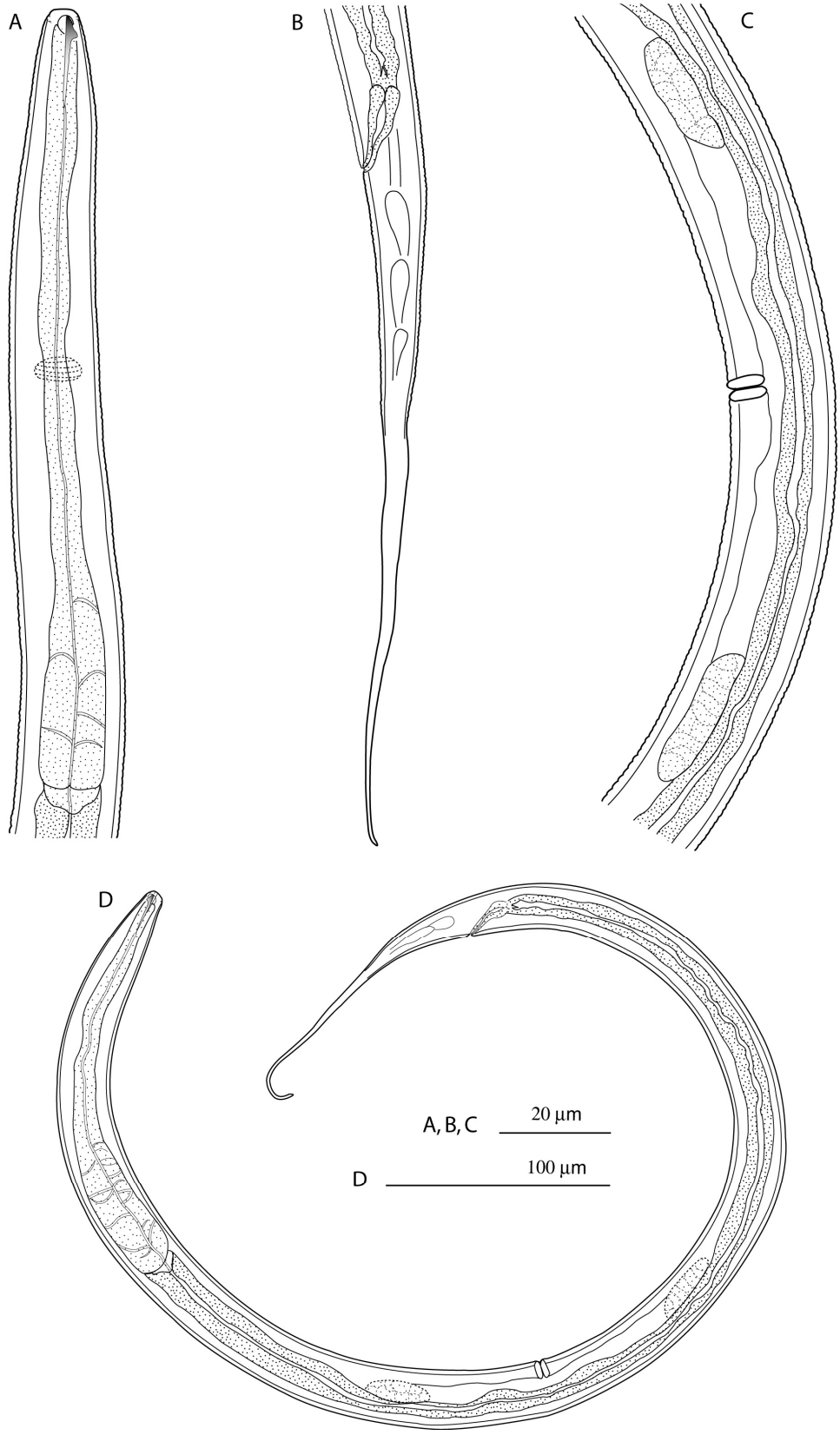

Figure 12. *Deontolaimus mangrovi* sp. nov. Female. A, Anterior end of female1; B, Tail of female1; C, Vulva region of female2; D Entire female2

***Deontolaimus pseudopapillatus* sp. nov.** (Figure 13, A-C; Figure 14, A-D)

Etymology. Specific name refers to the species resemblance to *D. papillatus* De Man, 1880

Morphometric data. ♂$_1$ (holotype): L = 607 µm; a = 30.3; b = 4.2; c = 9.7; c' = 3.7; spi 26 µm; sup = 31.

Paratype, ♂$_2$: L = 598 µm; a = 48.2; b = ?; c = 9.5; c′ = 6.3; spi not clear; sup = 32. ♂$_3$: L = 468 µm; a = 37.8; b = 4.2; c = 10.0; c′ = 4.4; spi not clear; sup = 35. ♀$_1$: L = 737 µm; a = 31.4; b = 4.9; c = 11.6; c′ = 4.6; V = 52%. ♀$_2$: L = 774 µm; a = 35.4; b = 5.3; c = 10.3; c' = 5.1; V = 51%. ♀$_3$: L = 600 µm; a = 30.3; b = 4.4; c = 8.7; c' = 5.1; V = 51%. ♀$_4$: L = 505 µm; a = 37.3; b = 4.7; c = 10.1; c' = 5.3; V = 50%.

Description

Males (mainly referring to holotype). Body length 607 µm, maximum diameter 20 µm. Cuticle finely annulated with a lateral field visible just behind to the base of oesophagous and ends in the tail region. Head with four small cephalic setae (R_3) 2µm long (0.25 hd), sensillae of R_1, and R_2 minute papiliform and difficult to detect. Amphids one turn spiral, 2 µm wide (0.25 hd), and located at equal position with cephalic setae (R3) from anterior end. Dorsal buccal tooth 14 µm long (2 hd), strongly cuticularised at the tip. Oesophagus cylindrical, only weakly enlarged at posterior end. Ventral gland or its exit pore not seen. Testes two, outstretched and directed forward, located on the left side of intestine. Spicules 26 µm measured on the chord (1.5 abd) slender, regularly bent with proximal half swollen. Gubernaculum small with curve dorsal-caudal apophysis. 31 precloacal supplements simple cup-shaped begin posterior to the end of the dorsal tooth and extend to middle body position (60% of body length from anterior end). Tail conical 62 µm long (3.7 abd). Tail tip very strongly cuticularised and unstriated. There are two minute postcloacal setae. First one located at 26 µm from cloaca (1.5 abd). The second one at 0.5 cbd from the first one. Three serial caudal glands.

Females (paratypes). Similar to males in general appearance. Body length average 654 µm (505-774 µm) Cuticle annulate with 3 weak lateral lines, visible in the middle body. The maximum diameter average 20 µm (14-23 µm). Dorsal tooth average 11 µm (9-14 µm) little smaller than in males. Amphids located at nearly the same position as in male. Ovaries opposed and reflexed antidromously. The anterior ovary on the right side of the intestine and the posterior ovary on the left side of intestine. Vulva at 50-52% of body length. Tail conical with tail tip pointed. Tubular structures (supplements) never seen in females.

Remarks

The new species resembles *D. papillatus* De Man, 1880 in the shape of body, especially in the tail region tail tip.

It differs from *D. papillatus* in shape of gubernaculum: simple plate-like in *D. papillatus* vs complicated plate-like with dorsal curve apophyses in *D. pseudopapillatus*.

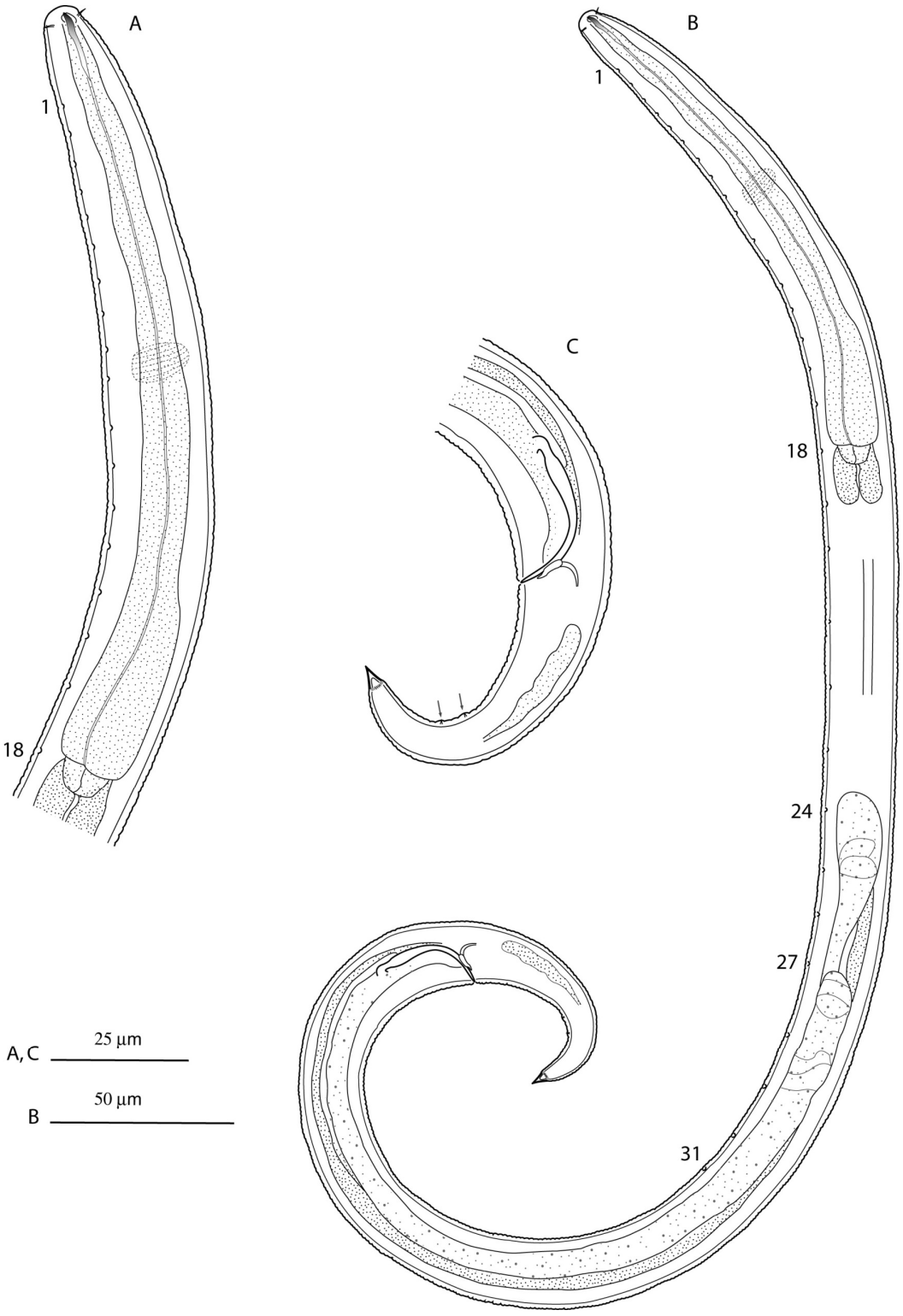

Figure 13. *Deontolaimus pseudopapillatus* sp. nov. Male. A. Anterior end of male; B. Entire male; C. Tail of male

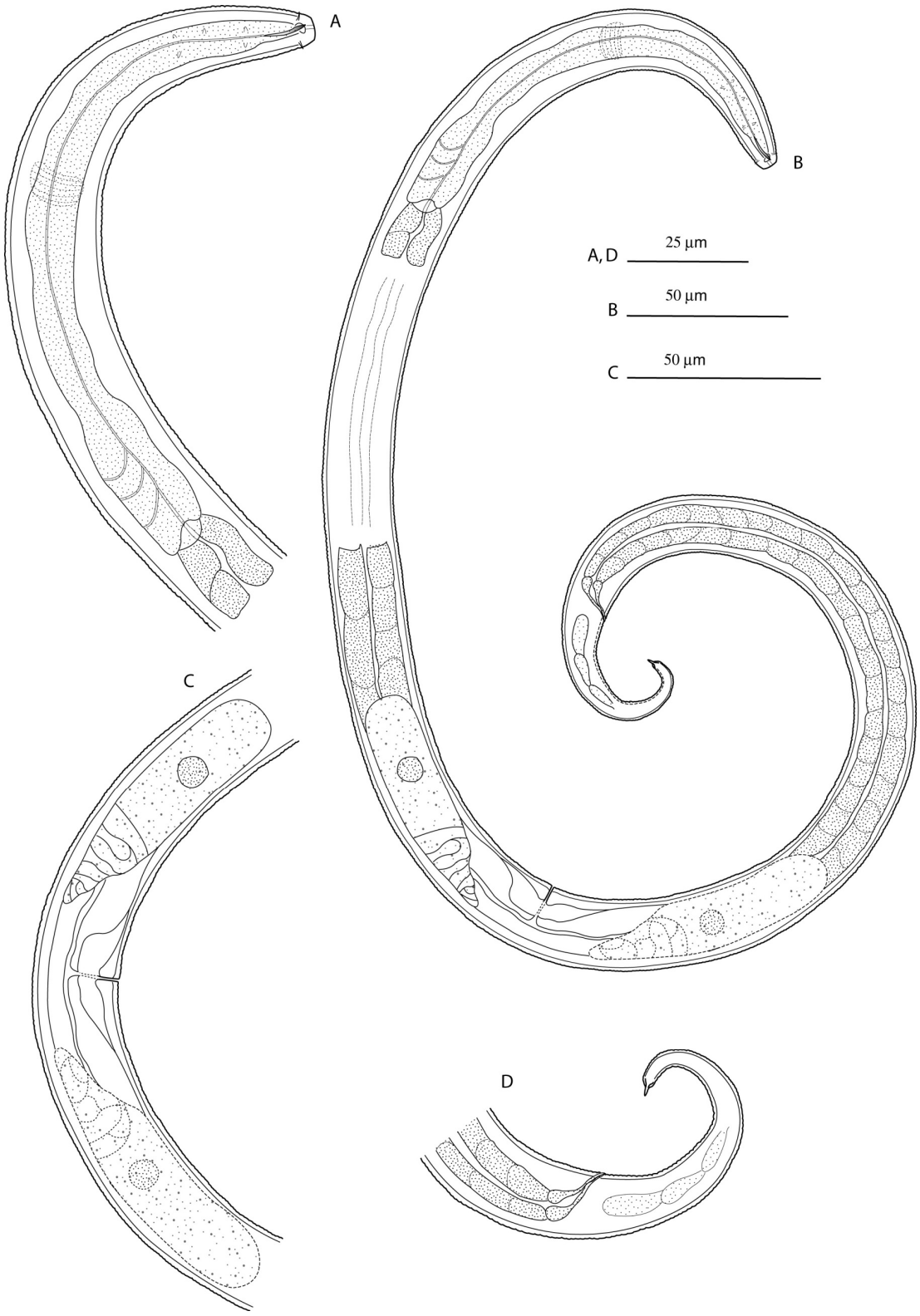

Figure 14. *Deontolaimus pseudopapillatus* sp. nov. Female. A. Anterior end of female; B. Entire female; C. Vulva region of female; D. Tail of female

Key to the species of the genus *Deontolaimus*

1(2). Tail conical and elongated without pointed tip……...*D. mangrovi* sp. nov.
2(1). Tail conical with pointed tip
3(4). Gubernaculum simple plate-like without apophyses…….....*D. papillatus* De Man, 1880
4(3). Gubernaculum complicated with dorsal curve apophyses ..……*D. pseudopapillatus* sp. nov.

3.3.2 Ecology

3.3.2.1 Nematode composition

Nematode composition in the dry season

In the dry season, 200 putative species, belonging to 89 genera, 34 families and 10 orders were recorded. In these families, 17 families with an abundance higher than 1% represent 87.8% total nematode individuals, in which the highest abundance was recorded for Linhomoeidae with 15%, second highest was Xyalidae with 12.5% and third highest was Comesomatidae with 10.2% (Figure 15).

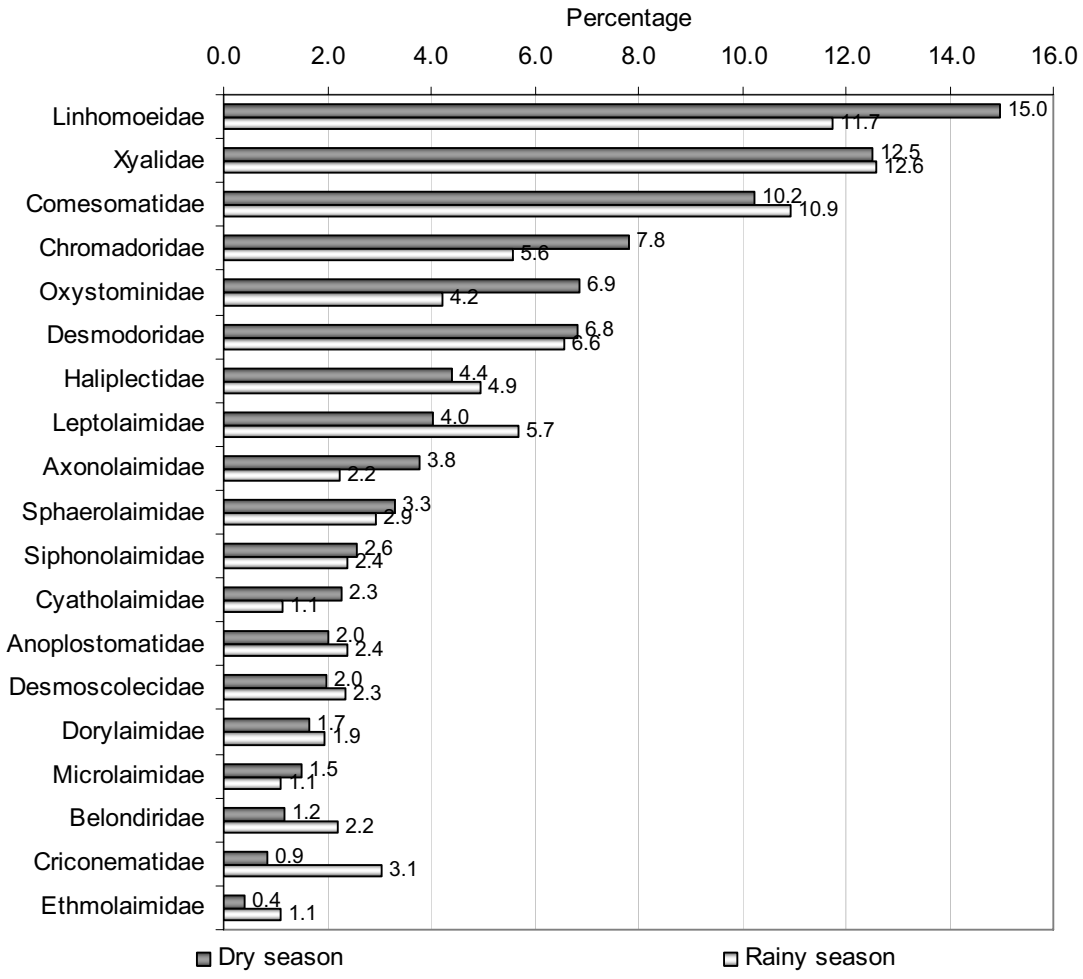

Figure 15. Percentile abundance of nematode families

Among these species, the most abundant species were *Theristus* sp1 (4.1%). *Hopperia* sp1 (4.0%). *Paracomesoma* sp2 (4.0%). *Terschellingia* sp3 (3.3%). *Terschellingia* sp4 (3.3%). *Parodontophora* sp1 (3.0%) and *Dichromadora* sp1 (2.9%) (Figure 16).

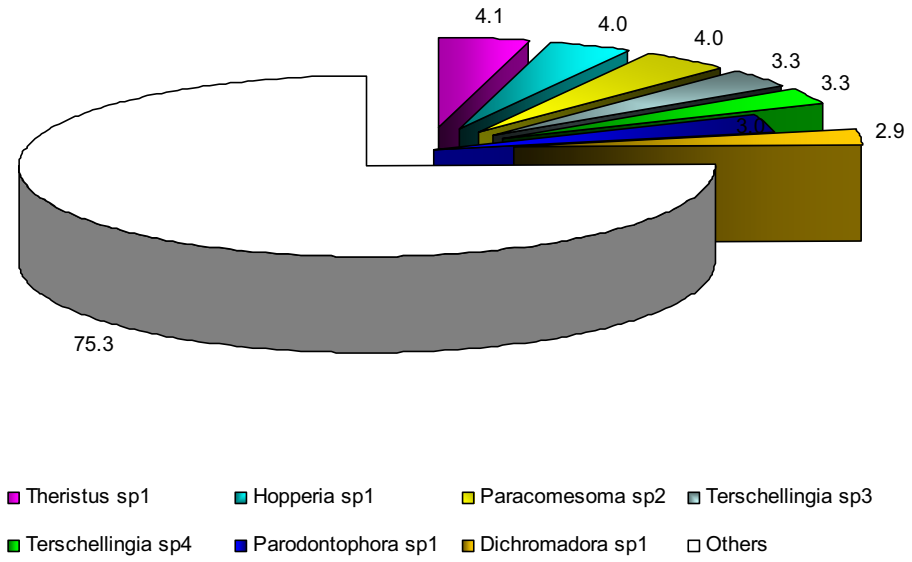

Figure 16. Nematode community composition in the dry season

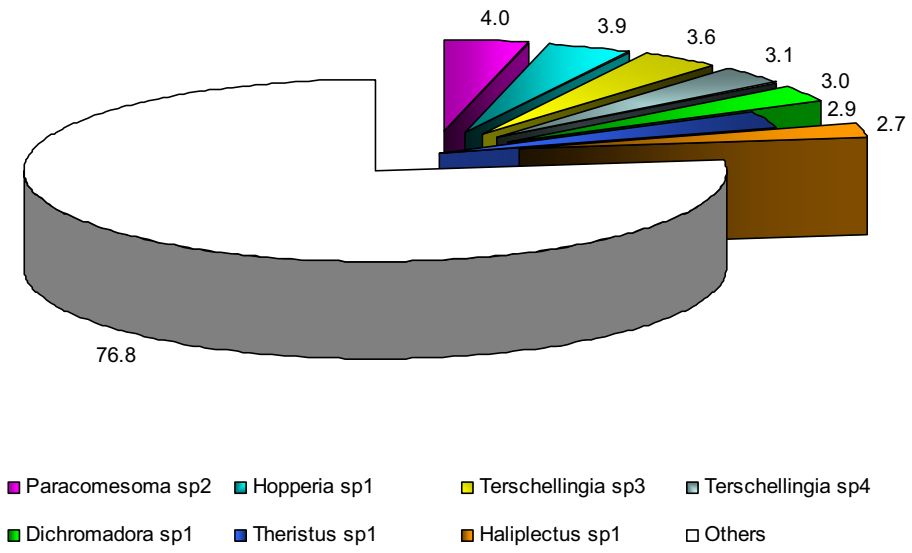

Figure 17. Nematode community composition in the rainy season

Nematode composition in the rainy season

In the rainy season 2005, investigation in Rach Oc showed 205 species, belonging to 90 genera, 36 families and 10 orders. In general, number of species varied between seasons, but the rainy season had a higher species number than the dry season. In these families, 19 families with abundance higher than 1% of total nematode

individuals representing 85% of total nematode individuals. The highest abundance was recorded for Xyalidae with 12.6%, second most abundant was Linhomoeidae with 11.7% and the third was Comesomatidae, with 10.9%. Between seasons, Linhomoeidae reduced drastically from 15.0% in the dry season to 11.7% in rainy season, Chromadoridae from 7.8% to 5.6%, and Oxystominidae from 6.9% to 4.2%. On the other hand, families as Criconematidae and Leptolaimidae increased from 0.9% to 3.1% and from 4.0% to 5.7% from the dry to the rainy season (Figure 15).

In reference to individual species, results showed that *Theristus* sp1 abundance was reduced from being the most abundant species in the dry season with 4.1%, to being the sixth most abundant in the rainy season, with 2.9%. *Hopperia* sp1 and *Paracomesoma* sp2 species abundance varies slightly between two seasons. The most abundant species in the rainy season were *Paracomesoma* sp2 (4.0%), *Hopperia* sp1 (3.9%), *Terschellingia* sp3 (3.6%), *Terschellingia* sp4 (3.1%), *Dichromadora* sp1 (3.0%), *Theristus* sp1 (2.9%) and *Haliplectus* sp1 (2.7%) (Figure 17).

3.3.2.2 Age and sex composition

To determine age structure of the nematode community, we assigned nematodes to 3 age categories: juveniles, adult males, and adult females. Data are shown in the Figure 18.

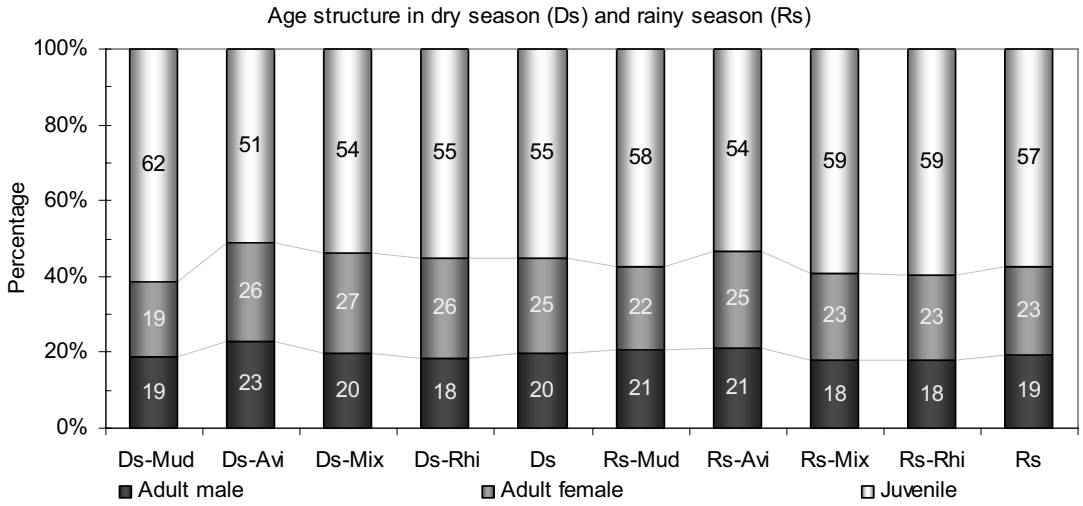

Figure 18. Age structure of nematode communities at different sites

Data showed juveniles were the most abundant at all sites in both seasons. In the dry season, percentage of juveniles was the highest at Mudflat sites with an average of 62% total individuals, and the lowest at *Avicennia* sites with an average of 51%. Male/female ratios were 1/1 at Mudflat sites, 1/1.1 at *Avicennia* sites, 1/1.4 at Mixed and *Rhizophora* sites. As shown in Figure 19, among Mudflat stations, percentage of juveniles ranged from a minimum of 55% at station Mud-3 to a maximum of 72% at Mud-4. Male/female ratio was the highest at Mud-4 and lowest at Mud-2 (Figure 19A). Within *Avicennia* sites, percentages of juveniles were the lowest at Avi-a1 with 43% and the highest at Avi-b2 with 56%. Numbers of males were generally lower than number of females, except at Avi-b2 and Avi-c (Figure 19B). At Mixed sites, percentages of juveniles ranged between 49 and 60% among stations. The numbers of males were lower than females at all stations except Mix-b1 (Figure 19C). Among stations at *Rhizophora* sites, result showed juveniles occupying between 47 and 60%

of total nematodes and males were lower than females in all stations except Rhi-a1 (Figure 19D).

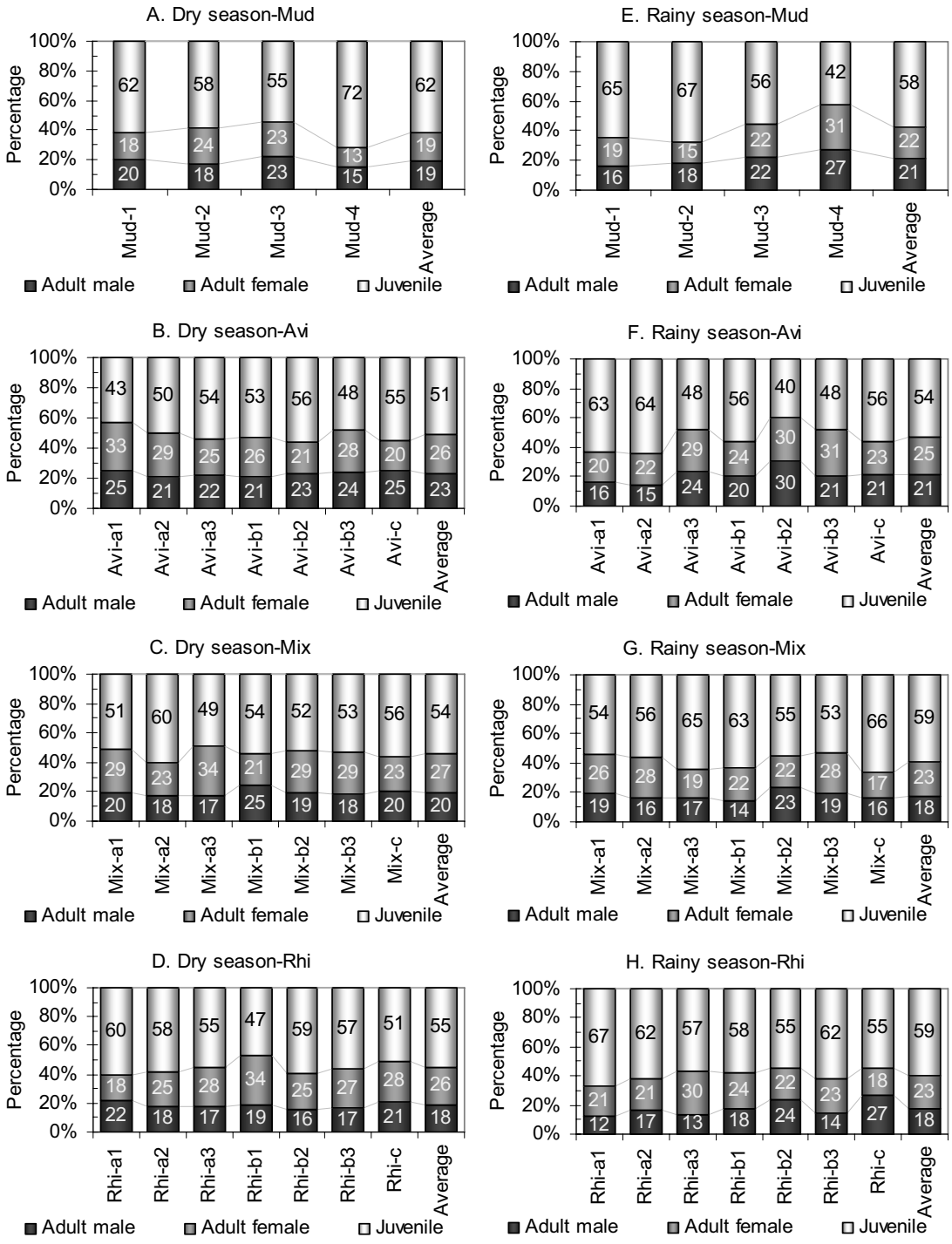

Figure 19. Age structure of nematode communities at different stations

In the rainy season, juveniles showed little variation between sites, ranging from 54% at *Avicennia* sites to 59% at Mixed and *Rhizophora* sites. Male/female ratio at different sites changed very little between the dry and rainy seasons. It was 1/1 at Mudflat sites, 1/1.2 at *Avicennia* sites, 1/1.3 at Mixed and *Rhizophora* sites (Figure 18). Among stations at Mud sites, the percentages of juveniles at station Mud-4 were highly reduced from 72% in the dry season to 42% in the rainy season. Numbers of

males were equal to or lower than females, except at Mud-2 (Figure 19E). At *Avicennia* sites, the percentages of juveniles ranged between 40 to 64% within stations. Here, the numbers of males was generally lower than females at all stations (Figure 19F). Within stations at Mixed sites, the percentages of juveniles ranged from 53 to 65%. Numbers of males was lower than females at all stations, except at Mix-b2 (Figure 19G). At *Rhizophora* sites, the percentages of juveniles varied between 55 and 67% and the numbers of males was lower than females at almost stations, except stations Rhi-b2 and Rhi-c (Figure 19H).

Between the dry and rainy seasons, percentage of juveniles, males and females remained generally unchanged. Percentages of juvenile were the highest (62%) at Mudflat sites and ranged from 51 to 55% at other sites in the dry season. Similarly, the percentage in rainy season ranged from 54 to 59% among study sites (Figure 18).

3.3.2.3 Trophic structure

Trophic structure was constructed by grouping free living marine nematodes based on morphological criteria (size of buccal cavity, presence or absence of buccal armature…) (Wieser 1953)

Type 1A: species with or without minute buccal cavity, by which food particles are selected on the basis of their size. Selective deposit-feeders.
Type 1B: species with a conical, cup-shaped or cylindrical buccal cavity. Non-selective deposit-feeders.
Type 2A: species with small to medium sized buccal cavity, with teeth. Epistratum-feeders.
Type 2B: species with large buccal cavity armed with large teeth. Predators/ omnivores.

In this study, we divided nematode into 5 groups, 4 of which follow the work by Wieser (1953) and one group for phytoparasitic nematodes was added (PN).

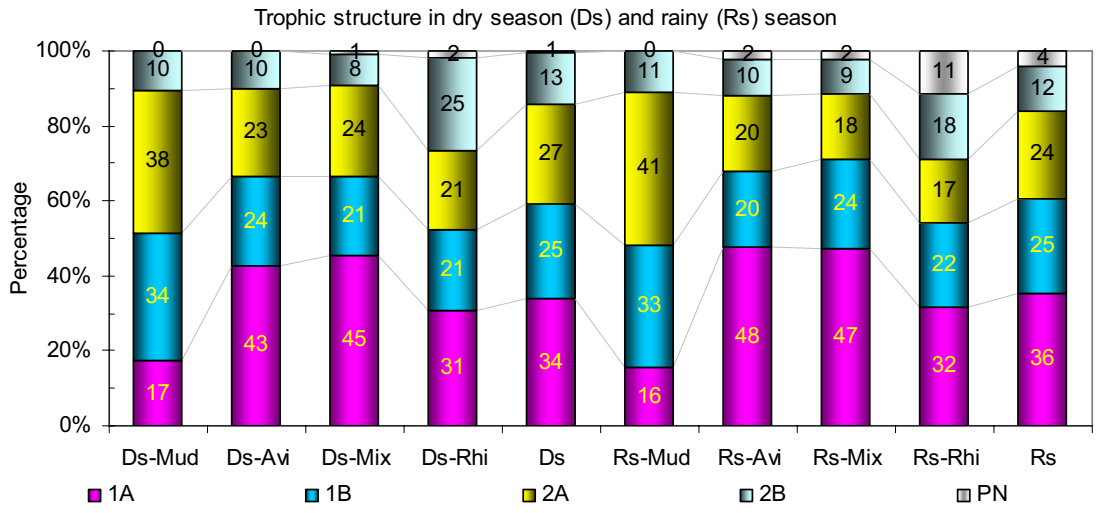

Figure 20. Nematode trophic structure at different sites

For the dry season 2005, trophic groups of nematodes at different sites are presented in Figure 20. Selective deposit feeders (1A) were highly dominant at *Avicennia* and Mixed sites, averaging 43-45% of the total nematode abundance. This trophic group

(1A) was reduced at *Rhizophora* sites (31%), and lowest at Mudflat sites with an average of 17%. Non-selective deposit feeders (1B) were dominant (34%) at Mudflat sites. At other sites, the percentile contribution of this trophic group remained fairly similar, with averages of 21-24%. Group 2A, epistratum-feeders, was also most dominant at Mudflat sites, occupied 38% total nematode community. In the meantime, at *Avicennia*, *Rhizophora* and Mixed sites, this group was equally abundant as group 1B (21-24%). Among the four sites, group 2B, which includes predators and omnivores, was the most dominant at *Rhizophora* sites (25%). This trophic group was represented with only 8-10% at *Avicennia*, Mixed and Mudflat sites. Assessment of phytoparasitic nematodes, this group occupying an average of only 1% in general, was present with 1.4% at *Rhizophora* sites, 0.7% at Mixed sites, very few at *Avicennia* sites and were absent at Mudflat sites (Figure 20).

Within *Avicennia* and Mixed sites, group 1A was highly represented with 43-58% at almost stations. However, at low altitude stations Avi-a1, Avi-a2 and subtidal stations Avi-c, Mix-c, group 1A showed a low percentage (Figure 21B, 21C). Among stations at *Rhizophora* sites, group 1A was reduced to 21-41% (Figure 21D). At Mudflat stations, the percentage of group 1A was the lowest at station Mud-4 with only 9% (Figure 21A). Group 1B was the most abundant at Mudflat sites, mainly due to percentages at stations Mud-3, Mud-4, which were 44 and 68% respectively (Figure 21A). At *Avicennia* and Mixed sites, group 1B was recorded with high percentages at stations Avi-c and Mix-c (Figure 21B, 21C). Group 2A was also dominant at Mudflat sites, with highest percentages at Mud-1 and Mud-2 (53 and 55% respectively) (Figure 21A). At *Rhizophora* sites, group 2B was the most abundant at Rhi-a3 and Rhi-b2, with 34 and 33%, respectively. Between stations, phytoparasitic nematodes showed the highest abundance at high altitude station Rhi-a3, with 3% (Figure 21D).

In the rainy season, selective deposit feeders (1A) were dominant at *Avicennia* and Mixed sites with 47-48% of total individuals. At *Rhizophora* sites, percentile contribution was reduced and the lowest percentages were found at Mudflat site with 16%. Non selective deposit feeders (1B) reached the highest percentage (33%) at Mudflat sites. At other sites, percentages varied little between 20-24%. Group 2A had the highest percentage at Mudflat sites, with 41% total of individuals. In the meantime, at *Avicennia*, *Rhizophora* and Mixed sites, the group was less abundant than group 1B, occupying between 18 and 20%. Group 2B abundance was highest at *Rhizophora* sites with 18%. The group was reduced to 9-11% at Mixed, *Avicennia* and Mudflat sites. In addition, 11% of the nematodes at *Rhizophora* sites were phytoparasitic nematodes. At Mixed and *Avicennia* sites, this group was at approximately 2% and there were no phytoparasitic nematodes at Mudflat site. In general, percentage of phytoparasitic nematodes was 4% in the rainy season (Figure 20).

As result in Figure 21F and 21G show, group 1A had the highest abundance at Avi-b2 and Mix-b2, with 72 and 68%, respectively. Group 1B was the most dominant at station Mud-4 in the dry season (Figure 21E). In *Avicennia* and Mixed sites, results are the same as in the dry season where group 1B recorded the highest percentage at the subtidal stations Avi-c and Mix-c (Figure 21F, 21G). Group 2A remained most abundant percentage at Mud-3 (Figure 21E). At *Rhizophora* sites, group 2B was most abundant at Rhi-b1 with 27%. In addition, phytoparasitic nematodes increased to 66% at station Rhi-a1 in the rainy season (Figure 21H).

In general, percentile contribution of nematode trophic groups varied among sites in the same season but changed little between seasons at the same sites (Figure 20).

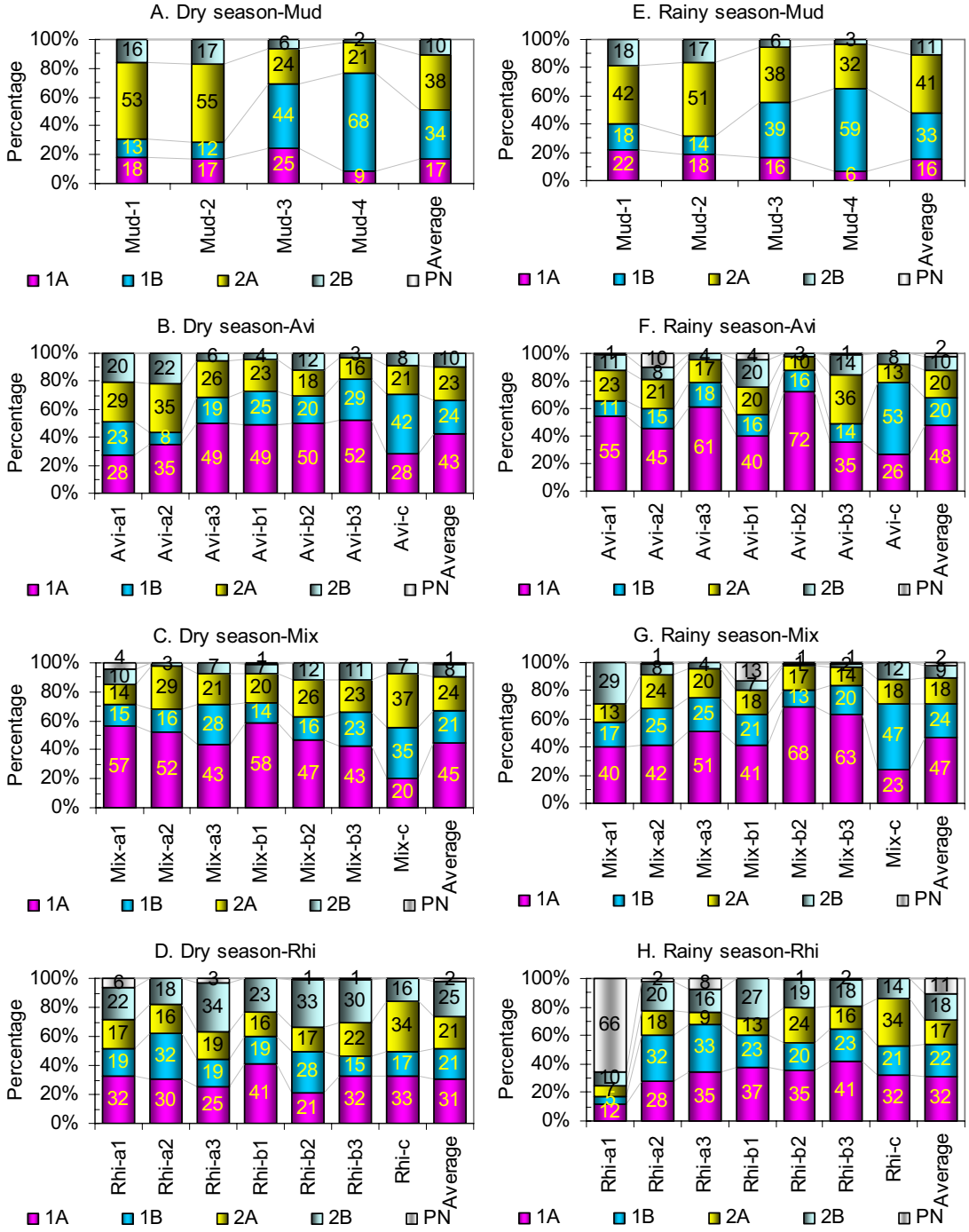

Figure 21. Nematode trophic structure at different stations

3.3.2.4 Nematode diversity

Diversity indexes

Figure 22 shows nematode diversity indexes in the dry season. Number of species (S) was the lowest at station Mud-4 with 28 observed species. At stations Avi-a3, Avi-b2, Mix-b3, the number of species was significantly higher than Mud-4 with 55, 55 and 59 species, respectively. At other stations, differences of species number were not

significant (P>0.05) (Figure 22A).

Margalef species richness (d) showed that the index at station Mud-4 was the lowest among all stations. The index at stations Avi-a3, Avi-b2, Mix-b2, Mix-b3 and Rhi-a1 was significantly higher than at Mud-4 (P<0.05) (Figure 22B).

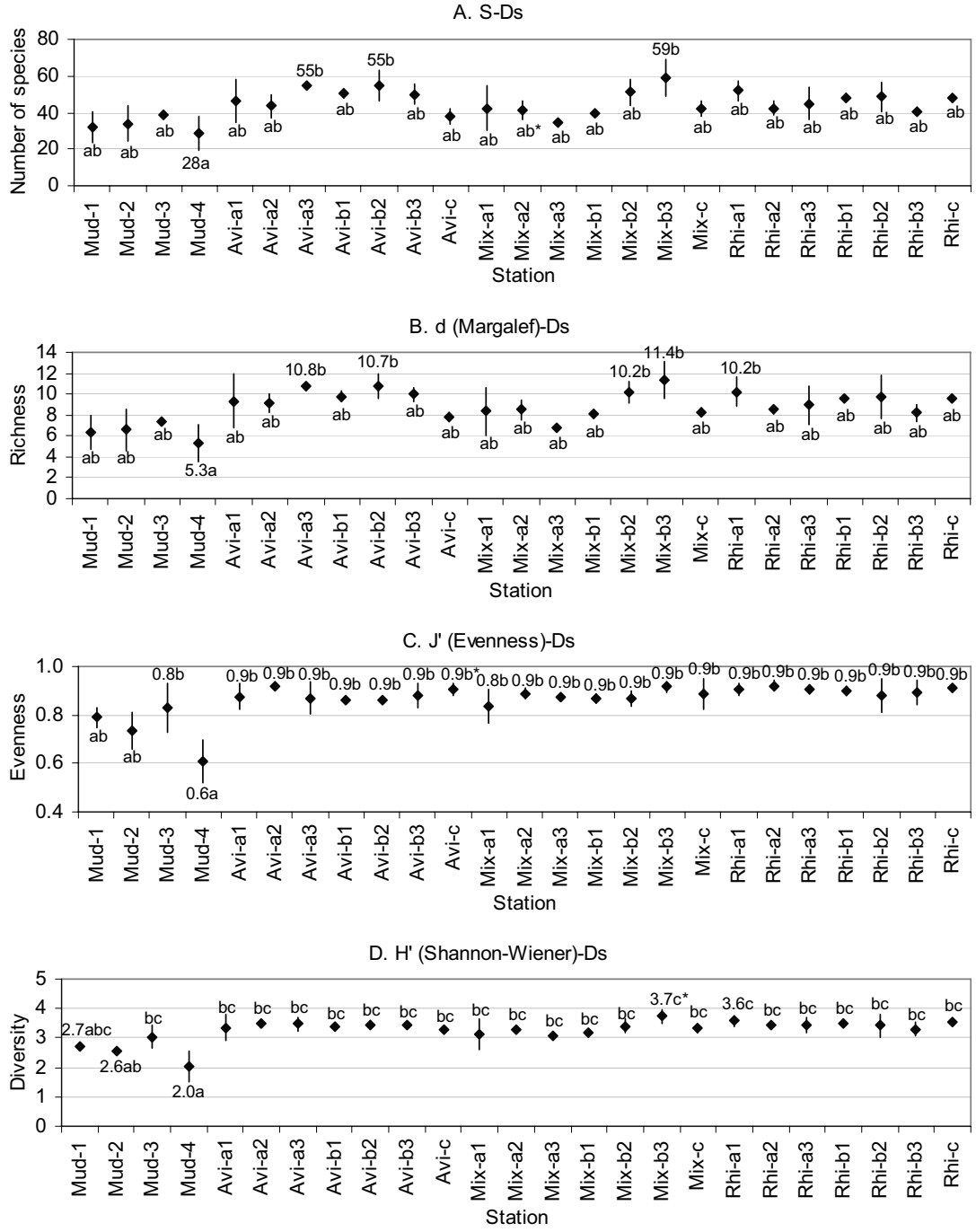

Figure 22. Nematode diversity indexes (mean ± sd) per station in the dry season

Values with the same letter are not significantly different (ANOVA, P>0.05)
Values with the star (*) are significantly different between seasons (T-test, P<0.05)

Evenness index (J') at station Mud-4 was also the lowest with a value of 0.6. At Mud-1 and Mud-2, the index was higher but the difference was not significant. At other stations, the index was significantly different in comparison with Mud-4 (Figure 22C).

Shannon-Wiener index (H') was the lowest at station Mud-4. At stations Mud-1 and Mud-2, the index was higher, but not significantly higher than at Mud-4. At other stations, the index H' was significantly higher than at Mud-4. The index was the highest at Mix-b3 and Rhi-a1 with 3.7 and 3.6, respectively and this difference was significant in relation to Mud-4 and Mud-2 (Figure 22D).

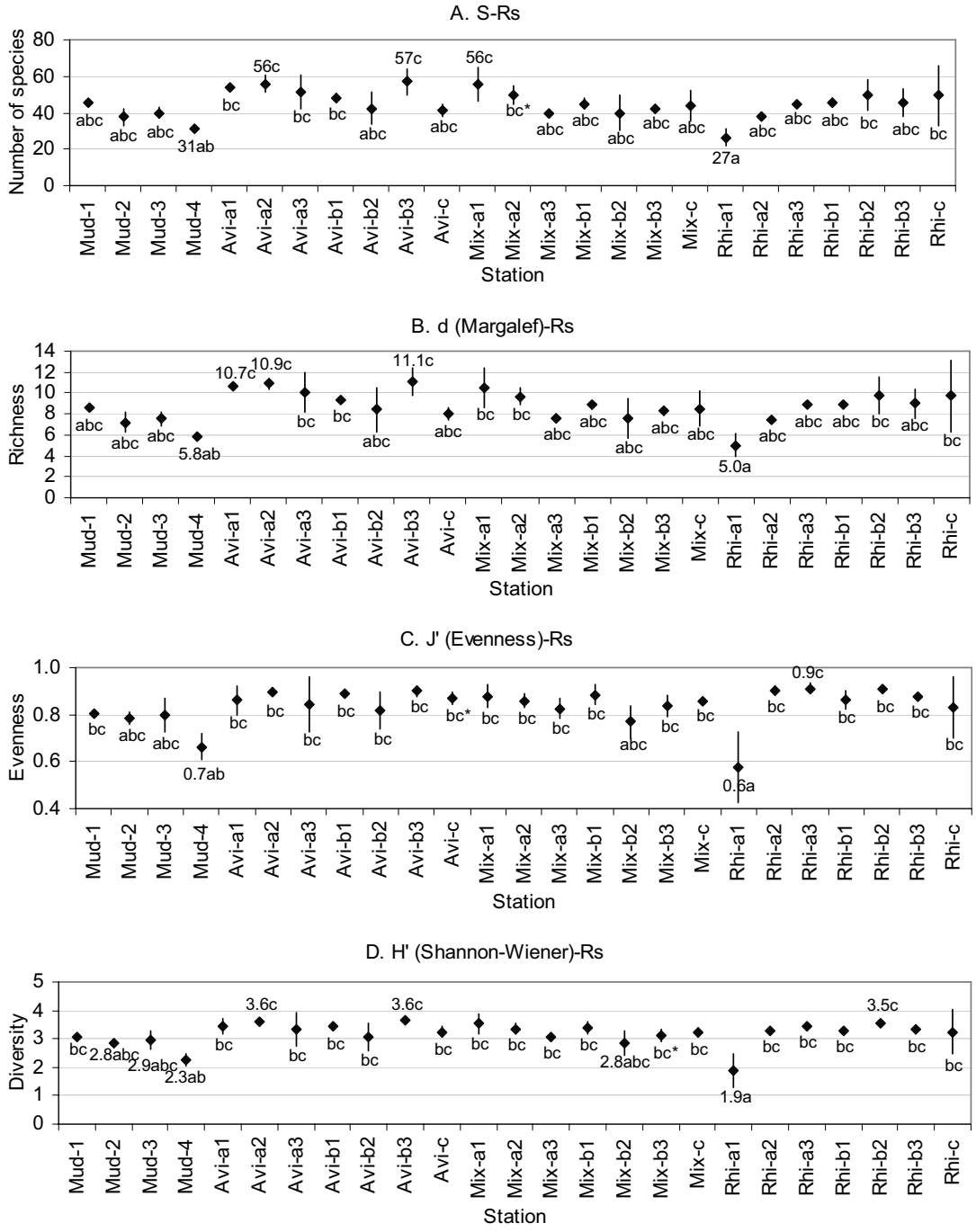

Figure 23. Nematode diversity indexes (mean ± sd) per station in the rainy season

Values with the same letter are not significantly different (ANOVA, P>0.05)
Values with the star (*) are significantly different between seasons (T-test, P<0.05)

Figure 23 shows results of some diversity indexes in the rainy season. Number of species was the lowest at station Rhi-a1 with 27 species. Mud-4 with 31 species was

higher but the difference was not significant. At other stations, such as Mix-a1, Avi-a2 and Avi-b3, the number of species was significantly higher than at Rhi-a1 and Mud-4 (Figure 23A). Change in number of species between the dry and rainy season was significant at Mix-a2. At other stations, the changes were not significant (Figure 22A, 23A).

Richness of species (d) was different among stations. At stations Rhi-a1 and Mud-4, the index was 5.0 and 5.8. At stations Avi-a1, Avi-a2 and Avi-b3, the index was 10.7, 10.9 and 11.1, respectively. Differences between stations Rhi-a1, Mud-4 and Avi-a1, Avi-a2, Avi-b3 were significant ($P<0.05$) (Figure 23B). Between seasons, the difference of this index was not significant (P.0.05) (Figure 22B, 23B).

Evenness index (J') was the lowest at stations Rhi-a1, Mud-4, and the highest at station Rhi-a3. The differences of the index between Rhi-a1, Mud-4 and Rhi-a3 were significant. The difference in the index between seasons was significant at subtidal station Avi-c ($P<0.05$) (Figure 22C, 23C).

In the rainy season, Shannon-Wiener index showed the lowest value at station Rhi-a1. The index at station Mud-2, Mud-3, Mud-4 was higher than at Rhi-a1, but not significantly so ($P>0.05$). At stations Avi-a2, Avi-b3 and Rhi-b2, the index was significantly higher than at Rhi-a1 and Mud-4 ($P<0.05$). The index showed a significant difference between seasons at Mix-b3 ($P<0.05$) (Figure 22D, 23D).

K-dominance curves for nematode species

K-dominance curve for nematode species in dry season illustrated that nematode assemblage was more diverse at *Avicennia*, Mixed and *Rhizophora* stations than Mudflat stations (Figure 24A). Figure 24B showed the diversity at subtidal stations was higher than at Mudflat stations but less than at intertidal stations. This was no clear difference of diversities in bank "a" and bank "b" of creek. In high intertidal, middle intertidal, low intertidal and subtidal stations, biodiversity of nematode assemblage among sites was not clear difference (Figure 24).

K-dominance curves based on nematode composition in the rainy season showed the same results as in dry season, where the diversity at *Avicennia*, Mixed and *Rhizophora* stations was higher than at Mudflat stations (Figure 25A). The diversity of subtidal stations Avi-c, Mix-c and Avi-c was higher than Mudflat stations, but lower than intertidal stations. As depicted in Figure 25B, diversity in bank "a" was a little higher than bank "b". In the middle intertidal, Mixed stations showed lower diversity than *Avicennia* and *Rhizophora* stations (Figure 25D). In low intertidal stations, the diversity at *Rhizophora* stations was lower than at *Avicennia* and Mixed stations (Figure 25E). In the high intertidal and subtidal, difference among stations was not clear (Figure 25C, 25F).

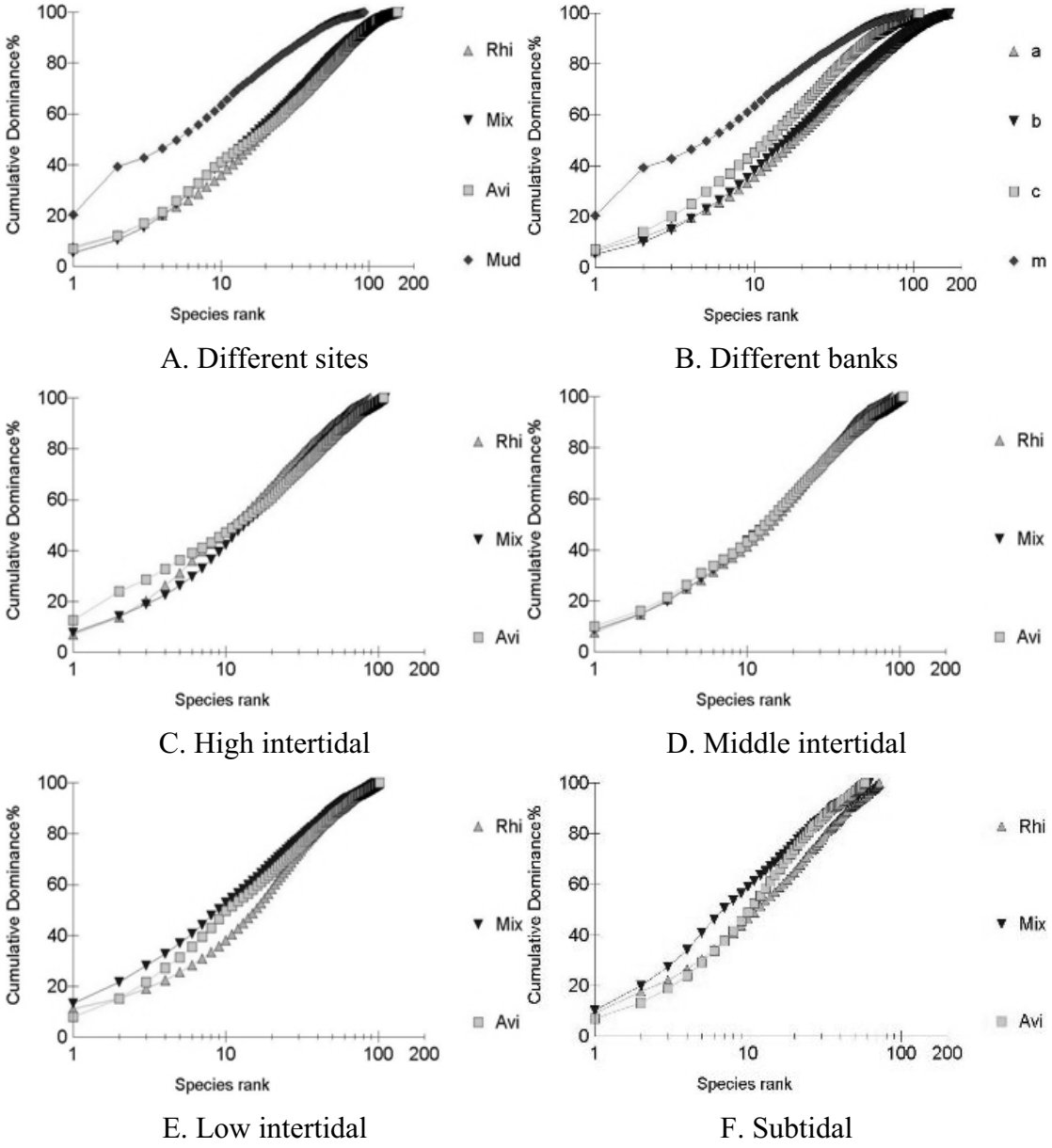

Figure 24. K-dominance curves of nematode abundance in: A. Different sites; B Different banks "a" & "b", subtidal "c" and mudflat "m"; C. High intertidal; D. Middle intertidal; E. Low intertidal and F. Subtidal in the dry season

3.3.2.5 Multivariate analysis

Cluster analysis and MDS

Cluster dendrogram based on Bray-Curtis similarities of square root transformed abundance data of nematode species are shown in Figure 26. Dry season samples clustered into 3 main groups at about 45% Bray-Curtis similarity. Group 1 included all stations of Mudflat sites, three subtidal stations, Avi-c, Mix-c and Rhi-c. Group 2 contained intertidal stations of *Avicennia* and Mixed sites, except stations Avi-a1, Avi-a2 and Mix-a1. Group 3 included all intertidal stations at *Rhizophora* sites and stations Avi-a1, Avi-a2, and Mix-a1.

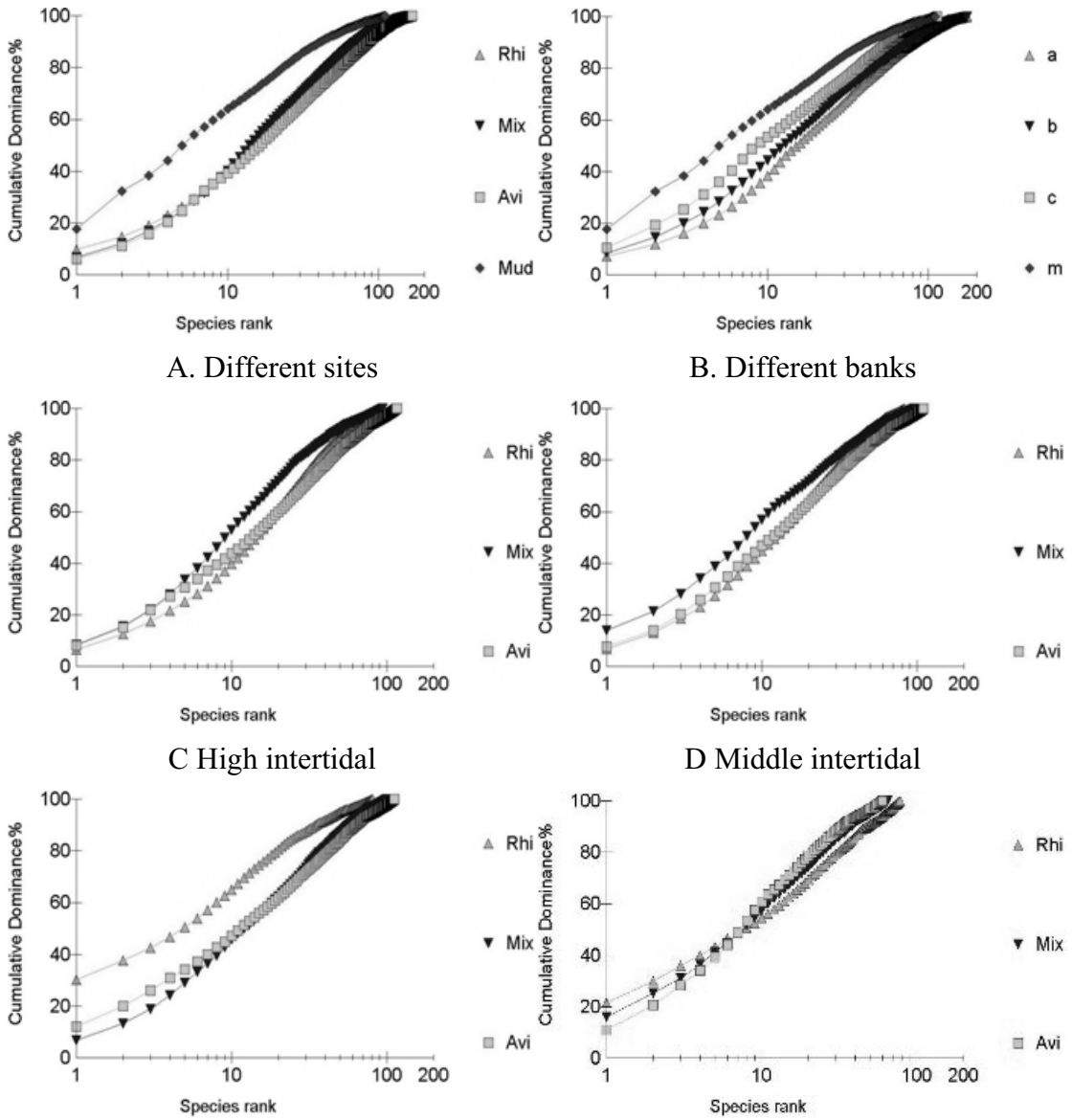

Figure 25. K-dominance curves of nematode abundance in: A. Different sites; B Different banks "a" & "b", subtidal "c" and mudflat "m"; C. High intertidal; D. Middle intertidal; E. Low intertidal and F. Subtidal in the rainy season

In MDS ordination of sampling stations, discrimination between the four sampling sites was clearer. All stations at Mudflat sites showed obvious differences from intertidal stations at *Avicennia*, Mixed and *Rhizophora* sites. Subtidal stations Avi-c, Mix-c and Rhi-c are clustered in Group 1, but tend to Group 2 and 3. Group 2 includes stations in *Avicennia* and Mixed sites except stations Avi-a1, Avi-a2 and Mix-a1. All remaining stations in *Rhizophora* site concentrate in Group 3. Three stations, Avi-a1, Avi-a2 and Mix-a1, are also in Group 3 but tend to Group 2 (Figure 27).

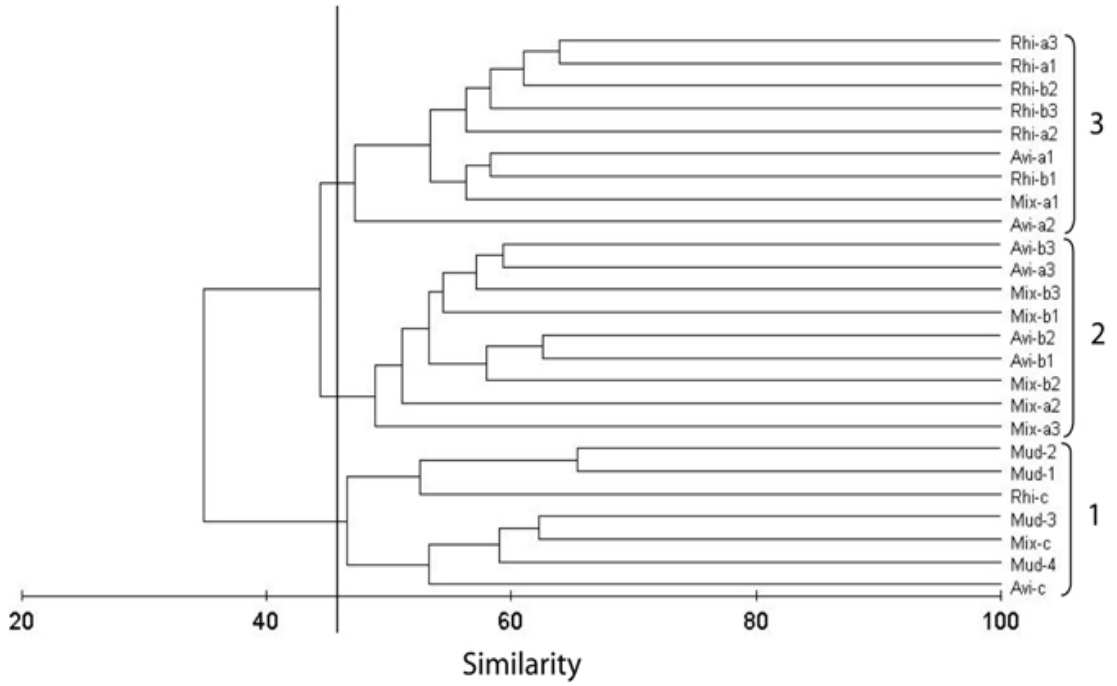

Figure 26. Cluster dendrogram based on similarity of square root transformed abundances of nematodes species in the dry season

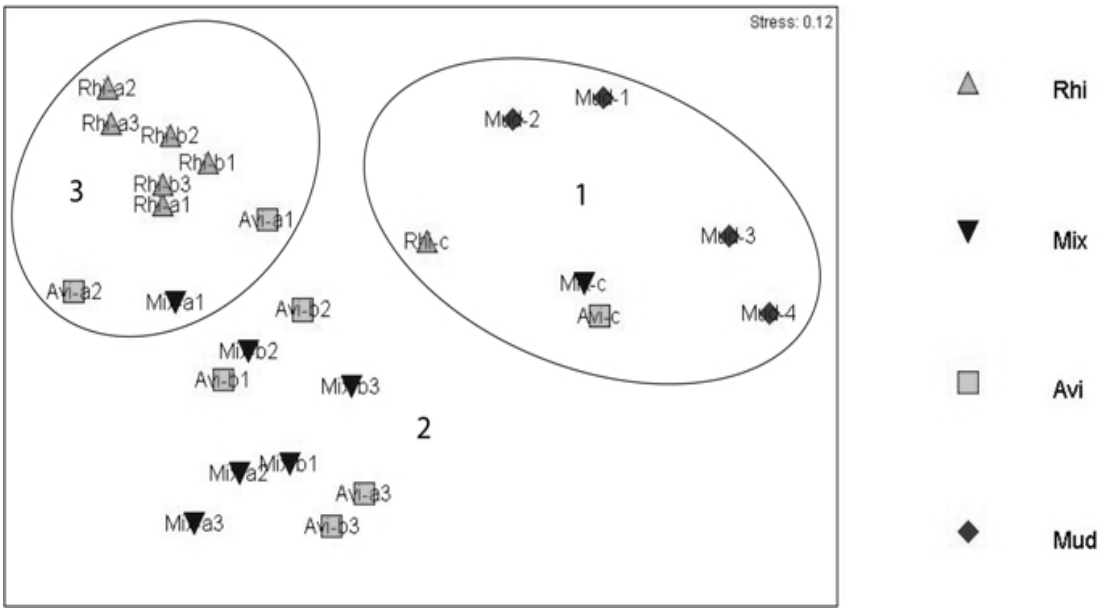

Figure 27. MDS ordination plots based on Bay-Curtis similarity of square root transformed abundances of nematode species in the dry season

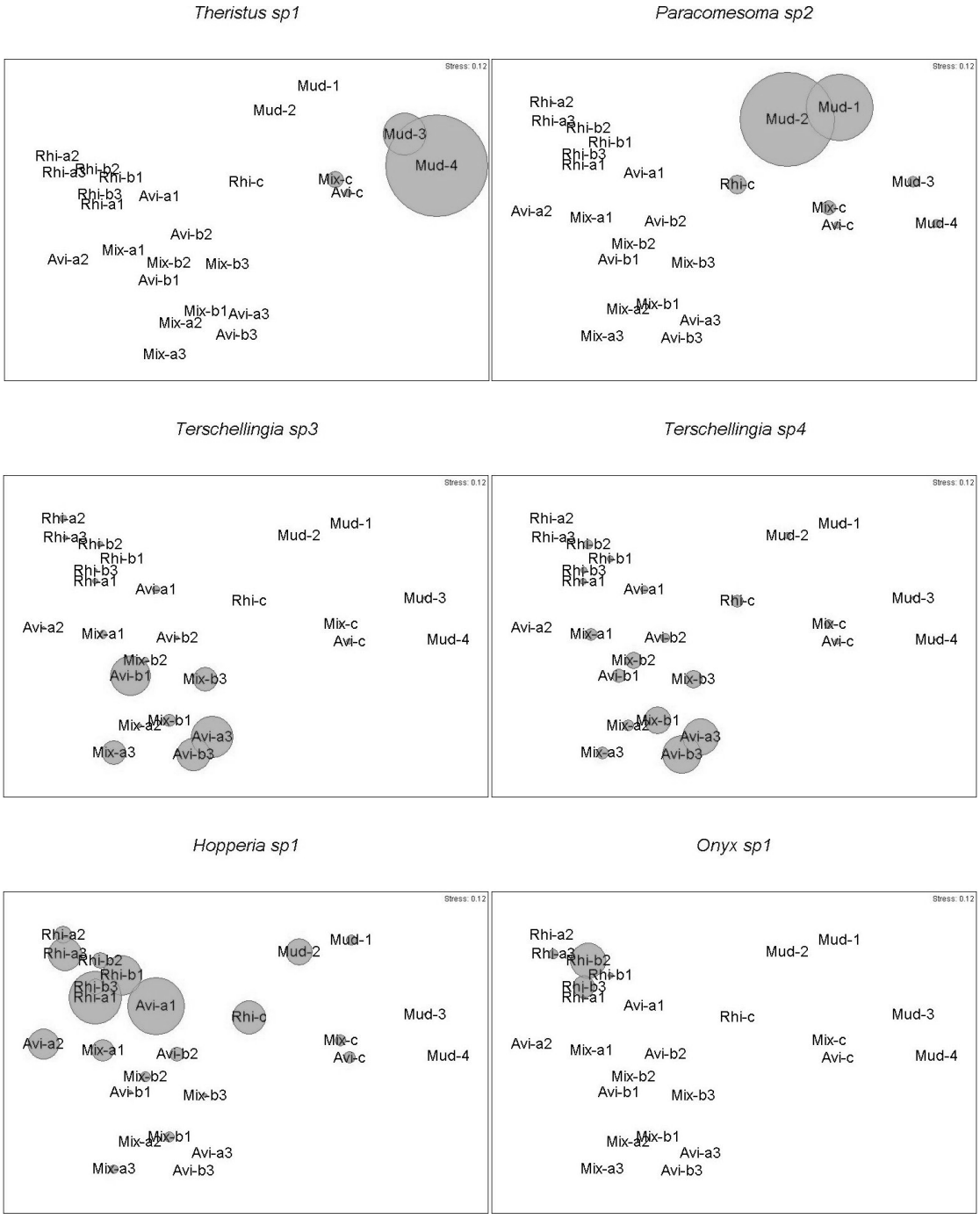

Figure 28. Distribution of some most dominant nematode species in different mangrove types in the dry season

Base on the data from nematode species abundance, MDS ordination plots displayed some most abundant species in relation to different types of mangrove in Can Gio (Figure 28).

At Mudflat sites, *Theristus* sp1 was the most dominant with 19.4% and *Paracomesoma* sp2 was second most dominant with 18.0%. Their density was reduced at subtidal stations Avi-c, Mix-c, Rhi-c, and very few were found at the

intertidal stations. Distributions of these species at stations in the dry season are shown in Figure 28.

At *Avicennia* and Mixed sites, the most abundant species were *Terschellingia* sp3 with 5.1%; and *Terschellingia* sp4 with 4.7%. Their distribution is shown in Figure 28.

At *Rhizophora* sites, *Hopperia* sp1 with 7.0% was the most abundant, second most abundant was *Onyx* sp1 with 4.3%. Distribution of these species is illustrated in Figure 28.

For the rainy season, similarity of nematode assemblage was illustrated in Figure 29. There were three main groups base on similarity of approximately 40% of total abundance. Group 1 includes all Mudflat stations and three subtidal stations Avi-c, Mix-c and Rhi-c. Group 2 is the smallest group with 4 intertidal stations Avi-b2, Avi-a3, Mix-b2 and Mix-b3. Group 3 includes all intertidal stations at *Rhizophora* sites (except Rhi-a1), and intertidal stations at *Avicennia* and Mixed sites (except 4 stations in group2). On the other hand, intertidal station Rhi-a1 differed from the 3 above groups by the drastic increase of phytonematodes *Criconemella* sp1.

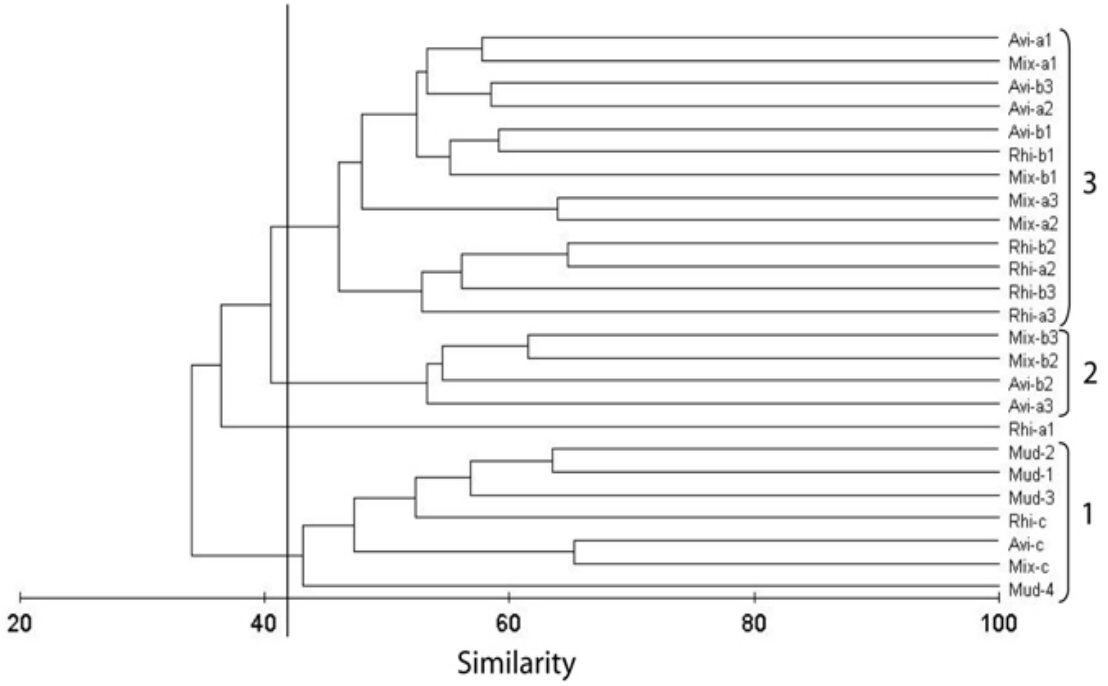

Figure 29. Cluster dendrogram based on similarity of square root transformed abundances of nematodes species in the rainy season

Distribution of sampling stations by multy-dimension scaling (MDS) clearly shows 3 main groups. Group 1 includes all Mudflat stations and subtidal stations. Among them, three subtidal stations Avi-c, Mix-c Rhi-c and station Mud-1 tend to group 2 and group 3. Group 2 includes 4 stations at *Avicennia* and Mixed sites (Avi-b2, Avi-a3, Mix-b2 and Mix-b3). Group 3 includes all intertidal stations at *Rhizophora*, Mixed and *Avicennia* sites, except those stations clustered in group 2 and station Rhi-a1. Single station Rhi-a1 is not included in the 3 main groups due to the presence of species *Criconemella* sp1 in very high numbers. However, Rhi-a1 tends to stations in group 3. On the other hand, stations at *Avicennia* and Mixed sites tend to group 2, which includes only 4 stations from *Avicennia* and Mixed sites (Figure 30).

In general, between the dry and rainy seasons, results showed all stations in Mudflat site and 3 subtidal stations Avi-c, Mix-c and Rhi-c clustered into one group. Intertidal stations at *Avicennia* and Mixed site also form one group. This was more apparent in the dry season, since in rainy season, grouping is limited to the middle and high intertidal stations at *Avicennia* and Mixed sites. All intertidal stations in *Rhizophora* sites are in one group. This too, was clearer in the dry season.

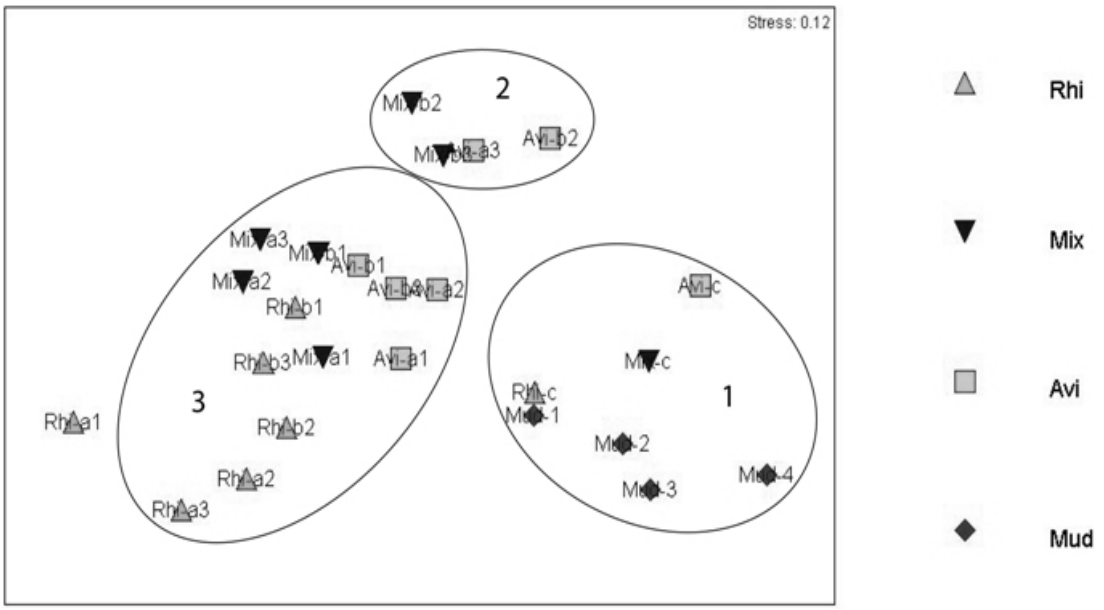

Figure 30. MDS ordination plots based on Bay-Curtis similarity of square root transformed abundances of nematode species in the rainy season

Base on the data from nematode species abundance in the rainy season, MDS ordination plots displayed some most abundant species in relation to different types of mangrove in Can Gio (Figure 31).

At Mudflat sites, *Paracomesoma* sp2 increased to be the most dominant species with 16.5% and *Theristus* sp1 is reduced to second, with 13.6%. Distributions of the species according to stations in the rainy season are shown in Figure 31.

At *Avicennia* and Mixed sites, the most abundance species were also *Terschellingia* sp3 and *Terschellingia* sp4. Percentages of *Terschellingia* sp3 and *Terschellingia* sp4 were nearly the same as in the dry season (5.1 and 4.5%, respectively). Their distributions are shown in Figure 31.

At *Rhizophora* sites, *Criconemella* sp1 increased drastically from the dry season and was the most abundant with 8.6%. The second most abundant was *Hopperia* sp1 with 4.4%. Distribution of this species is illustrated in Figure 31.

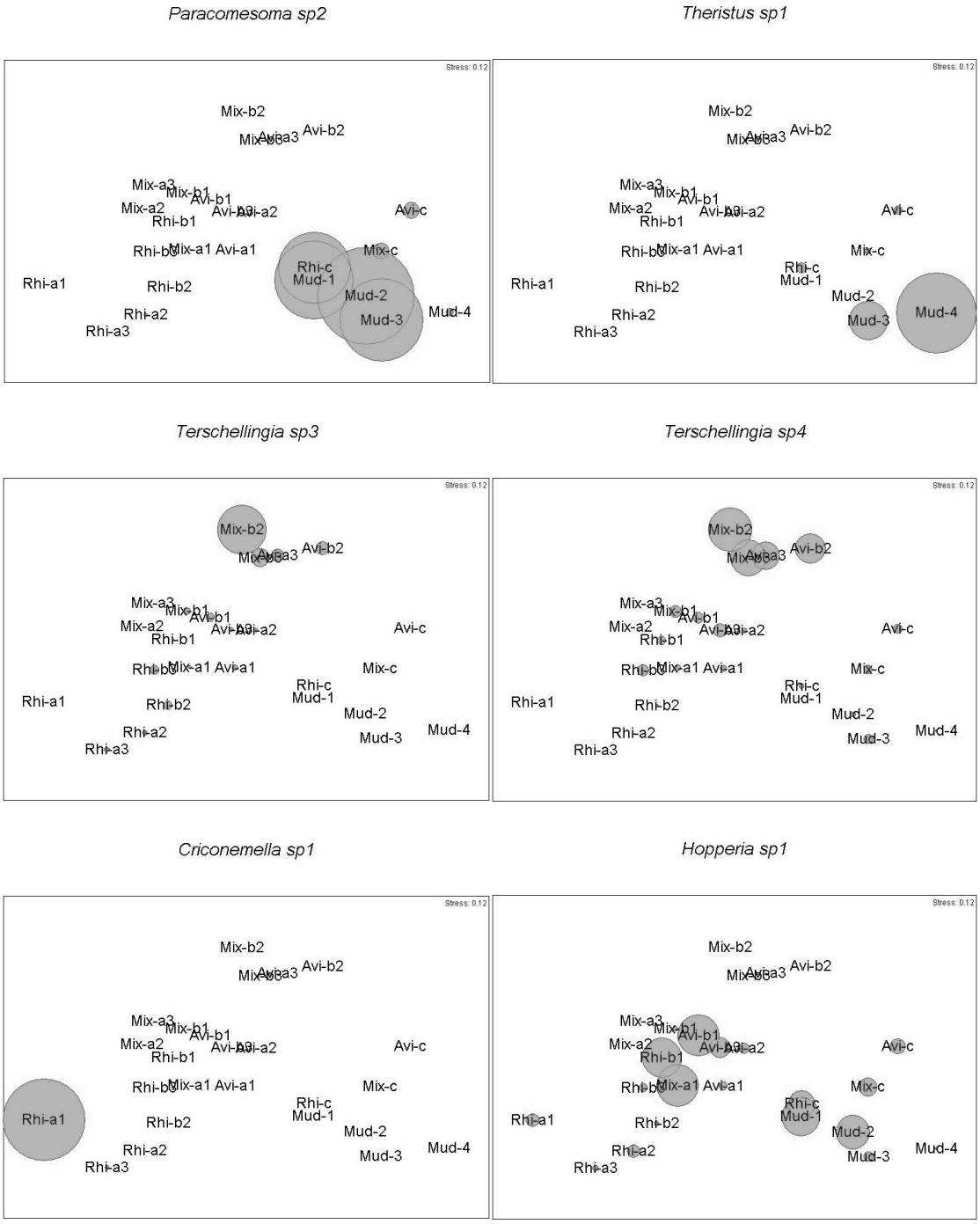

Figure 31. Distribution of some most dominant nematode species in different mangrove types in the rainy season

Similarity of nematode communities

Result of ANOSIM test for variation of nematode community structure among study sites are given in Table 2. Nematode assemblage varied significantly among sites in the dry and rainy season (P<5%). Global R and almost all other R values in pairwise tests in the dry season were higher than in the rainy season. This indicates that differences between sites in the dry season were higher than in the rainy season.

Table 2. Result of ANOSIM tests (values of R statistics and significance from permutation tests) for differences of nematode community structure between 4 sites in the dry and rainy seasons (The analysis was based on abundance data of nematode species in total samples for each season. Data were square root transformed prior to analysis)

Pairwise tests	Dry season Global R = 0.438, P = 0.1%		Rainy season Global R = 0.372, P = 0.1%	
	R	P%	R	P%
Mud vs Avi	0.616	0.1	0.537	0.1
Mud vs Mix	0.651	0.1	0.611	0.1
Mud vs Rhi	0.823	0.1	0.698	0.1
Avi vs Mix	0.027	25.1	0.080	7.8
Avi vs Rhi	0.357	0.1	0.369	0.1
Mix vs Rhi	0.435	0.1	0.222	0.2

Table 2 gives pairwise tests comparisons between the four groups. All groups (except group *Avicennia* vs Mixed) were seen to be significantly different from each other, with significance levels at less than 5% in all case, usually even less. However, the importance of the pairwise test usually does not lie with the significance level, but with the pairwise R value, since that give an absolute measure of how separated the groups are, on a scale of 0 (indistinguishable) to 1 (all similarities within groups are less than any similarity between groups). In the dry season, groups Mudflat vs *Rhizophora* was well separated (R>0.75), groups Mudflat vs *Avicennia*, Mudflat vs Mixed were overlapping but clearly different (R>0.50), groups *Avicennia* vs Mixed were barely separable at all (R<0.25). In the rainy season, separations between group reduced, where groups Mudflat vs *Rhizophora*, Mudflat vs Mixed and Mudflat vs *Avicennia* were different but not well separated (0.50<R<0.75), groups Mixed vs *Rhizophora* and *Avicennia* vs *Rhizophora* were barely separable (R<0.25).

To investigate variations of nematode assemblages among stations and sites, total samples (dry plus rainy seasons) from stations were assessed by ANOSIM (Table 3). Nematode assemblages varied significantly among sites at different intertidal stations (P<0.05) except at low intertidal stations (P>0.05). Pairwise tests between the four sites by total samples showed R value reduced from group Mudflat-*Rhizophora*, to Mudflat-Mixed and Mudflat-*Avicennia*, which means that separation between Mudflat and *Rhizophora* sites was well accomplished (R>0.75) and clear between Mudflat and Mixed, *Avicennia* sites (0.50<R<0.75). Differences in groups *Avicennia*-*Rhizophora* and Mixed-*Rhizophora* were clear and significant at high and mid intertidal stations (P<0.05) (Table 3A).

Among stations within sites, differences were significant for all sites (P<0.05) (Table 3B). at Mudflat sites, results indicate significant differences between stations 1, 2, 3 and station 4 (P<0.05). Pairwise tests for Mudflat sites showed that difference between stations Mud-1 vs Mud-4 (R = 1) and between Mud-2 vs Mud-4 (R=0.979) were higher than difference between Mud-3 vs Mud-4 (R = 0.448). At other sites, differences between subtidal station (c) and intertidal stations (a1, a2, a3, b1, b2, b3) were significant (P<0.05). R values of pairwise tests showed differences were well separated (R>0.75).

Table 3. Result of ANOSIM tests (values of R statistics and significance from permutation tests) for differences of nematode community structure between 4 sites and their stations (The analysis was based on abundance data of nematode species in total samples (dry+rainy). Data were square root transformed prior to analysis)

A. Among sites

Pairwise tests	Total stations GR=0.405 P=0.1%		High intertidal GR=0.560 P=0.1%		Mid intertidal GR=0.547 P=0.1%		Low intertidal GR=0.082 P=7.8%		Subtidal GR=0.313 P=2.5%	
	R	P%	R	P%	R	P%	R	P%	R	P%
Mud vs Avi	0.598	0.1								
Mud vs Mix	0.612	0.1								
Mud vs Rhi	0.757	0.1								
Avi vs Mix	0.061	3.1	0.146	5.1	0.230	2.8	-0.002	50.5	-0.083	74.3
Avi vs Rhi	0.363	0.1	0.859	0.1	0.746	0.1	0.110	6.8	0.677	2.9
Mix vs Rhi	0.308	0.1	0.643	0.1	0.615	0.1	0.148	2.3	0.448	2.9

B. Among stations within sites

Pairwise tests	Mud site GR=0.505, P=0.1%		Avi site GR=0.500, P=0.1%		Mix site GR=0.445, P=0.1%		Rhi site GR=0.434, P=0.1%	
	R	P%	R	P%	R	P%	R	P%
1 vs 2	-0.156	74.3						
1 vs 3	0.219	20.0						
1 vs 4	1.000	2.9						
2 vs 3	0.219	17.1						
2 vs 4	0.979	2.9						
3 vs 4	0.448	2.9						
a1 vs a2			0.167	17.1	0.344	8.6	0.198	17.1
a1 vs a3			0.875	2.9	0.188	25.7	0.250	8.6
a1 vs b1			0.094	31.4	0.010	42.9	0.271	5.7
a1 vs b2			0.583	2.9	0.458	11.4	0.375	2.9
a1 vs b3			0.583	2.9	0.667	2.9	0.177	20.0
a1 vs c			1.000	2.9	1.000	2.9	0.833	2.9
a2 vs a3			0.708	2.9	-0.031	54.3	-0.052	65.7
a2 vs b1			0.260	11.4	0.260	20.0	0.583	2.9
a2 vs b2			0.219	11.4	0.323	11.4	0.229	8.6
a2 vs b3			0.156	22.9	0.323	5.7	0.271	8.6
a2 vs c			0.854	2.9	1.000	2.9	0.938	2.9
a3 vs b1			0.406	5.7	0.115	25.7	0.656	2.9
a3 vs b2			0.188	22.9	0.073	34.3	0.240	11.4
a3 vs b3			0.094	37.1	0.302	14.3	0.323	11.4
a3 vs c			0.948	2.9	0.802	2.9	1.000	2.9
b1 vs b2			0.031	45.7	-0.021	54.3	0.708	2.9
b1 vs b3			-0.010	48.6	0.156	22.9	0.563	2.9
b1 vs c			1.000	2.9	0.885	2.9	0.813	2.9
b2 vs b3			-0.031	60.0	-0.104	65.7	0.010	51.4
b2 vs c			0.885	2.9	1.000	2.9	0.969	2.9
b3 vs c			0.990	2.9	0.906	2.9	1.000	2.9

Contributions of the different nematode species to the similarity and dissimilarity of stations within sites and between sites

Similarity percentage (SIMPER) analyses were performed to show average similarities and average dissimilarities and contribution of nematode species to similarities and dissimilarities among sites.

Table 4. Average similarity and major nematode species contributing to similarity within sites in the dry and rainy seasons (Av Si: average similarity; Av Ab: average abundance; Con: contribute; Cum: cumulative)

A. Dry season	Av Si	Species	Av Ab	Av Si	Con%	Cum%
Mud site	41.11	*Paracomesoma* sp2	29.50	4.80	11.69	11.69
		Theristus sp1	31.75	3.09	7.51	19.20
		Pseudolella sp1	5.63	2.97	7.22	26.42
Avi site	36.99	*Ptycholaimellus* sp1	5.00	2.01	5.43	5.43
		Terschellingia sp4	7.00	1.94	5.23	10.66
		Dichromadora sp1	4.29	1.83	4.94	15.60
Mix site	37.40	*Terschellingia* sp4	6.79	2.68	7.17	7.17
		Parodontophora sp1	6.07	2.66	7.10	14.27
		Terschellingia sp3	5.64	2.19	5.84	20.11
Rhi site	42.43	*Hopperia* sp1	10.21	3.34	7.87	7.87
		Anoplostoma sp1	6.29	2.64	6.23	14.10
		Dichromadora sp1	3.50	2.02	4.75	18.85
B. Rainy season						
Mud site	44.25	*Paracomesoma* sp2	30.13	5.85	13.23	13.23
		Theristus sp1	24.88	3.30	7.46	20.69
		Hopperia sp1	9.75	2.89	6.54	27.23
Avi site	37.09	*Terschellingia* sp4	7.71	2.62	7.07	7.07
		Terschellingia sp3	6.79	1.99	5.36	12.44
		Dichromadora sp1	6.86	1.75	4.73	17.16
Mix site	36.28	*Astomonema* sp1	6.00	2.27	6.26	6.26
		Pseudochromadora sp1	5.86	1.90	5.24	11.50
		Terschellingia sp3	10.71	1.68	4.62	16.12
Rhi site	36.84	*Hopperia* sp1	7.43	2.41	6.55	6.55
		Sphaerolaimus sp3	5.79	2.17	5.89	12.44
		Haliplectus sp3	4.29	1.95	5.30	17.74

As listed in Table 4A, similarities of stations within the Mudflat and *Rhizophora* sites were higher than stations within *Avicennia* and Mixed sites in the dry season. Main species contributing to similarities within Mudflat sites were *Paracomesoma* sp2, *Theristus* sp1 and *Pseudolella* sp1, while *Hopperia* sp1, *Anoplostoma* sp1 and *Dichromadora* sp1 contributed at *Rhizophora* sites. At Mixed sites, the three main species contributing to similarities were *Terschellingia* sp4, *Parodontophora* sp1, *Terschellingia* sp3. *Ptycholaimellus* sp1, *Terschellingia* sp4, *Dichromadora* sp1 were the three main species contributing to similarities of stations within *Avicennia* sites.

Table 5. Average dissimilarity and major nematode species contributing to dissimilarity between sites in the dry and rainy seasons (Av Dis: average dissimilarity; Av Ab1: average abundance site1; Av Ab2: average abundance site2; Con: contribute; Cum: cumulative)

A. Dry season	Av Dis	Species	Av Ab1	Av Ab2	Av Dis	Con%	Cum%
Mud &Avi	72.82	*Paracomesoma* sp2	29.50	0.93	3.31	4.54	4.54
		Theristus sp1	31.75	1.36	3.04	4.17	8.71
		Pseudolella sp1	5.63	0.14	1.65	2.27	10.98
Mud & Mix	72.55	*Paracomesoma* sp2	29.50	1.57	3.36	4.63	4.63
		Theristus sp1	31.75	2.29	3.17	4.38	9.00
		Astomonema sp1	0.00	6.36	1.69	2.33	11.34
Mud & Rhi	75.48	*Paracomesoma* sp2	29.50	2.07	3.27	4.34	4.34
		Theristus sp1	31.75	0.43	3.08	4.08	8.41
		Anoplostoma sp1	0.50	6.29	1.59	2.11	10.52
Avi & Mix	63.10	*Astomonema* sp1	6.64	6.36	1.37	2.18	2.18
		Terschellingia sp3	9.36	5.64	1.24	1.97	4.14
		Hopperia sp1	5.79	3.36	1.13	1.79	5.93
Avi & Rhi	65.93	*Hopperia* sp1	5.79	10.21	1.35	2.04	2.04
		Parodontophora sp1	6.07	0.79	1.25	1.89	3.93
		Onyx sp1	0.00	6.36	1.23	1.86	5.80
Mix & Rhi	66.46	*Parodontophora* sp1	6.07	0.79	1.35	2.03	2.03
		Astomonema sp1	6.36	0.64	1.32	1.99	4.02
		Hopperia sp1	3.36	10.21	1.28	1.93	5.95
B. Rainy season							
Mud & Avi	69.73	*Paracomesoma* sp2	30.13	1.21	3.23	4.63	4.63
		Theristus sp1	24.88	1.07	2.71	3.88	8.51
		Haliplectus sp1	0.25	8.93	1.61	2.30	10.81
Mud & Mix	73.19	*Paracomesoma* sp2	30.13	1.21	3.30	4.51	4.51
		Theristus sp1	24.88	1.07	2.65	3.63	8.14
		Hopperia sp1	9.75	4.43	1.61	2.20	10.34
Mud & Rhi	75.03	*Paracomesoma* sp2	30.13	5.00	3.35	4.46	4.46
		Theristus sp1	24.88	1.50	2.81	3.74	8.20
		Metadesmolaimus sp1	7.38	0.71	1.79	2.38	10.58
Avi & Mix	64.59	*Terschellingia* sp3	6.79	10.71	1.37	2.12	2.12
		Amphybelondira sp1	1.07	8.57	1.33	2.05	4.17
		Hopperia sp1	6.43	4.43	1.29	1.99	6.17
Avi & Rhi	69.11	*Haliplectus* sp1	8.93	2.43	1.39	2.01	2.01
		Criconemella sp1	0.00	14.57	1.36	1.97	3.98
		Haliplectus sp3	0.14	4.29	1.21	1.76	5.73
Mix & Rhi	67.37	*Hopperia* sp1	4.43	7.43	1.44	2.14	2.14
		Amphybelondira sp1	8.57	4.00	1.40	2.08	4.22
		Criconemella sp1	0.00	14.57	1.39	2.06	6.28

In the rainy season, average similarities of Mudflat sites were higher than of other sites. *Paracomesoma* sp2 and *Theristus* sp1 were the two main species contributing to similarities within Mudflat sites. However, the third species contributing was *Hopperia* sp1, instead of *Pseudollela* sp1, as seen in the dry season. At *Rhizophora* sites, main species contributing to similarities were *Hopperia* sp1, and two other species,

Sphaerolaimus sp3 and *Haliplectus* sp3. Species *Terschellingia* sp4, *Terschellingia* sp3 and *Dichromadora* sp1 were the three main species contributing to similarities within *Avicennia* sites. At Mixed sites, the three species contributing to similarities were *Astomonema* sp1, *Pseudochromadora* sp1 and *Terschellingia* sp3 (Table 4B).

Dissimilarities among sites in the dry season are shown in Table 5A. Between Mudflat sites and the three other sites, average dissimilarities were higher than 70. A high presence *Paracomesoma* sp2 and *Theristus* sp1 at Mudflat sites contributed mainly to the dissimilarities between Mudflat sites and the three other sites. Average dissimilarities among the three forest types *Avicennia*, *Rhizophora* and Mixed were smaller than between Mudflat sites and the three forest sites. Small changes of *Astomonema* sp1, *Terschellingia* sp3, *Hopperia* sp1 contributed to low average dissimilarity between *Avicennia* and Mixed sites. Reduction of *Onyx* sp1, *Hopperia* sp1 and an increase of *Parodontophora* sp1 at *Avicennia* sites were the most important contributors to dissimilarity between two sites. Between *Rhizophora* and Mixed sites, dissimilarity was mainly produced by reduction of *Parodontophora* sp1, *Astomonema* sp1 and an increase of *Hopperia* sp1 in *Rhizophora* sites.

For the rainy season, average dissimilarity between the four sites varied little (Table 5B). However, dissimilarities between Mudflat sites and *Avicennia*, Mixed, *Rhizophora* sites remained at high levels between 69.73 and 75.03. *Paracomesoma* sp2 and *Theristus* sp1 were also the most important species contributing to the dissimilarities between Mudflat and the three forest sites. Reduction of Terschellingia sp3 and *Amphybelondira* sp1 at *Avicennia* sites was most important in contributing to dissimilarity between these sites. Reduction in the abundance of *Haliplectus* sp1 and increase of *Criconemella* sp1 at the *Rhizophora* sites was the main contributor for the dissimilarity between *Rhizophora* and *Avicennia* sites. For dissimilarity between *Rhizophora* and Mixed sites, *Hopperia* sp1, *Amphybelondira* sp1 were two main responsible species (Table 5B).

3.4 Meiobenthos and nematode assemblage for differentiation of mangrove types

The above results show that meiobenthic community structure and especially nematodes varies in different types of mangrove in both the dry and rainy seasons in Can Gio Biosphere Reserve. Outlines for differentiation can be drawn as follows:

(i) Meiobenthic density as well as density of the abundant groups such as nematodes and foraminifera change relating to the surrounding mangrove types. Densities of total meiobenthos and nematodes in Mudflat site were higher than in *Avicennia* and *Rhizophora* forest in the dry season. In the rainy season, densities of total meiobenthos and nematodes at Mudflat sites and Mixed forests was higher than in *Avicennia* and *Rhizophora* forests. While density of foraminifera was highest in *Rhizophora* forests, it decreased in Mixed and *Avicennia* forests, as well as in Mudflat area in both the dry and rainy seasons.

(ii) Nematode trophic structure is diverse among habitats. Mudflat site was dominated by non-selective deposit feeders (type 1B) and epistratum feeders (type 2A). *Avicennia* and Mixed forests were dominanted by selective deposit feeders (type 1A). In *Rhizophora* forests, selective deposit feeders was also abundant, in addition to predators/omnivores (type 2B) and phytoparasitic nematodes (PN) occuping the highest percentage among the four different study sites. The nematode trophic struture was similar between seasons.

(iii) Nematode diversity indexes such as Shannon-Wiener diversity H' and Pielou's evenness J' are useful indexes for different habitat types. Diversity H' and evenness J' tend to be lower in Mudflat stations than in mangrove forest stations in both the dry and rainy seasons.

(iv) Results show that nematode assemblages vary in different mangrove forest types as demonstrated by multivariate analysis. Nematode community in Mudflat sites differed among the three mangrove types. Rehabilitated mangrove forest of *Rhizophora* also differed from naturally regenerated *Avicennia* and Mixed forests. The difference between *Avicennia*, Mixed forest and Rhizophora was clearer in the dry season than in the rainy season.

Summaries of major characteristic of meiobenthos and nematode assemblage in different habitat types are shown in the Table 6 for dry season and Table 7 for rainy season.

Table 6. Comparison of major characteristics of meiobenthos and nematode assemblage in different habitat types in dry season

	Avicennia	Mixed forest	*Rhizophora*
Mudflat	Meiobenthic density: Total meiobenthos (Mud>Avi) Nematodes (Mud>Avi) Foraminifera (Mud<Avi) Nematode trophic structure: 1A and PN: Mud<Avi 1B and 2A: Mud>Avi Nematode diversity indexes: Evenness J': Mud<Avi Diversity H': Mud<Avi Nematode assemblage (multivariate analysis): Mud≠ Avi	Meiobenthic density: Total meiobenthos (Mud=Mix) Nematodes (Mud=Mix) Foraminifera (Mud<Mix) Nematode trophic structure: 1A and PN: Mud<Mix 1B and 2A: Mud>Mix Nematode diversity indexes: Evenness J': Mud<Mix Diversity H': Mud<Mix Nematode assemblage (multivariate analysis): Mud≠ Mix	Meiobenthic density: Total meiobenthos (Mud>Rhi) Nematodes (Mud>Rhi) Foraminfera (Mud<Rhi) Nematode trophic structure: 1A, 2B and PN: Mud<Rhi 1B and 2A: Mud>Rhi Nematode diversity indexes: Evenness J': Mud<Rhi Diversity H': Mud<Rhi Nematode assemblage (multivariate analysis): Mud≠ Rhi
Avicennia		Meiobenthic density: Total meiobenthos and nematodes tend to Avi<Mix	Meiobenthic density: Meiobenthos (Avi=Rhi) Nematodes (Avi=Rhi) Foraminifera (Avi<Rhi) Nematode trophic structure: 1A: Avi>Rhi 2B and PN: Avi<Rhi Nematode assemblage (multivariate analysis): Avi≠ Rhi
Mixed forest			Meiobenthic density: Foraminifera (Mix<Rhi) Nematode trophic structure: 1A: Mix>Rhi 2B and PN: Mix<Rhi Nematode assemblage (multivariate analysis): Mix≠ Rhi

Nematode trophic structure: 1A: Selective deposit feeders 2A: Epistratum feeders
PN: Phytoparasitic nematodes 1B: Non-selective deposit feeders 2B: Predators/Omnivores

Table 7. Comparison of major characteristics of meiobenthos and nematode assemblage in different habitat types in rainy season

	Avicennia	Mixed forest	*Rhizophora*
Mudflat	Meiobenthic density: Total Meiobenthos (Mud>Avi) Nematodes (Mud>Avi) Nematode trophic structure: 1A: Mud<Avi 1B and 2A: Mud>Avi Nematode diversity indexes: Evenness J': Mud<Avi Diversity H': Mud<Avi Nematode assemblage (multivariate analysis): Mud≠ Avi	Meiobenthic density: Foraminifera (Mud<Mix) Nematode trophic structure: 1A: Mud<Mix 1B and 2A: Mud>Mix Nematode diversity indexes: Evenness J': Mud<Mix Diversity H': Mud<Mix Nematode assemblage (multivariate analysis): Mud≠ Mix	Meiobenthic density: Total Meiobenthos (Mud>Rhi) Nematodes (Mud>Rhi) Foraminifera (Mud<Rhi) Nematode trophic structure: 1A, 2B and PN: Mud<Rhi 1B and 2A: Mud>Rhi Nematode diversity indexes: Evenness J': Mud<Rhi Diversity H': Mud<Rhi Nematode assemblage (multivariate analysis): Mud≠ Rhi
Avicennia		Meiobenthic density: Total Meiobenthos (Avi<Mix) Nematodes (Avi<Mix)	Nematode trophic structure: 1A: Avi>Rhi 2B and PN: Avi<Rhi Nematode assemblage (multivariate analysis): Avi≠ Rhi
Mixed forest			Meiobenthic density: Total meiobenthos (Mix>Rhi) Nematodes (Mix>Rhi) Nematode trophic structure: 1A: Mix>Rhi 2B and PN: Mix<Rhi Nematode assemblage (multivariate analysis): Mix≠ Rhi

Nematode trophic structure: 1A: Selective deposit feeders 2A: Epistratum feeders
PN: Phytoparasitic nematodes 1B: Non-selective deposit feeders 2B: Predators/Omnivores

4 DISCUSSION

4.1 Meiobenthos

4.1.1 Composition and density of total meiobenthos

Meiobenthos in mangrove has been studied in several areas from tropical to sub-tropical as well as temperate mangrove in America (Cuba, Brazil), Africa (Kenia, Zanzibar, Sudan), Asia (India, Malaysia), Australia (Dye 1983a, 1983b, Sultan Ali *et al.* 1983, Kondalarao 1984, Hodda & Nicholas 1985, Lalara-Rueda & Gosselck 1986, Alongi 1987a, 1987b, 1989, 1990, Nicholas *et al.* 1991, Vanhove *et al.* 1992, Ólafsson 1995, 2000, Khalil 2001, Zhou 2001, Netto & Gallucci 2003, Armenteros *et al.* 2006, Chinnadurai & Fernando 2007). Meiobenthic studies in mangroves have concentrated primarily on composition and abundance of this fauna. Composition of meiobenthos is very variable over time. A study in the hypersaline mangrove of Unguja largest island, Zanzibar, showed that in its most basic composition it can include only four groups: nematodes, harpacticoid copepods, chironomids (Diptera larvae) and plathelminthes (Ólafsson 2000). Composition maxima were recorded in mangroves in Gazi Bay, Kenya. Here the meiofauna was comprised of 17 taxa, with nematodes and copepods as the most dominant representatives, and turbellarians, oligochaetes, polychaetes, ostracods, rotifers, which occur in high numbers in some areas, as the more common taxa. Few gastrotrichs, kinorhynchs and tardigrades were recorded (Vanhove *et al.* 1992). In general, the average number of taxa found in mangrove forests ranges from 7 to 14. In the present study, 13 taxa were collected which commonly also appear in other mangrove areas. In physically harsh environments the abundance and species diversity of benthic macrofauna is often greatly reduced and in the extreme, is completely absent. In contrast, benthic meiofauna may survive in such environments, often in relatively high abundance, although diversity is usually limited to a few specialized species (Ólafsson 1991, Modig & Ólafsson 1998).

Density of meiobenthos in mangrove sediments varies considerably on global and local scales. In the Americas, meiobenthic density has been recorded as relatively low. In a mangrove in South Cuba 36-245 ind/10 cm^2 were found (Lalara-Rueda & Gosselck 1986). Recently, Armenteros *et al.* (2006) recorded an average of 101 ind/10 cm^2 in mangrove adjacent to the Gulf of Batabano, Cuba. Netto & Gallucci (2003) showed that densities of meiobenthos varied between 77-1589 ind/10 cm^2 in a mangrove area on the Island of Santa Catarina, South Brazil.

Meiobenthic density in African mangrove is very high in comparison to mangroves in the Americas. Dye (1983a) recorded average total meiobenthos with 2460 ind/10 cm^2 in the Mngazana River. The highest meiofauna densities, of approximately 1000 ind/10 cm^2, were reached in mangrove sediments in Transkei, Southern Africa Dye (1983b). Vanhove *et al.* (1992) recorded minimum average meiofauna densities of 1976 ind/10 cm^2 in *Ceriops* forest and maxima of 6707 ind/10 cm^2 in *Bruguiera* forest, Kenia. Ólafsson (1995) reported average meiofauna densities of 1493 ind/10 cm^2, with maximal densities of 5263 ind/10 cm^2 in mangrove in Zanzibar (south-eastern Africa). Khali (2001), in a study of meiofauna in mangrove on the Red Sea coast (noth-eastern Africa), recognized that meiofaunal densities ranged from 98 to 1650 ind/10 cm^2.

Mangrove in Australia has also been studied extensively. Hodda & Nicholas (1985) found 64-12,058 ind/10 cm^2 in *Avicennia* mangrove in south-eastern Australia. In a study investigating the meiobenthos in five mangrove estuaries along the north-eastern coast of Australia, Alongi (1987a) recorded that total meiofauna averaged in the range of 66-1660 ind/10 cm^2 in the winter dry season and 217-2454 ind/10 cm^2 in the summer wet season. Alongi (1990) reported that meiobenthic density was 1840-2517 ind/10 cm^2 in a tropical mangrove estuarine, Hinchinbrook island, north-eastern of Australia.

In India, meiobenthic densities were quite similar to those found in the Americas. Sultan Ali *et al.* (1983), in a study on mangrove adjacent to the Bay of Bengal, reported only 35-280 ind/10 cm^2. Slightly higher meiobenthic numbers were presented by Chinnadurai & Fernando (2007), who found total densities of meiobenthos of 234-890 ind/10 cm^2 on the south-eastern coast of India during 2002 and 2003. Kondalarao's (1984) results of mean densities reaching 2130 ind/10 cm^2 in Gautami-Godavari estuarine system. In another part of Asia, Sasekumar (1994) recorded densities of meiobenthos ranging from 407 to 1109 ind/10 cm^2 in mangrove forest along the coast of Malaysia.

Predation, competition and spatial and temporal changes in environmental factors and food resources have traditionally been implicated in regulating meiobenthic communities inhabiting sheltered intertidal systems (Reise 1985).

Sheltered regions with muddy sediment rich in detritus generally are characterized by high meiofaunal densities (Heip *et al.* 1985, Coull 1988, Giere *et al.* 1988). In the present study, grain size distribution of sediment from fine silt to coarse silt (Figure A1, A2, A3, A4) supported the development of meiobenthos. Calculations based on all sample stations in the three study creeks showed that total meiobenthic densities ranged from 304 ind/10 cm^2 to 7611 ind/10 cm^2, with an average of 2067 ind/10 cm^2. These results are very high in comparison with any other study on meiobenthic densities in mangrove. Among three study creeks, densities decreased from Khe Nhan to Rach Oc to Nang Hai Creek in the rainy season 2004 with an average of 2440, 2158, 1303, ind/10 cm^2, respectively. These densities could relate with distribution of sediment in the creeks. Sediment samples collected from Khe Nhan Creek had unimodal grain size distribution with fine silt and bimodal distribution with fine and very coarse silt. In the meantime, sediment samples from the mangrove forest in Nang Hai Creek had mainly bimodal grain size distribution with fine and very coarse silt as well as bimodal distribution with fine silt and domination of very coarse silt. Sediment from Rach Oc Creek had intermediate situation between tow creeks (Figure A1, A2, A3, A4).

In present study, the tidal level was identified as one of the major factors influencing density. The low water stations generally had higher densities than mid and high water stations. Several authors have found significant differences in the meiofaunal densities among intertidal positions in mangrove areas with highest densities at low water stations (Hodda & Nicholas 1985, Alongi 1987b, 1990, Nicholas *et al.* 1991, Ólafsson 1995), while Dye (1983a) found meiofauna in highest numbers at the mid water level. Meiofaunal densities were generally highest at low intertidal and shallow subtidal levels at all sampling sites (Khalil 2001). This study also showed higher densities of meiobenthos in shallow subtidal levels at some stations.

Dye (1983a) reported the highest number of meiofauna reached in summer, although autumn and spring peaks were found at some tidal levels. Alongi (1987b) also

reported higher meiofauna densities in the wet summer season than in the winter season in tropical areas. Temperature has been shown to be an important factor in nematode development and reproduction (Tietjen & Lee 1972, Hopper *et al.* 1973), and since nematodes are the dominant group, it would be expected that the highest meiofauna density would occur during summer. Our study have the similar trend when densities of meiobenthos in dry season (higher temperature) was higher than in rainy season (lower temperature).

Dye (1983a) recognized that plant density is a determining factor in meiofauna distribution and this is born out by the fact that meiofauna density increases as the mangroves proper are penetrated. However, Gee & Somerfield (1997) have shown that within the same tidal level the species of tree appear to have little effect on the structure and diversity of the meiofauna community.

When studying meiofauna in different mangrove forests in India, Chinnadurai & Fernando's (2007) observed that plant cover did have an effect on the meiobenthic density, possibly because it determines the type of sediment and food available in that environment, thereby determining the species composition of the dominant group present. They found that meiofauna densities were 633-890 ind/10 cm^2 in *Avicennia marina*, 234-474 ind/10 cm^2 in *Rhizophora apiculata*, 297-302 ind/10 cm^2 in replanted *R. apiculata*. Generally, areas with *A. marina* cover had relatively higher densities of meiofauna than areas with *R. apiculata* cover. They stated that higher silt and clay content observed in areas with *A. marina* cover, compared to areas *R. apiculata,* may be due to the morphology of the mangrove. *A. marine* roots with numerous pneumatophors projecting upwards from the sediment may form an effective barrier compared to the *R. apiculata* prop root.

In a study on meiobenthos in Malaysian mangrove, the result of Sasekumar (1994) seems to be approximate those by Chinnadurai & Fernando (2007), as he reported meiobenthic densities of 1109 ind/10 cm^2 in *Avicennia*, 583 ind/10 cm^2 in *Rhizophora*, and 407 ind/10 cm^2 in *Bruguiera* forest.

When studying mangrove leaf degradation, Robertson (1988) showed that *Avicennia* with their high initial nitrogen content, low C:N ratio and low hydrolyzable tannin concentration had the most rapid decomposition rate. By contrast, leaves of *Ceriops* and *Rhizophora* with low initial nitrogen concentration, high C:N ratios and very high tannin concentration decayed much more slowly. The decomposition rate of *Avicennia* is apparently twice as fast as that of *Rhizophora*, probably due to the relatively thinner nature of the *Avicennia* leaves (Boonruang 1984). Tannins may deter detritus feeding by meiofauna either through acidity or by imparting a noxious flavor to detritus (Alongi 1987c). Chinnadurai & Fernando (2007) speculated that *A. marina* may be more attractive to meiofauna than *R. apiculata* because of the high initial nitrogen concentration and low hydrolyzable tannin concentration, which result in a rapid decomposition rate compared to *R. apiculata*.

However, Vanhove *et al.* (1992) noted that meiobenthos density in *Bruguiera gymnorrhiza* forests was highest (6707 ind/10 cm^2), lower in *Rhizophora mucronata* (3998 ind/10 cm^2), 3442 ind/10 cm^2 in *Avicennia marina*, 2889 ind/10 cm^2 in *Sonneratia alba*, and lowest in *Ceriops tagal* (1976 ind/ 10 cm^2). The survey was conducted in the mangrove forests adjacent to Gazi Bay, Kenya. This result stands in contrast to mentioned results of Sasekumar (1994) as well as Chinnadurai & Fernando (2007).

The present study showed similarity with Vanhove *et al.* (1992) results. Based on all samples in three creeks, meiobenthos densities were 1617 ind/10 cm^2 in *Avicennia*, 2516 ind/10 cm^2 in mixed forest of *Avicennia* and *Rhizophora*, 2058 ind/10 cm^2 in *Rhizophora*. It appears that *Rhizophora* in Can Gio mangrove may be more attractive to meiobenthos than *Avicennia*. In addition, the highest densities of meiobenthos in mixed forest of *Avicennia* and *Rhizophora* suggested that mangroves with multy plant species can create a habitat that more appropriate for development of meiobenthos than mono plant species mangroves. Our result agreed with statements by Tietjen & Alongi (1990) that a mix species litter is advantageous for the growth and maintenance of nematode populations, and Mall *et al.* (1991) show that litter decomposition rates and soil respiration rates are higher in mixed species litter than in monogeneric species litter.

4.1.2 Abundance of major meiobenthic groups

As in most other sediment, nematodes are regularly the most dominant among meiobenthic taxa in the mangrove sediment. Normally, nematodes occupy over 80% of total meiobenthos, sometimes even up to 95 - 99% (Dye 1983a, 1983b, Kondalarao 1984, Hodda & Nicholas 1985, Lalara-Rueda & Gosselck 1986, Alongi 1987b, 1989, 1990, Nicholas *et al.* 1991, Vanhove *et al.* 1992, Ólafsson 1995, 2000, Khalil 2001, Netto & Gallucci 2003, Armenteros *et al.* 2006, Chinnadurai & Fernando 2007). Nematodes seem to be less important in a study in Australian mangroves with 27-31% (Alongi 1987a), and in Cuban mangroves with a percentages of 35-61% (Lalana-Rueda & Gosselck 1986).

In the present study, nematodes were also the most abundant taxa. Average nematode percentages ranged from 87-91% throughout the three study creeks. The lowest percentage was 66% in the mud flat stations of Nang Hai Creek in the rainy season. The reason is the sediment pattern in the mud flat of Nang Hai Creek with a high ratio of sand and low silt and mud content (La Thi Cang *et al.* 2006). Among the three types of mangroves in Rach Oc Creek, the nematode percentages and densities were generally higher in mud flat sites and mixed forest sites than *Avicennia* and *Rhizophora* sites. Between two seasons, comparison in Rach Oc Creek showed that nematode percentages and densities in the dry season were higher than in the rainy season. Heavy rains could disturb the sediment surface and influence the ratio and density of meiobenthos as well as nematodes. The dry season in Can Gio created a more appropriately environmental condition for nematode development than the rainy season.

Copepods are usually the second most abundant taxon in terms of individual dominance. They occupy about 3-34% of the total meiobenthos (Lalana-Rueda & Gosselck 1986, Sasekumar 1994, Ólafsson 2000, Chinnadurai & Fernando 2006). Armanteros *et al.* (2006) and Vanhove *et al.* (1992) stated that copepod densities, particularly harpacticoids, were low in comparison to nematodes (in *Bruguiera* forest 16.6%, *Avicennia* 6.2%, *Ceriops* 3.1, *Rhizophora* 2.1%, *Sonneratia* 1.8%). Alongi (1987a, b), Hodda & Nicholas (1985) and Dye (1983a, b) also noted a low copepod density (under 10%).

In our results, copepods were the second most abundant taxon in almost all study stations. Copepod percentages showed a gradual change from Nang Hai Creek (4.7%), to Rach Oc Creek (3.2%) and Khe Nhan Creek (2.4%). The highest percentage of copepods was found in Mud flat sites in Nang Hai Creek with 15.9% of

total meiobenthos (117 ind/10 cm^2). The reduction consequently concern sediment pattern, as they are coarser in Nang Hai than in Rach Oc and Khe Nhan Creeks. Chinnadurai & Fernando (2006) and Ólafsson (1995) made similar conclusions. Among three types of forests, copepod percentages were higher in *Avicennia* and *Rhizophora* sites than in Mixed forest site. The difference was clearer in the rainy season. They argue that plant cover and the number of trees in *Avicennia* and *Rhizophora* forests are much smaller than in Mixed forest (Table A8). This could influence the sediment surface between forest types and subsequently change copepod distribution. Vanhove *et al.* (1992) noted that low copepod percentages in silty/muddy sediment suggests that this taxon is more related to coarser grain texture. In addition, copepods and epsilonematid nematodes do not withstand high silt fraction. Copepods are reported as one of the most sensitive taxa to oxygen decrease and are usually restricted to occurrence in oxic condition (Coull & Chandler 1992).

A study by Alongi (1987a) showed that turbellarians were the most abundant meiobenthic group in the data with 58-67%. This could be due to the extraction technique used. Hodda & Nicholas (1985) found oligochaetes to be the most abundant group next to nematodes and copepods, while Dye (1983a, b) recorded 6.4% ciliates as second most abundant after nematodes, followed by oligochaetes (4.5%), kinorchychs (3.0%) turbellarians (2.8%) and calanoid copepods (1.6%).

In the present study, foraminifera was the second most abundant taxon in Khe Nhan and Rach Oc creeks and the third most abundant in Nang Hai Creek in the rainy season 2004. Among the three forest types, Foraminifera had the highest densities as well as percentage in *Rhizophora* forests. This was most obvious in the dry season. The reason could be tidal inundation, because *Rhizophora* forests are far from the mouth of the creek and lay in the highest area of study area (Figure A3). A preliminary study in Malaysian mangrove forest noted that foraminifera varied from 318 ind/10 cm^2 in *Avicennia* forest to 2573 ind/10 cm^2 in *Rhizophora* forest (Sasekumar 1981). This result is in accordance with our result.

In present study, nematode and copepod densities positively correlated with temperature. Nematode density also positively correlated with pH and polichaetes positively correlated with dissolved oxygen. Other meiobenthic group had no correlation with abiotic factors. However, Ólafsson (1995) pointed out that the lack of significant correlations between environmental factors measured did not mean that these factors were not contributing to the density variations observed. They may indeed control the population densities of the major taxa differently and in different proportion at the various stations. An experimental approach where the factor of interest can be manipulated while fluctuations in all other variables are kept to a minimum may be more appropriate than simple correlation analyses, in evaluating the importance of community control mechanisms. Other factors like food availability and sediment chemistry may also be of importance.

4.2 Nematode assemblage

4.2.1 Taxonomy

Nematodes are a highly diverse and very important group of multicellular animals, but their systematics have always been volatile and are currently entering a new phase of turbulence. There are some nematode systematics used in the past such as an early phylogeny by Micolezky (1922), the system of Filipjev (1934), Chitwood's

Adenophorea/Secernentea system (Chitwood & Chitwood 1933, Chitwood 1937), the systems of De Coninck (1965), Maggenti (1963-1983), Andrássy (1974, 1976), the system of Lorenzen (1981, 1994), the system of Malakhov (1994). Now, the system of De Ley & Blaxter (2002) is a new system based on morphology as well as molecular methods to classify nematodes. In the taxonomical classification, we generally followed De Ley and Blaxter (2002), and Lorenzen (1994) in part.

Number of free-living marine nematode taxa in Can Gio mangrove forest is very high and its species composition is very abundant. However, here we only mention and discuss an example of the family Leptolaimidae, and two of its genera *Leptolaimoides* and *Deontolaimus*. Based on systems of De Ley & Blaxter (2002), and Lorenzen (1994), the family Leptolaimidae and two genera *Leptolaimoides*, *Deontolaimus* can be classified as follow:

PHYLUM NEMATODA Potts, 1932
CLASS CHROMADOREA Inglis, 1983
SUBCLASS CHROMADORIA Pearse, 1942
ORDER PLECTIDA Malakhov, 1982
SUPERFAMILY LEPTOLAIMOIDEA Örley, 1880
FAMILY LEPTOLAIMIDAE Örley, 1880
Leptolaiminae Örley, 1880
Genus *Leptolaimoides* Vitiello, 1971
Camacolaiminae Micoletzky, 1924
Genus *Deontolaimus* De Man, 1880

The family Leptolaimidae is one of the families with the highest number of individuals in Can Gio mangrove. It is in eighth position, occupying 4.0% of the total nematode individuals in the dry season, and in fifth position, with 5.7%, in the rainy season. There were 27 species belonging to 6 genera of Leptolaimidae in this study. However, Leptolaimidae is a family rarely present in mangrove sediment concerning the number of species/genus as well as the quantity of individuals. The publications on Leptolaimidae nematodes in mangroves around the world showed no leptolaimids in the study of Sasekumar (1994), 1 species belonging to 1 genus (1-2.4% total nematode individuals) in the study of Chinnadurai & Fernando (2007), 2 species, 2 genera (Nicholas *et al.* 1991), 3 species, 2 genera (<4%) (Ólafsson *et al.* 2000), 3 species, 3 genera (Decreamer & Coomans 1978), 3 species, 3 genera (0.7%) (Netto & Gallucci 2003), 3 species, 3 genera (3.7%) (Khalil 2001), 3 species, 3 genera (Gwyther & Fairweather 2005), 4 species, 3 genera (Hodda & Nicholas 1985), 5 species, 5 genera (1.9%) (Ólafsson 1995), and 8 species belonging 7 genera (Somerfield *et al.* 1998).

It is easily recognized that only the study by Somerfield *et al.* (1998) with 7 genera exceeds results of the present study, which recorded 6 genera. But no comparable studies can be found for the species abundance reported in the present study.

Genus *Leptolaimoides* Vitiello, 1971

The nematode genus *Leptolaimoides* Vitiello, 1971 is a rare genus within the family Leptolaimidae Örley, 1880 until now mostly found in European marine waters and in low abundance. Type species is *L. thermastris,* first described by Lorenzen (1966) as *Leptolaimus thermastris* Lorenzen, 1966. Later, four further species, *L. tubulosus*

Vitiello, 1971; *L. haploopis* Jensen, 1978; *L. asiaticus* Gagarin & Nguyen Vu Thanh, 2005 and *L. punctatus* Yong Huang & Zhinan Zhang, 2006 were published. Main characters of *Leptolaimoides* are the four short sensillae of R_3, the ovally elongated amphids, tubular precloacal supplements (in the male) being present or absent, and the tail with a filiform portion.

In studies on nematodes in mangrove forest, there are two papers by Ólafsson (1995) and Somerfield *et al.* (1998) showing the presence of one species of *Letolaimoides* in Unguja island, Zanzibar and Merbok, Malaysia, respectively. However, these specimens were only identified to unnamed species level. The present study reports five new species of *Leptolaimoides*.

The first species *L. tropicus* sp. nov. resembles *L. thermastris* Lorenzen, 1966 and *L. haploopis* Jensen, 1978 in the absence of precloacal supplements. It differs from *L. thermastris* in the body size (605 µm vs 350-380 µm) and in having longer amphids (19-23 µm vs 8-12 µm). Further, *L. tropicus* is also distinguished from *L. thermastris* by shorter spicules (10-11 µm vs 13 µm) and the more anterior location of vulva (V = 40-42 % vs V = 43-46 %). The new species differs from *L. haploopis* Jensen, 1978 by the smaller body size (605 µm vs 770 µm), shorter spicules (11-12 µm vs 16 µm) and shorter amphids (19-23 µm vs 30 µm).

In the genus *Leptolaimoides*, the second species *L. cangioensis* sp. nov. is characterized by the presence of two precloacal supplements in the male. Moreover, it also differs from known species in having the shortest amphids (4-6 µm), in the original structure of spicules and gubernaculum with apophysis right then and bent to dosal side. Two tubular equally sized precloacal supplements, 5-7 µm long. Tail 67-78 µm long, conical in 34% of its length, then narrowing to be filiform and in the female the filiform portion appearing to be set off by a slight constriction.

The third species *L. mangrovi* sp. nov. resembles *L. asiaticus* Gagarin & Nguyen Vu Thanh, 2005, but it differs from *L. asiaticus* in having shorter amphids (10-14 µm vs 17-18 µm) and in the further anterior location of the amphids (6-8 µm from anterior end of body vs 11 µm). It differs also in the smaller size of the spicules (11-12 µm vs 15-16 µm) and shorter supplements (4-7 µm vs 7-8 µm).

Within the genus, the fourth species *L. clavicaudatus* sp. nov is characterized by the presence of four precloacal supplements in the male. It is close to *L. punctatus*, but differs from this species in absence of two longitudinal rows of dots and in smallest size of body (213-384 µm vs 615-692 µm in *L. punctatus*), it also differs from that by having a small length of the spicules (8.7 µm vs 17 µm) and smaller length of the amphids (9.8 µm vs 19-23 µm). Moreover, it also differs from all known being the smallest one (213 µm), by shorter spicules (9 µm) and a shorter tail (47 µm) with a club-shaped terminal portion.

The last new species of the genus in this study, *L. hexatubolosus* sp. nov. is characterized by the presence of six tubular precloacal supplements in the male. In addition, it has a more complicated lateral field with 2 longitudinal ridges in comparision with other *Leptolaimoides* species

Altogether, there have been only few records on members of this genus in the past, hitherto comprising five species. The three known species were recorded from European marine waters: North Sea (eulittoral, mud, saltmarsh - *L. thermastris*), Mediterranean (sublittoral, mud - *L. tubulosus*), West Channel/Bay of Morlaix (estuarine, sublittoral, silt deposits - *L. tubulosus*), Baltic/Oeresund (sublittoral, silty

sand, mud – *L. haploopis*), basing at maximum on five specimens (*L. thermastris*). Apart from these, 2 other were described in Asia, *L. asiaticus* from Cam estuary muddy sediment in the north of Vietnam and *L. punctatus* from subtidal muddy sediment in the Yellow Sea of China, basing at maximum on three specimens.

The description of five new species from a comparatively narrow area of Vietnamese mangrove coasts/muds with comparatively respectable numbers of specimens opens a new view on that small, little known genus. May be that the tropical region of the south eastern Asia/south western Pacific coasts, particularly mangrove habitats, are the proper habitat/centre of/for members of that genus. Keeping this in mind, the records of the European species may be records of "neozoans" ("alien species", "invasive species", "introduced species"), carried by vessel activities i.e. ballast waters – or in the past by ballast sands or stones – or secondly by currents into those Oceans.

Genus *Deontolaimus* De Man, 1880

The nematode genus *Deontolaimus* De Man, 1880 with the single type species *D. papillatus* De Man, 1880 is one of the rarest genus in the family Leptolaimidae, Örley, 1880. Some authors have described this species, such as De Man (1921), De Coninck (1944), Loof (1961), Lorenzen (1969), Alekseev (1981) and Vinciguerra & Orselli (1997). Recently, *D. papillatus* was reviewed and described in much detail by Holovachov (2006). Main characters of *Deontolaimus* genus are buccal cavity with stylet-like dorsal tooth, precloacal cup shape supplements present in cervical region.

Only one paper by Hodda & Nicholas (1985) stated the presence of a *Deontolaimus* species in the Hunter River estuary, Australia, covered by a single species of mangrove, *Avicennia marina*. However, no details about the density and description of this species were mentioned. The present study contributes to the description of two new *Deontolaimus* species from mangrove forest in Can Gio, Vietnam.

The new species *Deontolaimus mangrovi* nov. sp. differs from *D. papillatus* in shape of tail: conical then elongated and end without pointed tip vs conical with pointed tip strongly cuticularised.

The second new species *Deontolaimus pseudopapillatus* nov. sp. resembles *D. papillatus* De Man, 1880 (type species) in the shape of body, especially in the tail region tail tip. It differs from *D. papillatus* in shape of gubernaculum: simple plate-like in *D. papillatus* vs complicated plate-like with dorsal curve apophyses in *D. pseudopapillatus* nov sp.

Deontolaimus papillatus has been recovered from brackish sediment on the island of Walcheren, Scheldt estuary, The Netherlands (De Man 1921), from sediment in the North Sea (Lorenzen 1969), from brackish waters in southern Sakhalin, Russia (Alekseev 1981), from Italian sand dunes (Vinciguerra & Orselli 1997), from salt marshes in The Netherlands (Holovachov 2006). Maximum number of specimen was 12 (Holovachov 2006). Although *Deontolaimus papillatus* is not present in the Can Gio mangrove, there were two other new species belonging to this genus described. Number of individuals was about one hundred. This result of *Deontolaimus* with above data of *Leptolaimoides* may be examples for the high biodiversity in Can Gio mangrove forest, Vietnam

4.2.2 Nematode community structure

4.2.2.1 Nematode composition

The results of this study showed that the fauna of the free-living marine nematodes in tropical mangrove forest are very diverse. Throughout 75 sampling stations, 214 putative species, belonging to 92 genera, and 36 families were identified. Investigation of nematode composition in mangrove at the genus or species level is limited to several studies (Decreamer & Coomans 1978, Hodda & Nicholas 1985, Alongi 1987b, Nicholas *et al.* 1991, Sasekumar 1994, Ólafsson 1995, Somerfield *et al.* 1998, Khalil 2001, Netto & Gallucci 2003, Chinnadurai & Fernando 2007). The highest number of nematode species was recorded in Malaysian mangrove, Southeastern Asia with 107 putative species (Somerfiled *et al.* 1998), and in Zanzibar, Southeastern Africa with 94 genera (Ólafsson 1995). The number of genera found in the Can Gio mangrove well compares with Ólafsson's list of nematode genera in Zanzibar (92 genera in Can Gio vs 94 genera in Zanzibar, Ólafsson 1995). But the quantity of putative nematode species in Can Gio is twice as high as that registered by Somerfield *et al.* in Merbok, Malaysia (214 putative species in Can Gio vs 107 putative species in Merbok, Somerfield *et al.* 1998).

The common families in the mangrove in Merbok, Malaysia were Desmodoridae, Microlaimidae, Xyalidae, Chromadoridae (Somefield *et al.* 1998). Chromadoridae is the most dominant family in number of individuals in Zanzibar (Ólafsson 1995). In the present study, Linhomoeidae, Xyalidae, Comesomatidae, Chromadoridae, Oxystominidae and Desmodoridae were the most common. Each family occupied an average percentage of at least over 5% of the total nematode individuals. The study by Somerfield *et al.* (1998), surprisingly found Comesomatidae to be rare, particularly species of *Sabatieria*, which are often dominant communities in such habitat. But in our study, Comesomatidae was abundant with over 10% of the total individuals. However, instead of *Sabatieria* species being the most abundant species in the family, in this case it was *Paracomesoma* sp2.

Alongi (1987a), after statistical analysis of the nematode fauna from a number of tropical mangrove-lined estuaries, concluded that the species assemblages differed according to environmental factors characterizing each estuary. This finding is supported by other results from around the world. Decreamer & Coomans (1978) showed that *Microlaimus* was very abundant in all samples. Nicholas *et al.* (1991) studied *Avicennia* mangrove mud flats on the Clyde River estuary, Australia. *Microlaimus capillaries* and *Desmodora cazca* occured in high numbers at the middle and low tidal levels, while *Terschellingia* was abundant in mangrove species at high tidal levels. Typical for marine littoral genera *Anoplostoma capano, Haliplectus minimus, Actinonema longicaudatum, Camacolaimus* sp, *Diplolaimelloides brucei*, 2 species of Dorylaimidae, *Tylencholaimellus* and *Prodorylaimus* and several kind of Tylenchida, were numerous at the high tidal level. Sasekumar (1994) recorded common species such as *Terschellingia longicaudata*, *Ptycholaimellus* sp, *Spirinia* sp, *Sabatieria* sp, *Dolicholaimus* sp, and *Sphaerolaimus* sp4. Ólafsson (1995) noted that genera with the highest abundance were *Microlaimus, Spirinia, Desmodora,* and *Metachromadora*. In hypersaline *Avicennia marina* mangrove Ólafsson *et al.* (2000) found *Microlaimus* sp, *Metalinhomoeus* sp, *Daptonema* sp1, and *Chromadorina* sp to be the most abundant. Khalil (2001) stated the most dominant species as *Terschellingia* sp, *Daptonema* sp, *Spirinia* sp, *Metachromadora* sp1 in Sudanese mangrove. According to Netto & Gallucci (2003), three species, *Haliplectus* sp1,

Anoplostoma sp1, and *Terschellingia* sp3, dominate over 60% of total individuals in the mangroves *Avicennia schaueriana* and *Laguncularia racemosa*, south Brazil.

The most abundant species in the present study were *Theristus* sp1, *Hopperia* sp1, *Paracomesoma* sp2, *Terschellingia* sp3, *Terschellingia* sp4 and *Dichromadora* sp1. We would agree with Alongi's interpretation, because the species we found share common genera with the above results, but they do not match any one particular very closely.

The nematode composition was different between different types of mangroves in the present study. In general, the number of species at mudflat sites was 93-109 species with *Theristus* sp1 and *Paracomesoma* sp2 as the most abundant. *Avicennia* forests had between 152-163 species and *Terschellingia* sp3, *Terschellingia* sp4, *Haliplectus* sp1, *Astomonema* sp1, *Parodontophora* sp1, *Hopperia* sp1, and *Dichromadora* sp1 were most abundant. Mixed forests had 153-157 species and the most abundant were *Terschellingia* sp3, *Haliplectus* sp1, *Terschellingia* sp4, *Astomonema* sp1, *Parodontophora* sp2, and *Amphybelondira* sp1. *Rhizophora* forests had 141-149 species and *Hopperia* sp1, *Onyx* sp1, *Anoplostoma* sp1, and *Criconemella* sp1 were the most abundant.

In a study on nematode composition in different mangroves, Sasekumar (1994) showed that *Avicennia* forests harbored 51 species, 40 species in *Bruguiera* forest, and only 29 species in *Rhizophora* forests. The dominant species in *Avicennia* forests was *Ptycholaimellus*. In *Rhizophora* forest, Siphonolaimidae sp1, sp2 and *Terschellingia longicaudata* were dominant. *Terschellingia longicaudata* and *Ptycholaimellus* sp were the most dominant in *Bruguiera* forest.

Chinnadurai & Fernando (2007), studying nematodes in Indian mangroves, reported that the dominant families in areas with *Avicennia marina* cover were Comesomatidae, Chromadoridae and Linhomoeidae, and that *Rhizophora apiculata* cover was dominated by Xyalidae, Oncholaimidae and Comesomatidae. However, members of the family Comesomatidae were the most dominant forms at replanted *R. apiculata,* constituting 27.2%. *A. marina* was dominated by *Dorylaimopsis*, followed by *Hopperia*, *Ptycholaimellus ponticus*, and *Terschellingia*. *R. apiculata* was dominated by *Daptonema* and *Theristus*, followed by *Viscosia*. In replanted *R. apiculata* the most abundant species were *Halichoanolaimus dolichurus*, followed by *Sphaerolaimus maeoticus*. Three species, *Hopperia* sp, *Dorylaimopsis punctata*, and *Terschellingia longicaudata*, could be characterized as common to all stations.

Alongi (1987c), when studying the influence of tannin on meiobenthos density, stated that mangrove-derived tannin negatively effected laboratory-reared nematode populations and natural communities of meiobenthos in tropical mangrove forest along the northern coast of Australia. Reports by Sasekumar (1994) and Chinnadurai & Fernando (2007) agreed with Alongi (1987c), because meiobenthic densities (nematodes dominant) in their studies all decreased when comparing *Avicennia* forest (low tannin) with *Rhizophora* forest (high tannin). However the laboratory experiment of Alongi (1987c) was conducted exclusively with *Terschellingia longicaudata*. In the present study, meiobenthic density, as well as nematode density in *Avicennia* forest (low tannin), were little lower than in *Rhizophora* forests (high tannin). But density of *Terschellingia* in *Avicennia* forests (dry season average 24 ind/10 cm^2, rainy season 23 ind/10 cm^2) was much higher than in *Rhizophora* forests (dry season 8 ind/10 cm^2, rainy season 10 ind/10 cm^2). In Mixed forest, the density of nematodes was much higher than in either *Avicennia* forest or *Rhizophora* forest, while the density of

Teschellingia alone was similar to that found in *Avicennia* forests (dry season 24 ind/10 cm^2, rainy season 27 ind/10 cm^2). We suggest that tannin negatively affects nematode species, especially *Terschellingia*. This influence is stronger in the dry season than in the rainy season.

From these studies it is clear that there is no distinct nematode assemblage confined to the mangrove areas i.e. there appear to be no numerically dominant species endemic (Alongi 1987b) or common dominant genera among mangrove forests. However a dominance of Desmodoridae and Microlaimidae has also been reported for other mangrove areas (Decraemer & Coomans 1978, Nicholas *et al.* 1991) though not in all (Hodda & Nicholas 1986). The most common genera found in this study are found in marine sediments all over the globe. That we do not have a well defined nematode assemblage in mangrove sediments may most likely be attributed to the heterogeneity of the environment, both in space and time. With only a handful of studies on meiofauna assemblage structure in mangrove sediments all generalizations regarding the structure and the control factors of meiobenthic assemblages in these diverse ecosystems must be regarded as tentative.

4.2.2.2 Age and sex composition

Age structure and sex ratio are characteristics to adjust population development and strengthen stability and resistance of the population. Following Warwick and Price (1979), juveniles dominated the population throughout the year for the most species. Some evidence showed that the turnover time was faster in the spring and summer (juveniles about 60% of the total population in autumn and winter but 70% in spring and summer). From the present results, juveniles of the nematode community dominated in number over other age groups at all sites and stations. They decreased from Mud flat stations (highest in Mud-4, the furthest from river bank) to mangrove forest types in the dry season. The trend was the same but in the opposite direction when juveniles increase from Mud flat (lowest in Mud-4) to mangrove forest regions in the rainy season. Reasons could include that in light of the appropriate conditions required, such as temperature, salinity, and food in the dry season, nematode communities in Mud flat area are influenced much more strongly than those in mangrove forests further inside the intertidal creek. In contrast, in the rainy season, nematode communities in Mud flat area are influenced much by unappropriate condition. The low proportion of juveniles in Mud flat area in the rainy season in comparison with the dry season showed that juveniles are more sensitive to environmental conditions.

Male/female ratio is influenced by different environmental factors. However, the decrease of male/female ratio in mangrove forests in comparison with Mudflat areas could be by no male detection in some nematode species at mangrove forest types.

4.2.2.3 Trophic structure

In free-living marine nematodes, Wieser (1953) uses the buccal morphology (size and shape of buccal cavity and its armature) to distinguish 4 trophic groups:

Type 1A: *Selective deposit feeders* have minute, small buccal cavities or not. These nematodes feed on dissolved organic matter, bacteria and particles in the bacterial size. There is no empirical evidence that substantiates more selective feeding strategy than in other trophic types (Jensen 1987), but the basic idea is that the size of the buccal cavity invalidates a non-selective feeding behaviour because it would be

energetically unfavourable (Wieser 1953). Selective deposit feeders tend to dominate in different environments from non-selective deposit feeders (Heip *et al.* 1985, Moens & Vincx 1997).

Type 1B: *Non-selective deposit feeders* have larger buccal cavity than type 1A, buccal cavities are conical, cup or cylindrical shapes. These nematodes also feed on bacteria, as well as detritus, occasionally diatom, large-sized protozoan and even metazoan organism. Observation on some representatives of this group suggest that particle selection is largely a matter of particle size, shape and associated characteristics, such as particles that fit into the nematode's mouth are readily ingested (Nehring 1992b, Moens & Vincx 1997). However, this does not imply that food selection is only or even a major part determined by those 'physical' particle properties, as chemical food recognition from a distance may be important.

Type 2A: *Epistratum feeders* have a small to medium buccal cavity with a tooth, or similar structures. These nematodes mainly feed on diatoms and other unicellular microalgae and filamentous green and blue-green algae, but bacteria may be equally important (Moens & Vincx 1997). Food organisms can be pierced by a tooth, as *Pareudiplogaster*, *Dichromadora*, or cracked after partial intake into the mouth, as in *Hypodontolaimus*, *Chromadorita,* (Jensen 1982, Romeyn & Bouwman 1983, Moens & Vincx 1997). Several chromadorid genera like *Hypodontolaimus* and *Ptycholaimellus* were listed as predators/omnivores (2B) in Wieser (1953) original classification because of their large tooth and pronounced muscular pharynx, but the few available observations suggest they are in fact epistratum feeders (Nehring 1992a, Moens & Vincx 1997).

Type 2B: *Predators/omnivores* typically have large buccal cavity with more pronounced tooth or mandibles and pharyngeal musculature than the epistratum feeders. Many feed as predators on other metazoans as well as protozoans (Moens & Vincx 1997, Moens *et al.* 1999, 2000), however their feeding behaviour is poorly known and other feeding strategies may prevail (Jensen 1987, Moens & Vincx 1997, Moens *et al.* 1999).

Modifications of Wieser's feeding type classification have been proposed by Jensen (1987), Moens & Vincx (1997) on the basis of live observations and ecological information. However, Wieser's trophic classification is the most commonly used for separation of nematode feeding types.

In general, deposit feeders are dominant in finer sediment, while epistratum feeders and predators/omnivores are dominant in sandier sediment (Wieser 1959, Hopper & Meyers 1967, Hodda & Nicholas 1986).

Studies in mangroves have substantiated the correlation between trophic groups and sediment composition. Ólafsson (1995) also stated that the numbers of selective deposit feeders was negatively correlated with average grain size in Zanzibar. In Australian mangroves, deposit feeders usually outnumber other feeding guilds (Hodda & Nicholas 1986, Alongi 1987b) but there the sediment was much finer. Khalil (2001) stated that epistratum feeders were more abundant in sandy sediments while deposit-feeders were predominant in finer sediments in Sudan. Nematode assemblages at non-cleared mangrove sites were dominated by selective deposit feeders in summer and both selective/non-selective deposit feeders in winter. In mangrove on the Island of Santa Catarina, Brazil, nematode trophic structure was dominated by deposit feeders (47% selective deposit feeders, 29% non-selective deposit feeders). Netto & Gallucci

(2003) observed that food sources were highly abundant over the different stages of the mangrove litter decomposition, and possibly had a close relationship with the detritus biomass.

Chinnadurai & Fernando (2007) reported, concerning ecological feeding groups, that nematode communities in areas with *Avicennia marina* cover were dominated in terms of abundance by epistratum feeders (75.9%). In areas with *Rhizophora apiculata* cover the deposit-feeders/ciliate feeders were the most abundant (46.1%) with predators/facultative predators being the second most abundant feeding type constituting 29.8%. Sediment in the areas with *R. apiculata* cover had finer sediments than areas with *A. marina* cover. The difference in feeders in different mangrove forests could have been due to the biochemical composition of the mangrove leaf litter occurring in that area which may provide varying levels of energy sources the form of bacterial and fungal growth on it and the changes that take place during degradation.

Nematode assemblages in the Mudflat sites were dominanted by non-selective deposit feeders and epistratum feeders in the present study. Differences in the available foods probably accounts in large parts for differences in the meiofauna. In the bare mud, epistratum feeders were the most common (eg *Paracomesoma* sp2), which probably feed on diatoms near the surface of the mud. The reason may be the type of sediment (bimodal with fine silt and domination of very coarse silt) which may trap many kinds of detritus inside, sufficient for the development of non-selective deposit feeders such as *Theristus* sp1. In the *Avicennia* and Mixed forests, among the mangrove roots, selective deposit feeders such as *Terschellingia* spp were the most common, occuring with several less numerous nematodes that probably feed on diatoms and detritus. The sediment here was characterized as unimodal with fine silt or bimodal with fine silt and domination of very coarse silt. *Rhizophora* forests also had sediment with mostly fine silt. Here, selective-deposit feeders were also most dominant, however predators/omnivores (*Hopperia* sp1 and *Onyx* sp1) occupied a highest percentage in comparison with other forest types and mudflat areas. In addition, there was a number of plant root feeders commonly present at *Rhizophora* sites, representing an intrusion of terrestrial nematodes into the upper littoral zone. This could be influenced by the high altitude of the sampling stations and lower salinity, especially in the rainy season.

Based on several studies, Alongi (1987b) suggested that predatory nematodes are more abundant in the tropics than in other intertidal areas. The results of this study do not support this generalization. It appears that predatory nematodes were slightly more dominant in *Rhizophora* forests, though at other sites the proportion of feeding categories is as variable in the tropical mangrove sediments as in other intertidal areas.

4.2.2.4 Nematode diversity

Alongi (1987a, b) concluded that tropical intertidal benthos in Australian estuaries is subjected to greater physical stress than temperate intertidal communities. Such stress may be reflected in the relatively low nematode species diversity H' (2.05-2.91) and number of species (11-53) inhabiting the mangroves. Low rates of organic matter deposition, rapid rates of detrital utilization and high disturbance rates by large infauna have been cited as factors leading to low nematode diversity in the tropics (Alongi 1986).

However other studies have produced different data. According to Nicholas *et al.* (1991), diversity indexes of nematode assemblage of temperate Australian *Avicennia marina* mangrove mudflat were 1.43-2.76 (H') and 0.53-0.86 (J').

In tropical mangrove areas of Zanzibar, diversity indexes H' ranged from 0.94 to 4.25, evenness indexes J' from 0.32 to 0.89. Diversity index H' decreased to 0.49, and evenness J' declined to 0.31 in hypersanline stations (Ólafsson 1995).

In sub-tropical *Avicennia schaueriana* and *Languncularia racemosa* mangrove forests in south of Brazil, Netto & Gallucci (2003) recorded that the diversity index H' fluctuated about 2.7-3.3, and evenness index J' about 0.6-0.75.

Generally, increasing levels of environmental stress have generally been considered to decrease diversity, decrease species richness and decrease evenness. In the present study, diversity was generally high. Shannon-Wiener diversity index H' ranged from 1.9 to 3.7 across stations. H' differed between different mangrove forests: Mudflat sites (2.0-3.1), *Avicennia* forests (3.1-3.6), Mixed forests (2.8-3.7), *Rhizophora* forests (1.9-3.6). Evenness J' varied from 0.6-0.9, with Mudflat sites 0.6-0.8, *Avicennia* forests 0.8-0.9, Mixed forests 0.8-0.9, and *Rhizophora* forests 0.6-0.9. Diversity was slightly higher in *Avicennia* and Mixed forests than in Mudflat and *Rhizophora* forests. The diversity in Mudflat areas decreased mainly via two dominant species, *Theristus* sp1 and *Paracomesoma* sp2, and by phytoparasitic nematode species *Criconemella* sp1 in *Rhizophora* forests in the rainy season

On the other hand, Gee & Somerfield (1997) had shown that within the same tidal inundation regime the species of tree (and the species of leaf making up the leaf litter) appears to have little effect on the structure and diversity of the meiofaunal community. The implication is that to conserve the high species richness in such areas it is important that some form of mangrove tree community is conserved over as wide a range of physical conditions as possible, as opposed to the diverse mangrove tree community being conserved over a small range of physical conditions.

4.2.2.5 Community structure analysis by multivariate analysis

Multivariate analysis was used to compare nematode community structure in different types of mangrove. Base on cluster dendrogram and Multidimentional scaling (MDS) analysis, nematode community structure clearly showed differences between Mudflat sites and the three other types forests, as well as between *Rhizophora* forests and *Avicennia* forests or Mixed forests. The difference was clearer in the rainy season than in the dry season. Analysis of similarity (ANOSIM) showed that the differences among study sites were significant. Pairwise tests predicted that the difference between Mudflat sites and *Avicennia* forests was smallest, Mudflat site and *Rhizophora* forests was highest, Mudflat site and Mixed forests was in the middle. The difference was correlated with the distance from the Mudflat to other forests sites. The differences between *Rhizophora* forests and the group *Avicennia* forests/Mixed forests were significant but not much. However, the difference between *Avicennia* forests and Mixed forests was not significant, especially in dry season. This can be explained by that *Avicennia* and Mixed forests are naturally regenerated forests, nematode communities are similar while *Rhizophora* forests are rehabilitated forests.

The variations between studies sites were detected in detail by using Similarity percentage analysis (SIMPER). The result demonstrated that the four most important typifying species at Mudflat site were *Theristus* sp1*, Paracomesoma* sp2*, Pseudolella* sp1 and *Hopperia* sp1. These species belong to non-selective deposit feeders (*Theristus*

sp1), epistratum feeders (*Paracomesoma* sp2 and *Pseudolella* sp1) and predators (*Hopperia* sp1). In *Avicennia* and Mixed forests, most important typifying species were *Terschellingia* sp3, *Terschellingia* sp4, *Dichromadora* sp1, *Ptycholaimellus* sp1, *Astomonema* sp1, *Pseudochromadora* sp1. In there, *Terschellingia* sp3, *Terschellingia* sp4, *Astomonema* sp1 are selective deposit feeders, other species *Dichromadora* sp1, *Ptycholaimellus* sp1, *Pseudochromadora* sp1 are epistratum feeders. In *Rhizophora* forests, the most important typifying species were *Hopperia* sp1 and *Sphaerolaimus* sp3 belonging to predators, *Anoplostoma* sp1 belonging to non selective deposit feeders, *Haliplectus* sp3 belonging to selective deposit feeders, and *Dichromadora* sp1 belonging to the epistratum feeder group.

Use of nematode community structure as a useful tool for differentiation of regenerated/rehabilitated mangrove forests has proved to be an effective method in present study. Obviously, natural regenerating mangrove forests and rehabilitated mangrove forests differ in their vegetation and physical properties, in such that benthic community structure is impacted. This result supports the suggestion made by Hourston *et al.* (2005) that the compositions of nematode assemblages in a region are related to habitat types.

5 CONCLUSIONS

Meiobenthic composition included mainly nematodes, copepods, nauplii, foraminifera, polychaetes, oligochaetes, kinorhynchs, acari, ostracods, and others less abundant groups (bivalves, gastropods, insect larvae, turbellaria, nemertinea).

Of the three creeks studied, meiobenthic densities were highest in Khe Nhan Creek (2440 ind/10cm^2), lowest in Nang Hai Creek (1303 ind/10 cm^2) and intermediate in Rach Oc Creek (2158 ind/10 cm^2). Meiobenthic densities in Mudflats and Mixed forests were higher than in *Avicennia* forests or *Rhizophora* forests.

Nematodes were most abundant at all stations. Nematode percentages were the highest in Khe Nhan Creek (91.1%), lower in Nang Hai Creek (88.0%) and lowest in Rach Oc Creek (87.1%). Nematode percentages in Mixed forests and Mudflat sites were higher than in *Avicennia* and *Rhizophora* forests. But in Nang Hai Creek, nematode percentage was the lowest in the Mudflat site (65.9%). Copepods were the second most abundant group in Nang Hai Creek (4.7%) and the density there was the highest among three creeks, especially in the Mudflat site (117 ind/10cm^2). Foraminifera were the second most abundant in Khe Nhan and Rach Oc Creeks, with highest percentages always in *Rhizophora* forests. Meiobenthic density in the dry season was higher than in the rainy season. Nematode and copepod densities increased, in the meantime nauplii and foraminifera decreased in the dry season.

The nematode community was highly diverse, including 214 putative species, belonging to 92 genera, 36 families, and 10 orders. The family Leptolaimidae was present with 27 species belonging to 6 genera. Of the genus *Leptolaimoides* five known species were found, the present study contributing to five new species *L. tropicus* sp. nov., *L. cangioensis* sp. nov., *L. mangrovi* sp. nov., *L. clavicaudatus* sp. nov. and *L. hexatubolosus* sp. nov.. Genus *Deontolaimus* was represented with a typical single species and two newly described species, *D. mangrovi* sp. nov. and *D. pseudopapillatus* sp. nov., that the present study is contributing.

In the dry season, there were 200 putative species, belonging to 89 genera, 34 families and 10 orders. 17 families with an abundance of more than 1% occupied 87.8% of total nematode individuals, most important families were Linhomoeidae, Xyalidae, Comesomatidae. The most abundant species were *Theristus* sp1, *Hopperia* sp1, *Paracomesoma* sp2, *Terschellingia* sp3, *Terschellingia* sp4, *Parodontophora* sp1, and *Dichromadora* sp1. In the rainy season, the nematode community included 205 species, belonging to 90 genera, 36 families and 10 orders. 19 families with an abundance of more than 1% occupied 85% of total nematode individuals, the most important families were Xyalidae, Linhomoeudae, Comesomatidae. Between seasons, the number of individuals of Linhomoeidae, Chromadoridae, Oxystominidae decreased drastically from the dry season to the rainy season. On the other hand, individuals of Criconematidae and Leptolaimidae increased from the dry season to the rainy season. The most abundant species in the rainy season were *Paracomesoma* sp2, *Hopperia* sp1, *Terschellingia* sp3, *Terschellingia* sp4, *Dichromadora* sp1, *Theristus* sp1 and *Haliplectus* sp1. Between seasons, *Theristus* sp1 decreased from the most abundant species in the dry season to the sixth most abundant in the rainy season, while *Hopperia* sp1 and *Paracomesoma* sp2 changed slightly.

Age composition showed that juveniles were most abundant at all sites in both seasons. Juveniles were the highest in the Mudflat sites, and male/female ratios

increased from Mudflat site to *Avicennia* forests, Mixed forests and *Rhizophora* forests.

Trophic structure showed that non-selective deposit feeders (1B) and epistratum feeders (2A) were dominant in Mudflat sites, while selective deposit feeders (1A) were dominant in *Avicennia* forests, Mixed forests, and *Rhizophora* forest. In addition, predators and phytoparasitic nematodes in *Rhizophora* forests were also higher than at all other sites.

Nematode diversity index was generally high. Shannon-Wiener diversity indexes H' ranged from 1.9 to 3.7, evenness J were from 0.6-0.9 throughout all stations. Diversity was higher in *Avicennia* and Mixed forests than in Mudflats and *Rhizophora* forests. The diversity was mainly decreased in Mudflat areas via two dominant species, *Theristus* sp1 and *Paracomesoma* sp2, and by phytoparasitic nematode *Criconemella* sp1 in *Rhizophora* forests in the rainy season.

Base on composition and abundance of nematode community, sample stations clustered into 3 main groups: Group 1 included all stations of the Mudflat site, three subtidal stations of *Avicennia* forest, Mixed forest and *Rhizophora* forest; Group 2 contained intertidal stations of *Avicennia* forest and Mixed forest; Group 3 included intertidal stations of *Rhizophora* forest. The separation was clearer in the dry season than in the rainy season.

Most important typifying species in Mudflat site were *Theristus* sp1*, Paracomesoma* sp2*, Pseudolella* sp1 *and Hopperia* sp1. In *Avicennia* and Mixed forest, most important typifying species were *Terschellingia* sp3, *Terschellingia* sp4, *Dichromadora* sp1, *Ptycholaimellus* sp1, *Astomonema* sp1, *Pseudochromadora* sp1. In *Rhizophora* forest, the most important typifying species were *Hopperia* sp1, *Sphaerolaimus* sp3 *Anoplostoma* sp1, *Haliplectus* sp3, *Dichromadora* sp1 and *Criconemmella* sp1.

Above results showed that meiobenthos and nematode community structure varied in different types of mangrove in both dry and rainy seasons. They can be used to separate natural regenerated forest and rehabilitated forests, as well as forest types and mudflat sites in Can Gio Biosphere Reserve. The characteristics most considered should be: (i) densities of total meiobenthos, nematodes, foraminifera; (ii) nematode trophic structure; (iii) nematode diversity indexes (iv) nematode assemblage based on multivariate analysis.

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APPENDIX

Table A1. Hydrological factors of station at the time of sampling
(RS: Rainy season; DS: Dry season)
(NH: Nang Hai; KH: Khe Nhan; RO: Rach Oc)

Season	Station	Date	Time	Hydrological factors				
				T (°C)	DO (mg/l)	pH	NaCl (‰)	Tu (mg/l)
RS 2004	NH-Rhi-c	6/10/04	08h38	27.3	2.7	7.1	11.5	18
	NH-Mix-c	6/10/04	10h04	27.6	2.2	7.0	11.4	44
	NH-Avi-c	6/10/04	10h55	28.1	2.1	7.0	11.5	65
	KN-Rhi-c	7/10/04	09h10	28.2	2.7	7.2	11.5	19
	KN-Mix-c	7/10/04	10h30	28.2	2.1	7.0	12.6	28
	KN-Avi-c	7/10/04	11h20	28.4	2.1	7.0	12.6	69
	RO-Rhi-c	5/10/04	09h00	27.4	2.9	7.1	11.8	138
	RO-Mix-c	5/10/04	10h39	27.6	2.6	7.0	12.0	222
	RO-Avi-c	5/10/04	12h30	27.8	3.0	6.4	12.2	168
DS 2005	RO-Rhi-c	12/4/05	11h30	30.7	4.0	7.3	32.9	159
	RO-Mix-c	12/4/05	09h45	28.9	3.2	7.2	33.1	129
	RO-Avi-c	12/4/05	08h45	28.3	3.3	7.2	32.4	115
RS 2005	RO-Rhi-c	2/11/05	06h00	28.0	5.0	7.1	21.7	144
	RO-Mix-c	2/11/05	07h00	28.0	4.6	7.1	21.5	200
	RO-Avi-c	2/11/05	08h00	28.0	4.5	7.1	21.5	241

Table A2. Meiobenthic composition in Khe Nhan creek in the rainy season 2004

Order	Station	Meiobenthic composition										
		Ne	Co	Na	Po	Ol	Ki	Ac	Os	Fo	Ot	Sum
1	KN-Mud-1	2475	87	53	13	7	0	13	0	33	60	2741
2	KN-Mud-2	1122	60	27	7	7	0	0	7	47	13	1288
3	KN-Mud-3	1820	60	47	0	0	0	7	0	40	7	1980
4	KN-Mud-4	1898	40	27	0	0	0	0	0	0	13	1978
	Ave Mud	**1829**	**62**	**38**	**5**	**3**	**0**	**5**	**2**	**30**	**24**	**1997**
	Percentage	**91.6**	**3.1**	**1.9**	**0.3**	**0.2**	**0**	**0.3**	**0.1**	**1.5**	**1.2**	**100**
5	KN-Avi-a1	534	20	0	0	0	7	13	13	27	40	654
6	KN-Avi-a2	2048	27	33	7	0	0	0	0	40	20	2175
7	KN-Avi-a3	1806	53	13	7	7	0	7	7	40	20	1960
8	KN-Avi-b1	3837	60	53	0	20	0	0	20	113	33	4144
9	KN-Avi-b2	1913	60	40	0	0	0	27	20	87	20	2167
10	KN-Avi-b3	395	13	7	0	0	7	7	7	27	20	482
11	KN-Avi-c	2455	60	33	0	13	7	7	0	73	20	2668
	Ave Avi	**1856**	**42**	**26**	**2**	**6**	**3**	**9**	**10**	**58**	**26**	**2036**
	Percentage	**91.2**	**2.1**	**1.3**	**0.1**	**0.3**	**0.1**	**0.4**	**0.5**	**2.9**	**1.2**	**100**
12	KN-Mix-a1	1186	100	27	0	0	0	0	0	133	20	1466
13	KN-Mix-a2	1914	33	20	0	7	0	0	0	60	40	2074
14	KN-Mix-a3	2304	40	27	0	13	0	7	0	100	53	2544
15	KN-Mix-b1	7457	73	27	0	0	0	0	0	13	40	7611
16	KN-Mix-b2	3367	150	60	0	10	0	0	10	80	50	3727
17	KN-Mix-b3	2100	80	10	0	20	0	0	0	40	50	2300
18	KN-Mix-c	2317	60	13	7	0	0	13	0	33	33	2477
	Ave Mix	**2949**	**77**	**26**	**1**	**7**	**0**	**3**	**1**	**66**	**4,1**	**3171**
	Percentage	**93.0**	**2.4**	**0.8**	**0**	**0.2**	**0**	**0.1**	**0**	**2.1**	**1.3**	**100**
19	KN-Rhi-a1	3263	27	13	0	0	0	7	0	127	40	3477
20	KN-Rhi-a2	1315	93	20	0	0	0	7	13	260	13	1722
21	KN-Rhi-a3	1036	73	40	0	0	0	13	7	407	14	1589
22	KN-Rhi-b1	4382	113	80	0	7	0	13	0	93	40	4728
23	KN-Rhi-b2	557	40	7	0	0	0	7	0	73	13	697
24	KN-Rhi-b3	237	13	0	7	0	0	7	0	40	0	304
25	KN-Rhi-c	3848	47	20	0	0	0	7	0	47	87	4055
	Ave Rhi	**2091**	**58**	**26**	**1**	**1**	**0**	**9**	**3**	**150**	**30**	**2367**
	Percentage	**88.3**	**2.5**	**1.1**	**0**	**0**	**0**	**0.4**	**0.1**	**6.3**	**1.3**	**100**
Average		**2223**	**59**	**28**	**2**	**4**	**1**	**6**	**4**	**81**	**31**	**2440**
Percentage		**91.1**	**2.4**	**1.1**	**0.1**	**0.2**	**0**	**0.3**	**0.2**	**3.3**	**1.3**	**100**

Ne: Nematodes Co: Copepods Na: Nauplii Po: Polychaetes Ol: Oligochaetes
Ki: Kinorhynchs Ac: Acari Os: Ostracods Fo: Foraminifera Ot: Others

Table A3. Meiobenthic composition in Nang Hai creek in the rainy season 2004

Order	Station	Meiobenthic composition										
		Ne	Co	Na	Po	Ol	Ki	Ac	Os	Fo	Ot	Sum
1	NH-Mud-1	526	107	20	7	0	7	13	0	20	60	759
2	NH-Mud-2	471	67	7	7	0	0	7	0	13	54	624
3	NH-Mud-3	423	200	25	5	5	0	10	20	15	85	788
4	NH-Mud-4	512	93	20	13	7	7	27	13	7	60	759
	Ave Mud	**483**	**117**	**18**	**8**	**3**	**3**	**14**	**8**	**14**	**64**	**732**
	Percentage	**65.9**	**15.9**	**2.4**	**1.1**	**0.4**	**0.5**	**1.9**	**1.1**	**1.9**	**8.8**	**100**
5	NH-Avi-a1	592	40	7	0	0	0	0	0	27	0	665
6	NH-Avi-a2	1023	47	7	7	0	0	13	0	40	14	1150
7	NH-Avi-a3	929	40	7	0	0	0	7	0	33	20	1035
8	NH-Avi-b1	747	107	13	0	0	0	0	7	7	27	907
9	NH-Avi-b2	971	33	0	0	0	0	7	0	60	40	1111
10	NH-Avi-b3	619	7	0	0	0	0	0	0	7	7	639
11	NH-Avi-c	501	20	0	0	0	0	0	7	20	53	601
	Ave Avi	**769**	**42**	**5**	**1**	**0**	**0**	**4**	**2**	**28**	**23**	**873**
	Percentage	**88.1**	**4.8**	**0.5**	**0.1**	**0**	**0**	**0.4**	**0.2**	**3.2**	**2.6**	**100**
12	NH-Mix-a1	1535	27	0	7	0	0	0	0	13	7	1588
13	NH-Mix-a2	1360	60	0	7	7	7	7	20	67	46	1580
14	NH-Mix-a3	1495	10	0	0	0	0	0	10	20	20	1555
15	NH-Mix-b1	1456	33	0	0	0	0	0	0	40	27	1556
16	NH-Mix-b2	1825	73	33	0	13	0	0	13	80	13	2051
17	NH-Mix-b3	2577	113	27	7	13	0	7	0	53	7	2804
18	NH-Mix-c	675	27	20	0	0	0	7	0	13	27	769
	Ave Mix	**1561**	**49**	**11**	**3**	**5**	**1**	**3**	**6**	**41**	**21**	**1701**
	Percentage	**91.8**	**2.9**	**0.7**	**0.2**	**0.3**	**0.1**	**0.2**	**0.4**	**2.4**	**1.2**	**100**
19	NH-Rhi-a1	847	47	0	0	0	0	13	0	20	7	934
20	NH-Rhi-a2	1248	53	0	13	7	0	0	0	60	34	1414
21	NH-Rhi-a3	1165	20	0	0	0	0	7	0	53	40	1285
22	NH-Rhi-b1	983	120	0	0	0	0	0	0	33	0	1137
23	NH-Rhi-b2	2046	60	13	0	7	0	13	0	67	80	2286
24	NH-Rhi-b3	2436	73	7	0	7	0	7	0	160	47	2736
25	NH-Rhi-c	1703	40	7	7	0	0	7	0	40	47	1850
	Ave Rhi	**1490**	**59**	**4**	**3**	**3**	**0**	**7**	**0**	**62**	**36**	**1663**
	Percentage	**89.6**	**3.6**	**0.2**	**0.2**	**0.2**	**0**	**0.4**	**0**	**3.7**	**2.2**	**100**
Average		**1147**	**61**	**8**	**3**	**3**	**1**	**6**	**4**	**39**	**33**	**1303**
Percentage		**88.0**	**4.7**	**0.6**	**0.2**	**0.2**	**0.1**	**0.5**	**0.3**	**3.0**	**2.5**	**100**

Ne: Nematodes Co: Copepods Na: Nauplii Po: Polychaetes Ol: Oligochaetes
Ki: Kinorhynchs Ac: Acari Os: Ostracods Fo: Foraminifera Ot: Others

Table A4. Meiobenthic composition in Rach Oc creek in the rainy season 2004

Order	Station	Meiobenthic composition										
		Ne	Co	Na	Po	Ol	Ki	Ac	Os	Fo	Ot	Sum
1	RO-Mud-1	1741	55	50	5	0	0	0	0	55	10	1916
2	RO-Mud-2	2594	33	20	13	0	0	7	0	20	13	2701
3	RO-Mud-3	2051	25	15	0	0	0	0	0	25	20	2136
4	RO-Mud-4	2305	60	55	0	10	0	0	0	30	10	2470
	Ave Mud	**2173**	**43**	**35**	**5**	**3**	**0**	**2**	**0**	**33**	**13**	**2306**
	Percentage	**94.2**	**1.9**	**1.5**	**0.2**	**0.1**	**0**	**0.1**	**0**	**1.4**	**0.6**	**100**
5	RO-Avi-a1	1413	150	120	0	0	10	20	40	20	0	1773
6	RO-Avi-a2	559	20	40	0	0	0	0	7	13	0	639
7	RO-Avi-a3	1077	10	60	0	0	0	0	10	10	0	1167
8	RO-Avi-b1	2360	100	350	0	0	0	10	0	10	10	2840
9	RO-Avi-b2	1504	90	190	10	10	0	10	0	10	20	1844
10	RO-Avi-b3	2253	170	350	0	0	20	0	0	20	20	2833
11	RO-Avi-c	490	10	50	0	10	0	0	0	20	0	580
	Ave Avi	**1379**	**79**	**166**	**1**	**3**	**4**	**6**	**8**	**15**	**7**	**1668**
	Percentage	**82.7**	**4.7**	**9.9**	**0.1**	**0.2**	**0.3**	**0.3**	**0.5**	**0.9**	**0.4**	**100**
12	RO-Mix-a1	2978	147	27	7	7	7	7	0	40	0	3218
13	RO-Mix-a2	2045	110	70	0	0	10	10	0	70	0	2315
14	RO-Mix-a3	1768	80	40	0	20	0	0	0	30	0	1938
15	RO-Mix-b1	3946	175	235	0	5	10	10	15	100	5	4501
16	RO-Mix-b2	2060	60	120	0	0	10	0	0	140	0	2390
17	RO-Mix-b3	2813	40	20	0	0	0	0	0	140	20	3033
18	RO-Mix-c	762	33	53	0	0	0	0	0	120	7	975
	Ave Mix	**2339**	**92**	**81**	**1**	**5**	**5**	**4**	**2**	**91**	**5**	**2624**
	Percentage	**89.1**	**3.5**	**3.1**	**0**	**0.2**	**0.2**	**0.1**	**0.1**	**3.5**	**0.2**	**100**
19	RO-Rhi-a1	3071	53	40	0	7	0	0	7	147	7	3331
20	RO-Rhi-a2	1712	120	100	0	0	0	0	13	540	13	2498
21	RO-Rhi-a3	1330	55	30	0	5	0	0	5	460	10	1895
22	RO-Rhi-b1	2721	70	50	0	0	0	10	5	80	10	2946
23	RO-Rhi-b2	583	25	10	0	0	0	0	5	215	5	843
24	RO-Rhi-b3	1150	13	7	0	0	0	0	0	187	27	1384
25	RO-Rhi-c	1679	27	27	0	0	0	0	0	33	13	1779
	Ave Rhi	**1749**	**52**	**38**	**0**	**2**	**0**	**1**	**5**	**237**	**12**	**2096**
	Percentage	**83.4**	**2.5**	**1.8**	**0**	**0.1**	**0**	**0.1**	**0.2**	**11.3**	**0.6**	**100**
Average		**1878**	**69**	**85**	**1**	**3**	**3**	**3**	**4**	**101**	**8**	**2158**
Percentage		**87.1**	**3.2**	**3.9**	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**4.7**	**0.4**	**100**

Ne: Nematodes Co: Copepods Na: Nauplii Po: Polychaetes Ol: Oligochaetes
Ki: Kinorhynchs Ac: Acari Os: Ostracods Fo: Foraminifera Ot: Others

Table A5. Meiobenthic composition in Rach Oc creek in the dry season 2005

Order	Station	Meiobenthic composition										
		Ne	Co	Na	Po	Ol	Ki	Ac	Os	Fo	Ot	Sum
1	RO-Mud-1	3455	68	27	7	13	0	2	2	7	28	3608
2	RO-Mud-2	1823	35	20	8	5	0	2	10	10	55	1968
3	RO-Mud-3	2717	140	30	13	5	2	0	0	7	71	2985
4	RO-Mud-4	4908	113	27	3	5	3	0	7	0	50	5117
	Ave Mud	**3226**	**89**	**26**	**8**	**7**	**1**	**1**	**5**	**6**	**6**	**3420**
	Percentage	**94.3**	**2.6**	**0.8**	**0.2**	**0.2**	**0**	**0**	**0.1**	**0.2**	**0.2**	**100**
5	RO-Avi-a1	2867	70	27	7	3	7	10	3	18	57	3068
6	RO-Avi-a2	1145	70	22	0	3	3	5	13	22	47	1330
7	RO-Avi-a3	1175	103	35	8	5	13	2	3	15	65	1425
8	RO-Avi-b1	5093	85	57	7	7	10	8	5	20	55	5347
9	RO-Avi-b2	2657	102	53	8	2	12	8	10	13	76	2941
10	RO-Avi-b3	1837	153	38	3	0	15	3	12	25	56	2143
11	RO-Avi-c	412	15	3	2	0	0	5	0	13	39	489
	Ave Avi	**2169**	**85**	**34**	**5**	**3**	**9**	**6**	**7**	**18**	**57**	**2392**
	Percentage	**90.7**	**3.6**	**1.4**	**0.2**	**0.1**	**0.4**	**0.2**	**0.3**	**0.8**	**2.4**	**100**
12	RO-Mix-a1	3682	137	57	3	7	0	23	2	22	50	3982
13	RO-Mix-a2	3313	65	17	5	0	5	2	0	20	74	3500
14	RO-Mix-a3	2958	20	28	2	7	0	0	0	75	61	3151
15	RO-Mix-b1	2950	85	15	2	8	5	2	2	43	56	3168
16	RO-Mix-b2	3188	115	32	7	3	10	7	0	40	63	3465
17	RO-Mix-b3	2992	143	80	7	2	2	2	3	35	55	3320
18	RO-Mix-c	1198	48	28	0	2	0	3	0	7	33	1319
	Ave Mix	**2897**	**88**	**37**	**4**	**4**	**3**	**5**	**1**	**35**	**56**	**3129**
	Percentage	**92.6**	**2.8**	**1.2**	**0.1**	**0.1**	**0.1**	**0.2**	**0**	**1.1**	**1.8**	**100**
19	RO-Rhi-a1	2873	160	75	0	10	2	18	2	78	40	3258
20	RO-Rhi-a2	1110	132	52	0	0	0	10	0	222	33	1558
21	RO-Rhi-a3	1213	117	52	0	2	2	5	0	208	18	1616
22	RO-Rhi-b1	2972	115	28	2	7	0	8	15	40	58	3244
23	RO-Rhi-b2	1653	78	42	2	7	0	10	0	238	53	2083
24	RO-Rhi-b3	1532	113	62	0	7	0	8	2	283	16	2022
25	RO-Rhi-c	3745	57	30	3	10	2	8	0	32	68	3954
	Ave Rhi	**2157**	**110**	**49**	**1**	**6**	**1**	**10**	**3**	**157**	**41**	**2534**
	Percentage	**85.1**	**4.4**	**1.9**	**0**	**0.2**	**0**	**0.4**	**0.1**	**6.2**	**1.6**	**100**
Average		**2539**	**94**	**37**	**4**	**5**	**4**	**6**	**4**	**60**	**51**	**2803**
Percentage		**90.6**	**3.3**	**1.3**	**0.1**	**0.2**	**0.1**	**0.2**	**0.1**	**2.1**	**1.8**	**100**

Ne: Nematodes Co: Copepods Na: Nauplii Po: Polychaetes Ol: Oligochaetes
Ki: Kinorhynchs Ac: Acari Os: Ostracods Fo: Foraminifera Ot: Others

Table A6. Meiobenthic composition in Rach Oc creek in the rainy season 2005

Order	Station	Meiobenthic composition										
		Ne	Co	Na	Po	Ol	Ki	Ac	Os	Fo	Ot	Sum
1	RO-Mud-1	1902	112	81	11	5	0	3	2	6	13	2134
2	RO-Mud-2	1870	137	103	6	5	3	0	0	13	6	2143
3	RO-Mud-3	2064	117	123	4	4	0	7	2	6	9	2336
4	RO-Mud-4	2744	123	176	7	4	3	1	3	4	24	3090
	Ave Mud	**2145**	**122**	**121**	**7**	**5**	**2**	**3**	**2**	**7**	**13**	**2426**
	Percentage	**88.4**	**5.0**	**5.0**	**0.3**	**0.2**	**0.1**	**0.1**	**0.1**	**0.3**	**1.0**	**100**
5	RO-Avi-a1	942	50	82	1	4	2	1	3	45	11	1141
6	RO-Avi-a2	777	49	74	7	1	0	3	4	40	19	974
7	RO-Avi-a3	955	57	72	7	1	0	2	1	19	16	1130
8	RO-Avi-b1	1741	108	93	5	2	1	3	0	34	20	2006
9	RO-Avi-b2	886	35	14	11	2	3	0	0	10	17	979
10	RO-Avi-b3	961	43	36	3	2	3	1	0	16	20	1085
11	RO-Avi-c	447	17	10	4	7	0	0	0	12	14	511
	Ave Avi	**959**	**51**	**54**	**5**	**3**	**1**	**2**	**1**	**25**	**17**	**1118**
	Percentage	**85.7**	**4.6**	**4.9**	**0.5**	**0.2**	**0.1**	**0.1**	**0.1**	**2.2**	**1.0**	**100**
12	RO-Mix-a1	1760	65	52	5	5	0	6	0	76	25	1993
13	RO-Mix-a2	1877	51	75	5	3	1	0	0	60	14	2086
14	RO-Mix-a3	1890	46	59	5	13	0	3	0	68	11	2096
15	RO-Mix-b1	1966	92	43	6	3	0	10	0	21	39	2180
16	RO-Mix-b2	3109	48	55	10	0	0	3	0	29	28	3283
17	RO-Mix-b3	1467	22	35	4	1	3	0	0	19	10	1561
18	RO-Mix-c	445	15	10	9	3	1	0	0	13	3	501
	Ave Mix	**1788**	**48**	**47**	**6**	**4**	**1**	**3**	**0**	**41**	**19**	**1957**
	Percentage	**91.3**	**2.5**	**2.4**	**0.3**	**0.2**	**0**	**0.2**	**0**	**2.1**	**1.0**	**100**
19	RO-Rhi-a1	1931	369	170	4	11	0	5	0	60	20	2569
20	RO-Rhi-a2	1094	41	31	2	2	0	3	1	108	13	1294
21	RO-Rhi-a3	948	36	36	0	4	0	3	0	232	5	1265
22	RO-Rhi-b1	1995	105	80	2	5	0	2	0	32	9	2230
23	RO-Rhi-b2	626	48	35	0	1	0	3	0	107	8	827
24	RO-Rhi-b3	503	16	25	1	4	0	3	0	45	13	610
25	RO-Rhi-c	624	22	15	15	5	2	0	0	26	12	720
	Ave Rhi	**1103**	**91**	**56**	**3**	**5**	**0**	**3**	**0**	**87**	**11**	**1360**
	Percentage	**81.1**	**6.7**	**4.1**	**0.2**	**0.3**	**0**	**0.2**	**0**	**6.4**	**1.0**	**100**
Average		**1421**	**73**	**63**	**5**	**4**	**1**	**3**	**1**	**44**	**15**	**1630**
Percentage		**87.2**	**4.5**	**3.9**	**0.3**	**0.2**	**0.1**	**0.2**	**0.0**	**2.7**	**0.9**	**100**

Ne: Nematodes Co: Copepods Na: Nauplii Po: Polychaetes Ol: Oligochaetes
Ki: Kinorhynchs Ac: Acari Os: Ostracods Fo: Foraminifera Ot: Others

Table A7. List of nematodes in Rach Oc creek
(Ft: feeding type; L: body length; W: maximum body diameter; Lo: oesophagel length; Lt: tail length; a = L/W; b = L/Lo; c = L/ Lt)

Order/Family		Species	Ft	L	W	Lo	Lt	a	b	c
ORDER ENOPLIDA										
Anoplostomatidae	1	*Anoplostoma* sp1	1B	1010.0	28.9	220.0	140.0	34.9	4.6	7.2
Phanodermatidae	2	*Crenopharynx* sp1	1A	2810.1	44.3	640.1	355.9	63.5	4.4	7.9
	3	*Phanoderma* sp1	2A	1710	47.2	455.1	208.7	36.2	3.8	8.2
Oncholaimidae	4	*Adoncholaimus* sp1	2B	1280	33.0	281.5	53.6	38.7	4.5	23.8
	5	*Viscosia* sp1	2B	680.8	27.1	225.6	157.9	25.1	3.0	4.3
	6	*Viscosia* sp2	2B	3026.8	40.7	510.0	546.8	74.4	5.9	5.5
	7	*Viscosia* sp3	2B	1780.0	37.8	290.0	340.0	47.1	6.1	5.2
	8	*Viscosia* sp4	2B	1145.9	28.2	243.6	87.2	40.6	4.7	13.1
Enchelidiidae	9	*Eurystomina* sp1	2B	2660.0	41.9	411.9	138.1	63.5	6.5	19.3
	10	*Polygastrophora* sp1	2B	1160.0	30.0	320.0		38.7	3.6	
	11	*Polygastrophora* sp2	2B	1210.0	32.4	370.0	110.9	37.3	3.3	10.9
Ironidae	12	*Syringolaimus* sp1	2B	1770.9	30.8	223.1	361.5	57.6	7.9	4.9
	13	*Thalassinorus* sp1	2B		35.9	387.2	584.6			
	14	*Trissonchulus* sp1	1B	1860	43.0	360.2	50.7	43.2	5.2	36.7
Oxystominidae	15	*Halalaimus* sp1	1A	727.0	15.2	219.2	110.7	47.8	3.3	6.6
	16	*Halalaimus* sp2	1A	599.4	13.0	170.2	111.0	46.1	3.5	5.4
	17	*Halalaimus* sp3	1A	2140.0	30.0	710.0	180.0	71.3	3.0	11.9
	18	*Halalaimus* sp4	1A	999.0	14.8	236.8	173.9	67.5	4.2	5.7
	19	*Halalaimus* sp5	1A	991.6	18.5	170.2	210.9	53.6	5.8	4.7
	20	*Halalaimus* sp6	1A	1180.0	12.4	411.9	132.2	95.2	2.9	8.9
	21	*Halalaimus* sp7	1A	1210.0	24.8	255.2	217.1	48.8	4.7	5.6
	22	*Halalaimus* sp8	1A	2020.0	20.6	350.0	119.8	98.1	5.8	16.9
	23	*Halalaimus* sp9	1A	1290.0	18.9	260.0	180.0	68.3	5.0	7.2
	24	*Halalaimus* sp10	1A	1900.0	24.2	262.3	184.7	78.5	7.2	10.3
	25	*Halalaimus* sp11	1A	468.7	8.8	145.4	82.5	53.3	3.2	5.7
	26	*Halalaimus* sp12	1A	1810.0	25.4	380.0	250.0	71.3	4.8	7.2
	27	*Halalaimus* sp13	1A	895.4	14.2	155.4	192.4	63.1	5.8	4.7
	28	*Oxystomina* sp1	1A	2500.0	36.0	610.0	240.0	69.4	4.1	10.4
	29	*Oxystomina* sp2	1A	1240.0	20.1	269.3	66.7	61.8	4.6	18.6
	30	*Oxystomina* sp3	1A	1720.0	20.1	410.0	95.0	85.6	4.2	18.1
	31	*Oxystomina* sp4	1A	700.9	10.8	186.6	60.8	64.9	3.8	11.5
	32	*Oxystomina* sp5	1A	747.4	15.3	167.8	93.8	48.7	4.5	8.0
	33	*Oxystomina* sp6	1A	1140.0	19.5	260.0	59.6	58.5	4.4	19.1
	34	*Oxystomina* sp7	1A	1646.5	15.3	414.4	114.7	107.6	4.0	14.4
	35	*Oxystomina* sp8	1A	1440.0	28.9	304.6	79.1	49.8	4.7	18.2
	36	*Thalassoalaimus* sp1	1A	880.6	24.0	159.1	48.1	36.7	5.5	18.3
	37	*Thalassoalaimus* sp2	1A	4010.0	90.0	350.0	20.6	44.6	11.5	194.7
	38	*Thalassoalaimus* sp3	1A	1210.0	19.5	290.0	34.2	62.1	4.2	35.4
	39	*Thalassoalaimus* sp4	1A	2190.0	20.6	400.0	79.1	106.3	5.5	27.7
	40	*Thalassoalaimus* sp5	1A	2343.8	43.6	284.6	102.6	53.8	8.2	22.9
	41	*Wieseria* sp1	1A	1347.3	30.8	312.8	43.6	43.8	4.3	30.9
ORDER TRIPLONCHIDA										
Triodontolaimidae	42	*Triodontolaimus* sp1	2B	2110.0	43.7	320.0	310.0	48.3	6.6	6.8
ORDER DORYLAIMIDA										
Dorylaimidae	43	*Mesodorylaimus* sp1		873.2	22.4	178.0	17.1	38.9	4.9	51.0
	44	*Protodorylaimus* sp1		1920.0	49.6	300.2	21.2	38.7	6.4	90.4
Belondiridae	45	*Amphybelondira* sp1		1120.0	40.1	160.7	9.4	27.9	7.0	118.6

Qudsianematidae	46	*Eudorylaimus* sp1		366.4	15.3	106.2	86.1	23.9	3.5	4.3
ORDER DESMOSCOLECIDA										
Desmoscolecidae	47	*Calligyrus* sp1	1A	203.6	31.2	35.4	55.4	6.5	5.8	3.7
	48	*Desmoscolex* sp1	1A	218.6	35.3			6.2		
	49	*Desmoscolex* sp2	1A	181.9	31.0			5.9		
	50	*Desmoscolex* sp3	1A	286.2	40.9			7.0		
	51	*Desmoscolex* sp4	1A	202.6	38.5			5.3		
	52	*Greefiella* sp1	1A	248.2	35.9			6.9		
	53	*Pareudesmoscolex* sp1	1A	321.5	45.1		67.7	7.1		4.7
	54	*Quadricoma* sp1	1A	376.5	60.6			6.2		
	55	*Quadricoma* sp2	1A	269.3	38.1			7.1		
	56	*Tricoma* sp1	1A	211.5	29.6			7.1		
	57	*Tricoma* sp2	1A	506.9	47.9			10.6		
	58	*Tricoma* sp3	1A	272.1	43.7			6.2		
ORDER CHOMADORIDA										
Chromadoridae	59	*Actinonema* sp1	2A	857.2	26.0	145.4	212.7	33.0	5.9	4.0
	60	*Actinonema* sp2	2A	622.8	30.4	99.8	115.0	20.5	6.2	5.4
	61	*Dichromadora* sp1	2A	603.3	30.4	99.8	99.8	19.8	6.0	6.0
	62	*Dichromadora* sp2	2A	554.1	17.1	69.1	84.6	32.4	8.0	6.5
	63	*Dichromadora* sp3	2A	306.6	8.8	57.8	70.5	34.8	5.3	4.3
	64	*Ptycholaimellus* sp1	2A	825.1	33.3	140.6	129.5	24.8	5.9	6.4
	65	*Spilophorella* sp1	2A	531.6	28.2	121.5	80.3	18.9	4.4	6.6
	66	*Spilophorella* sp2	2A	913.6	56.4	186.6	138.9	16.2	4.9	6.6
	67	*Spilophorella* sp3	2A	411.7	21.2	100.9	55.5	19.4	4.1	7.4
Ethmolaimidae	68	*Comesa* sp1	2A	720.4	43.7	136.3	64.3	16.5	5.3	11.2
	69	*Comesa* sp2	2A	783.4	24.2	101.5	72.0	32.4	7.7	10.9
Neotonchidae	70	*Neotonchus* sp1	2A	887.5	26.0	112.8	102.0	34.1	7.9	8.7
Cyatholaimidae	71	*Longicyatholaimus* sp1	2A	1520.0	27.7	160.0	32.0	54.9	9.5	47.5
	72	*Longicyatholaimus* sp2	2A	2161.3	36.9	271.2	629.3	58.6	8.0	3.4
	73	*Longicyatholaimus* sp3	2A	2026.3	19.8		859.8	102.3		2.4
	74	*Longicyatholaimus* sp4	2A	1257.0	23.2	113.1	89.2	54.2	11.1	14.1
	75	*Paracanthonchus* sp2	2A	1470.0	67.3	250.0	123.3	21.9	5.9	11.9
	76	*Paracyatholaimus* sp1	2A	1006.4	35.4	199.8	151.7	28.4	5.0	6.6
	77	*Pomponema* sp1	2B	1953.6	22.2	148.0	543.9	88.0	13.2	3.6
	78	*Pomponema* sp2	2B	1552.6	48.7	187.2	189.7	31.9	8.3	8.2
Selachinematidae	79	*Halichoanolaimus* sp1	2B	3220.0	114.5	265.1	791.8	28.1	12.1	4.1
	80	*Halichoanolaimus* sp2	2B	858.4	42.5	170.2	95.6	20.2	5.0	9.0
	81	*Halichoanolaimus* sp3	2B	1560.0	60.2	200.0	205.9	25.9	7.8	7.6
ORDER DESMODORIDA										
Desmodoridae	82	*Desmodora* sp6	2A	863.2	20.7	66.1	118.6	41.8	13.1	7.3
	84	*Metachromadora* sp1	2B	713.9	43.4	160.6	56.4	16.4	4.4	12.7
	85	*Mongolaimus* sp1	1A	387.1	13.6	72.0	89.1	28.5	5.4	4.3
	86	*Mongolaimus* sp2	1A	906.5	26.6	107.3	199.8	34.1	8.4	4.5
	87	*Mongolaimus* sp3	1A	555.5	20.6	102.0	78.1	27.0	5.4	7.1
	88	*Mongolaimus* sp4	1A	589.7	28.2	107.7	143.6	20.9	5.5	4.1
	89	*Onyx* sp1	2B	691.9	43.7	155.1	26.8	15.8	4.5	25.8
	90	*Paradesmodora* sp1	2A	925.0	25.9	99.9	203.5	35.7	9.3	4.5
	91	*Pseudochromadora* sp1	2A	700.9	28.2	102.0	43.4	24.9	6.9	16.1
	92	*Pseudochromadora cazca*	2A	552.7	36.7	101.5	69.1	15.1	5.4	8.0
	93	*Pseudochromadora* sp3	2A	569.2	38.5	94.9	59.0	14.8	6.0	9.7
	94	*Pseudochromadora* sp4	2A	820.3	36.9	91.1	117.2	22.2	9.0	7.0
	83	*Pseudochromadora* sp5	2A	2080.0	107.6	200.8	120.1	19.3	10.4	17.3
	95	*Spirinia* sp1	1B	661.8	43.4	136.7	47.7	15.2	4.8	13.9
	96	*Spirinia* sp2	1B	1173.6	69.2	166.7	82.0	17.0	7.0	14.3

	97	*Zalonema* sp1	2A	1690.0	55.0		76.7	30.7		22.0
	98	*Zalonema* sp2	2A	186.5	21.9	52.1	19.8	8.5	3.6	9.4
Epsilonematidae	99	*Epsilonema* sp1	1A	405.1	25.6	76.9	53.8	15.8	5.3	7.5
Microlaimidae	100	*Microlaimus* sp1	2A	517.5	22.6	102.9	88.8	22.9	5.0	5.8
	101	*Microlaimus* sp2	2A	335.6	15.5	73.3	39.5	21.7	4.6	8.5
	102	*Microlaimus* sp3	2A	902.7	16.5	89.0		54.7	10.1	
	103	*Microlaimus* sp4	2A	525.1	20.1	89.7	72.6	26.1	5.9	7.2
	104	*Microlaimus* sp5	2A	451.4	17.7	89.0	73.8	25.5	5.1	6.1
ORDER MONHYSTERIDA										
Monhysteridae	105	*Diplolaimella* sp1	1B	2420.0	14.8	370.0	590.0	163.5	6.5	4.1
	106	*Diplolaimella* sp2	1B	1170.0	25.4	130.0	210.0	46.1	9.0	5.6
	107	*Diplolaimeloides* sp1	1B	899.1	18.3	121.5	88.5	49.2	7.4	10.2
Xyalidae	108	*Amphymonhystrella* sp1	1B	460.0	10.6	95.0	64.3	43.4	4.8	7.2
	109	*Cobbia* sp1	2A	928.7	11.1	112.7	200.6	83.7	8.2	4.6
	110	*Daptonema* sp1	1B	754.8	24.2	163.6	142.2	31.2	4.6	5.3
	114	*Daptonema* sp2	1B	625.0	21.7	106.2	106.3	28.8	5.9	5.9
	115	*Daptonema* sp4	1B	137.4	14.1	60.8	135.7	9.7	2.3	1.0
	116	*Daptonema* sp5	1B	1380.0	70.0	200.0	215.7	19.7	6.9	6.4
	117	*Daptonema* sp7	1B	614.2	17.7	118.4	107.3	34.7	5.2	5.7
	118	*Daptonema* sp9	1B	512.1	21.7	110.7	99.8	23.6	4.6	5.1
	111	*Daptonema* sp10	1B	769.6	14.8	92.5	151.7	52.0	8.3	5.1
	112	*Daptonema* sp12	1B	580.9	22.2	66.6	151.7	26.2	8.7	3.8
	113	*Daptonema* sp15	1B	748.6	26.0	143.2	119.4	28.8	5.2	6.3
	119	*Elzalia* sp1	1B			73.2	146.5			
	120	*Gnomoxyala* sp1	1B	1210.0	50.2	234.1	179.1	24.1	5.2	6.8
	121	*Lynhystera* sp1	1B	910.2	12.4	100.9	118.0	73.5	9.0	7.7
	122	*Lynhystera* sp2	1B	573.5	12.4	85.0	80.2	46.3	6.8	7.2
	123	*Metadesmolaimus* sp1	1B	984.2	74.0	192.4	155.4	13.3	5.1	6.3
	124	*Paramonohystera* sp1	1B	638.4	25.6	107.3	212.7	24.9	6.0	3.0
	125	*Theristus* sp1	1B	728.6	35.4	184.7	99.1	20.6	3.9	7.4
	126	*Theristus* sp2	1B	858.4	11.1		333.0	77.3		2.6
	127	*Theristus* sp3	1B	1195.1	13.0	243.9	279.2	92.1	4.9	4.3
	128	*Theristus* sp4	1B	507.8	10.9	80.3	164.9	46.6	6.3	3.1
	129	*Theristus* sp5	1B	762.2	13.0	118.4	103.6	58.6	6.4	7.4
	130	*Theristus* sp6	1B	616.3	21.2	138.9	132.4	29.1	4.4	4.7
	131	*Theristus* sp7	1B	778.9	30.8	166.7	61.5	25.3	4.7	12.7
Sphaerolaimidae	132	*Metasphaerolaimus* sp1	2B	1240.0	60.0	170.0	150.0	20.7	7.3	8.3
	133	*Parasphaerolaimus* sp1	2B	1330.0	78.5	350.0	145.1	16.9	3.8	9.2
	134	*Sphaerolaimus* sp1	2B	1220.0	70.0	330.0	190.0	17.4	3.7	6.4
	135	*Sphaerolaimus* sp2	2B	1310.0	70.0	290.0	170.0	18.7	4.5	7.7
	136	*Sphaerolaimus* sp3	2B	1040.0	44.8	310.0	120.0	23.2	3.4	8.7
	137	*Subsphaerolaimus* sp1	2B	847.3	25.4	170.2	111.0	33.4	5.0	7.6
	138	*Subsphaerolaimus* sp2	2B	523.0	17.1	125.9	65.1	30.6	4.2	8.0
Siphonolaimidae	139	*Astomonema* sp2	1A	5190.0	28.2			184.0		
Linhomoeidae	140	*Anticyathus* sp1	1B	635.9	30.8	143.6	61.5	20.7	4.4	10.3
	141	*Desmolaimus* sp1	1B	351.5	12.7	80.8	60.8	27.7	4.4	5.8
	142	*Eleutherolaimus* sp1	1B	1960.0	20.1	170.6	232.7	97.7	11.5	8.4
	143	*Eleutherolaimus* sp2	1B	1320.0	17.1	95.6	15.9	77.1	13.8	82.9
	144	*Eleutherolaimus* sp4	1B	1278.9		105.2	95.9		12.2	13.3
	145	*Linhomoeus* sp1	2A	1121.0	41.0	153.8	125.6	27.3	7.3	8.9
	146	*Linhomoeus* sp2	2A	2510.0	23.6	138.6	296.2	106.4	18.1	8.5
	147	*Metalinhomoeus* sp1	1B	1780.0	24.0	106.8	263.7	74.2	16.7	6.8
	148	*Metalinhomoeus* sp2	1B	3150.0	77.3	220.0	265.1	40.8	14.3	11.9
	149	*Metalinhomoeus* sp3	1B	1630.0	19.5	93.2	146.3	83.6	17.5	11.1

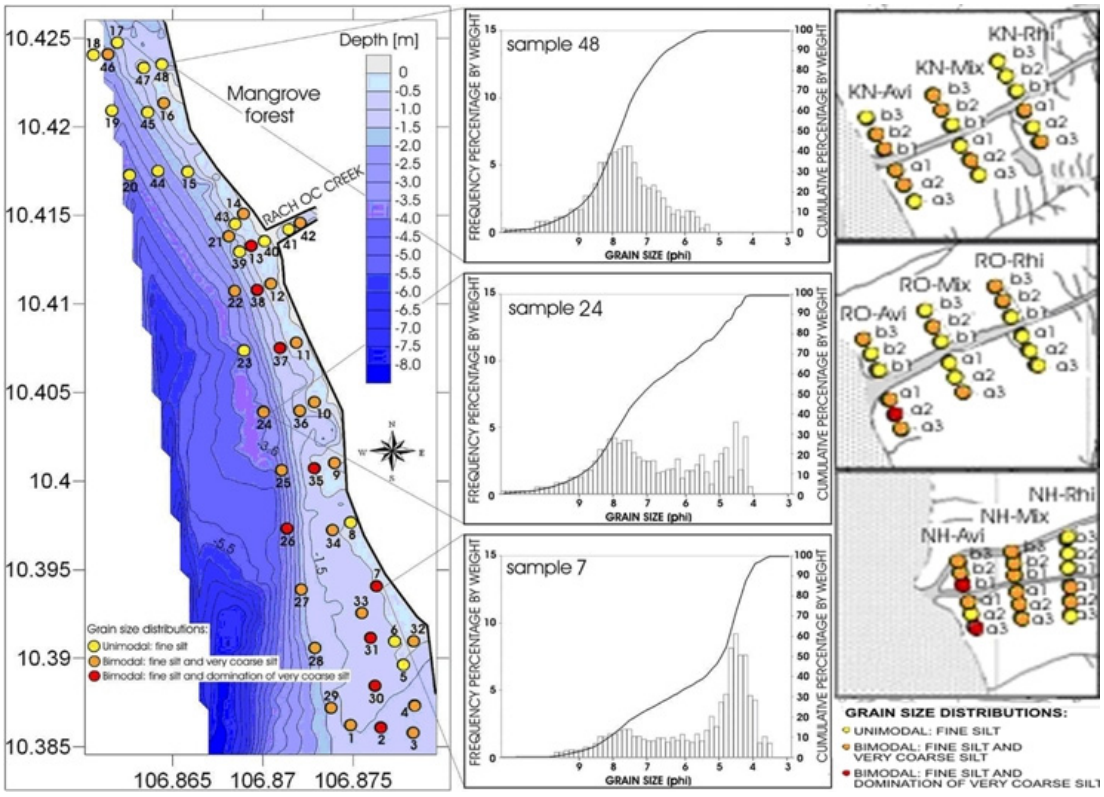
	150 *Paralinhomoeus* sp1	1B	2760.0	47.8	166.4		57.8	16.6	
	151 *Paralinhomoeus* sp3	1B	1639.1	31.9	148.0	336.7	51.4	11.1	4.9
	152 *Terschellingia* sp1	1A	846.3	17.7	69.4	225.7	47.8	12.2	3.7
	156 *Terschellingia* sp2	1A	1390.0	29.5	130.0	230.0	47.1	10.7	6.0
	157 *Terschellingia* sp3	1A	976.8	22.4	100.3	284.8	43.6	9.7	3.4
	158 *Terschellingia* sp4	1A	799.2	14.2	88.5	137.5	56.3	9.0	5.8
	159 *Terschellingia* sp7	1A	806.6	17.1	103.6	151.7	47.2	7.8	5.3
	160 *Terschellingia* sp8	1A	1058.2	15.9	103.6	358.9	66.6	10.2	2.9
	161 *Terschellingia* sp9	1A	991.6	27.1	118.4	111.0	36.6	8.4	8.9
	153 *Terschellingia* sp10	1A	1861.6	24.2	160.0	621.6	76.9	11.6	3.0
	154 *Terschellingia* sp11	1A	1940.0	40.1	132.5	414.0	48.4	14.6	4.7
	155 *Terschellingia* sp12	1A	1607.5	34.1	105.1	212.4	47.2	15.3	7.6
ORDER ARAEOLAIMIDA									
Axonolaimidae	162 *Parodontophora* sp1	1B	987.9	44.4	159.1	123.9	22.3	6.2	8.0
	163 *Pseudolella* sp1	2A	876.7	28.2	113.3	97.6	31.1	7.7	9.0
Comesomatidae	164 *Hopperia* sp1	2B	1750.0	31.9	190.0	164.0	54.9	9.2	10.7
	165 *Hopperia* sp2	2B	454.0	17.7	91.6	56.4	25.6	5.0	8.0
	166 *Laimella* sp1	2A	1380.1	23.6	103.6	381.1	58.5	13.3	3.6
	167 *Laimella* sp2	2A	1740.0	27.7	140.0	536.0	62.7	12.4	3.2
	168 *Laimella* sp4	2A	436.2	15.2	91.1	84.6	28.7	4.8	5.2
	169 *Paracomesoma* sp2	2A	1480.0	40.1	210.0	190.0	36.9	7.0	7.8
	170 *Sabatieria* sp1	1B	2670.0	57.8	225.6	248.2	46.2	11.8	10.8
	171 *Sabatieria* sp2	1B	1660.0	34.8	190.0	160.0	47.7	8.7	10.4
Diplopeltidae	172 *Campylaimus* sp1	1B	532.8	21.8	93.2	102.1	24.4	5.7	5.2
ORDER PLECTIDA									
Leptolaimidae	173 *Antomicron* sp1	1A	475.2	34.0	111.5	94.4	14.0	4.3	5.0
	174 *Antomicron* sp2	1A	507.8	19.5	103.2	95.6	26.0	4.9	5.3
	175 *Antomicron* sp3	1A	677.1	23.0	111.0	125.8	29.4	6.1	5.4
	176 *Antomicron* sp4	1A	592.0	24.2	99.7	112.1	24.5	5.9	5.3
	177 *Antomicron* sp5	1A	594.6	20.1	112.1	119.8	29.6	5.3	5.0
	178 *Antomicron* sp6	1A	478.2	18.9	103.5	82.8	25.3	4.6	5.8
	179 *Antomicron* sp7	1A	710.4	24.8	102.7	111.5	28.7	6.9	6.4
	180 *Antomicron* sp8	1A	462.0	17.1	100.3	76.1	27.0	4.6	6.1
	181 *Antomicron* sp9	1A	626.2	16.0	79.0	81.2	39.3	7.9	7.7
	182 *Antomicron* sp10	1A	633.3	17.7		138.6	35.8		4.6
	183 *Camacolaimus* sp1	2A	557.7	17.7	129.2	55.5	31.5	4.3	10.0
	184 *Deontolaimus* sp1	2A	729.1	14.5	128.3	100.1	50.3	5.7	7.3
	185 *Deontolaimus* sp2	2A	606.7	20.0	144.3	62.5	30.3	4.2	9.7
	186 *Leptolaimoides* sp1	1A	605.4	10.9	85.6	97.2	55.7	7.1	6.2
	187 *Leptolaimoides* sp2	1A	213.2	9.1	52.2	47.1	23.5	4.1	4.5
	188 *Leptolaimoides* sp3	1A	458.1	11.2	79.8	79.0	40.8	5.7	5.8
	189 *Leptolaimoides* sp4	1A	416.0	10.2	72.5	70.3	41.0	5.7	5.9
	190 *Leptolaimoides* sp5	1A	528.7	11	105	98	37.0	3.9	4.1
	191 *Leptolaimus* sp1	1A	380.7	21.2	83.8	47.2	18.0	4.5	8.1
	192 *Leptolaimus* sp2	1A	483.9	21.2	108.6	81.4	22.8	4.5	5.9
	193 *Leptolaimus* sp3	1A	349.4	13.0	75.5	59.0	26.9	4.6	5.9
	194 *Leptolaimus* sp4	1A	538.2	20.6	113.3	116.0	26.1	4.8	4.6
	195 *Leptolaimus* sp5	1A	386.7	15.9	61.6	77.6	24.3	6.3	5.0
	196 *Leptolaimus* sp6	1A	179.1	9.4	89.2	31.2	19.0	2.0	5.7
	197 *Leptolaimus* sp7	1A	341.0	16.7	76.1	62.5	20.5	4.5	5.5
	198 *Leptolaimus* sp8	1A	525.4	20.3	89.2	57.3	25.9	5.9	9.2
	199 *Onchium* sp1	2A	765.9	17.1	129.7	61.3	44.8	5.9	12.5
Aegialoalaimidae	200 *Aegialoalaimus* sp2	1A	588.3	22.2	103.6	54.9	26.5	5.7	10.7
	201 *Cyartonema* sp1	1A	632.7	22.2	94.4	93.8	28.5	6.7	6.7

Ceramonematidae	202 *Pselionema* sp1	1A	163.9	14.5			11.3		
Haliplectidae	203 *Haliplectus* sp1	1A	1670.0	35.0	106.8	95.6	47.7	15.6	17.5
	204 *Haliplectus* sp2	1A	286.2	18.3	66.3	31.6	15.6	4.3	9.1
	205 *Haliplectus* sp3	1A	487.2	20.5	84.6	48.7	23.8	5.8	10.0
	206 *Haliplectus* sp5	1A	714.1	43.1	88.8	33.6	16.6	8.0	21.3
ORDER RHABDITIDA									
Rhabditidae	207 *Protorhabditis* sp1		773.3	20.1			38.5		
Cephalobidae	208 *Acrobeloides* sp1		504.7	23.2	122.5	27.6	21.8	4.1	18.3
	209 *Eucephalobus* sp1		770.0	17.1	159.3	73.8	45.0	4.8	10.4
Criconematidae	210 *Criconemella* sp1	PN	349.8	27.7	84.9	28.3	12.6	4.1	12.4
	211 *Hemicriconemoides* sp1	PN	332.4	19.8			16.8		
Tylenchidae	212 *Filenchus* sp1	PN	339.5	8.3	80.2	86.1	41.1	4.2	3.9
Anguinidae	213 *Ditylenchus* sp1	PN	320.9	18.3	86.7		17.5	3.7	
	214 *Ditylenchus* sp2	PN	492.3	23.1		82.0	21.3		6.0

Table A8. Some characteristics of forest structure in the Can Gio mangrove

Characteristic	*Avicennia*	Mixed Avi/Rhi	*Rhizophora*
Number of sample square	16	8	5
Plant cover (%)	59.1 ± 19.3	61.4 ± 12.4	47.2 ± 7.0
Density of stands (No/100 m^2)	87 ± 31	110 ± 57	84 ± 53
Heigh of stands (m)	11.0 ± 4.8	9.4 ± 4.1	15.3 ± 4.9

Source: Tran Triet *et al.* 2007



(A) (B)

Figure A1. Grain size distribution of sediment samples from (A) Dong Tranh River and (B) mangrove forest adjacent to three tidal creeks

Source: La Thi Cang *et al.* 2007

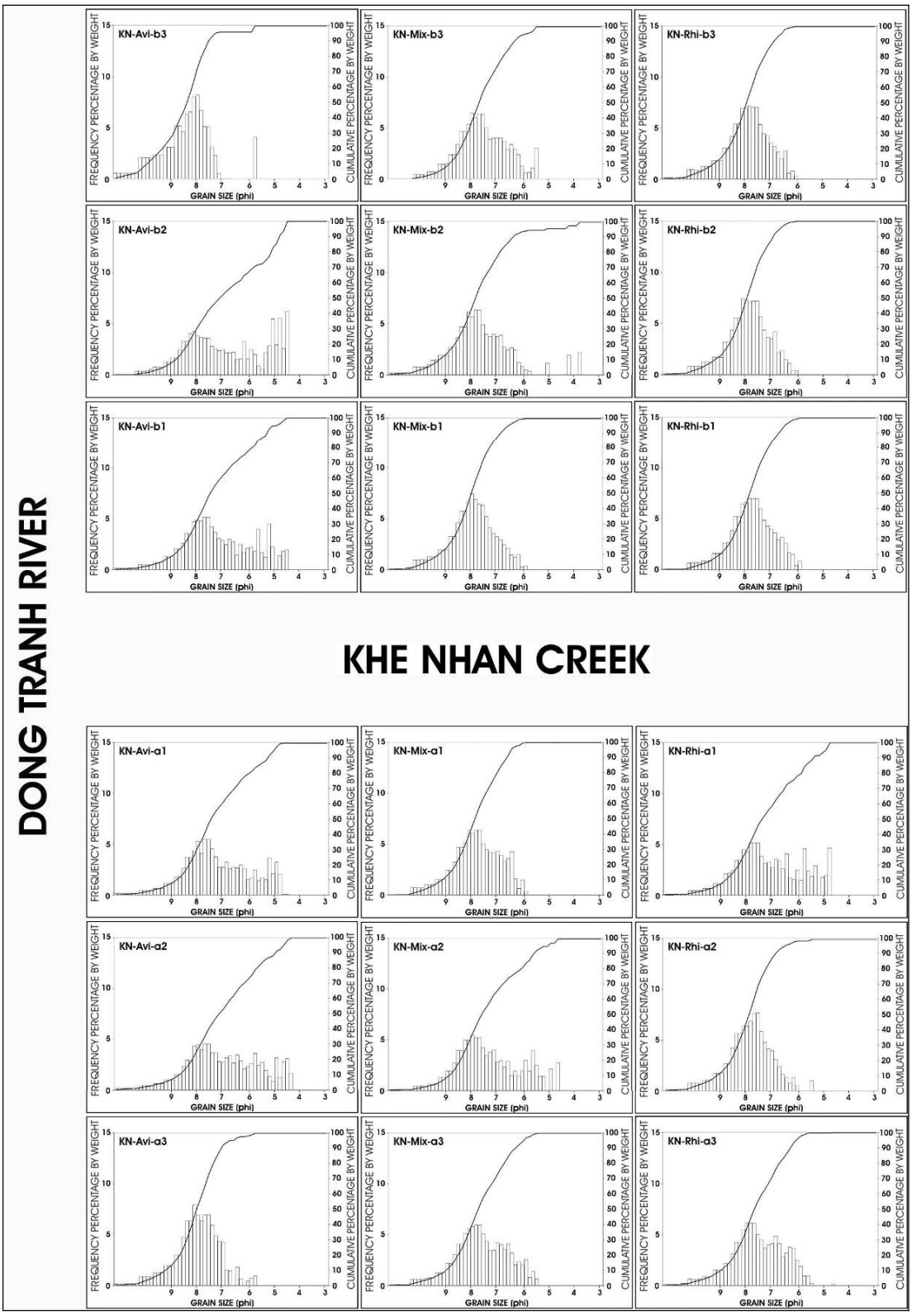


Figure A2. Grain size distribution for the mangrove forest adjacent to the Khe Nhan Creek

Source: La Thi Cang *et al.* 2007

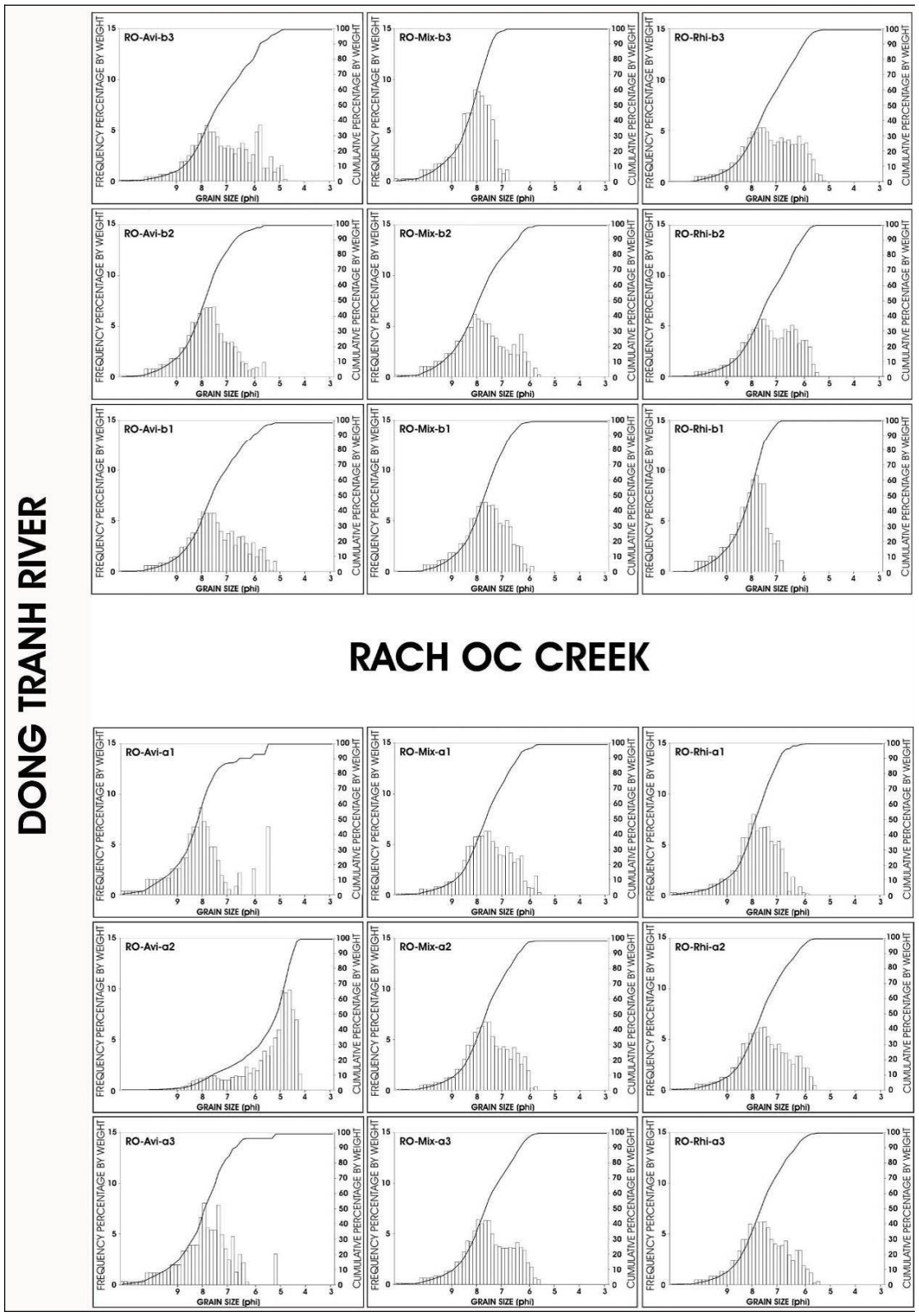


Figure A3. Grain size distribution for the mangrove forest adjacent to the Rach Oc Creek

Source: La Thi Cang *et al.* 2007

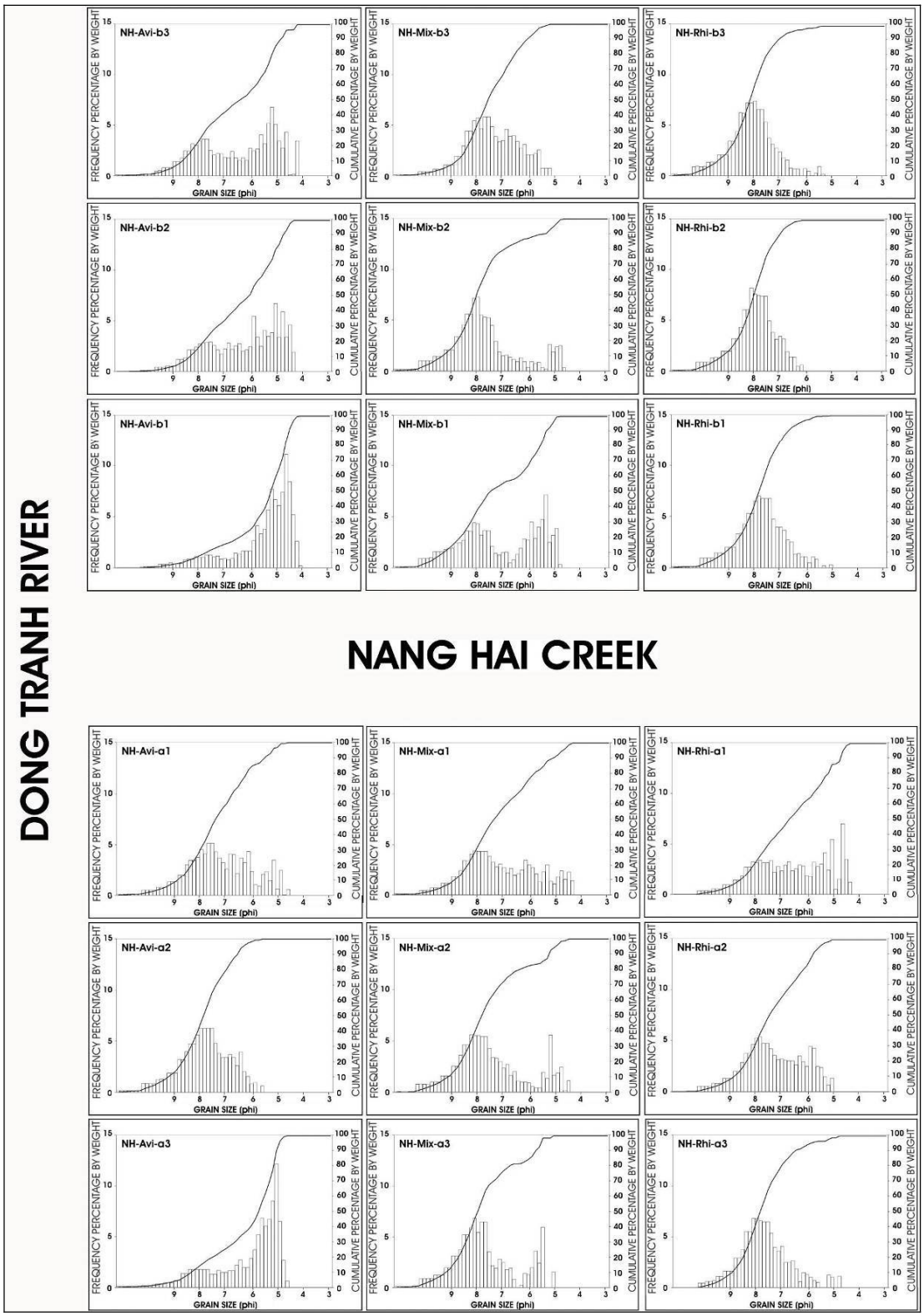


Figure A4. Grain size distribution for the mangrove forest adjacent to the Nang Hai Creek

Source: La Thi Cang *et al.* 2007