www.trjfas.org
ISSN 1303-2712
Turkish Journal of Fisheries and Aquatic Sciences 18: 277-287 (2018) DOI: 10.4194/1303-2712-v18_2_07

RESEARCH PAPER

Trophic Ecology of Eight Sympatric Nemipterid Fishes (Nemipteridae) in the Lower Part of the South China Sea

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Received 17 October 2016
Accepted 23 June 2017

Abstract

Trophic ecology of eight species of nemipterid fish including *Nemipterus mesoprion, N. hexodon, N. nemurus, N. nematophorus, N. tambuloides, N. peronii, N. furcosus* and *Scolopsis taeniopterus* were studied to investigate their diet composition and trophic relationships between them. Our findings revealed that they were specific predators feeding mainly on shrimp and fish. *N. nemurus* and *N. tambuloides* were the most piscivorous species of them all, and *N. mesoprion* was a specific shrimp predator. In general, there were highly significant differences of stomach fullness (FL) and average number of food item (AF) among species (P<0.01). Size classes significantly affected FL of five species including *N. nematophorus, N. mesoprion, N. nemurus, N. tamboloides* and *S. taeniopterus* (P<0.05) and AF of four species including *N. nemurus, S. taeniopterus, N. hexodon* and *N. Peronii* (P<0.05). Sex was an influential factor on FL of *N. mesoprion* (P<0.01) and *N. preonii* (P<0.05) and AF of *N. hexodon* (P<0.05) and *N. peronii* (P<0.05). Maturity stages significantly affected FL of *N. mesoprion* (P<0.01) and *S. taeniopterus* (P<0.05) , however, they had no impact on AF of any species (P>0.05). The co-existence of these species in the bottom waters of this habitat requires partitioning of available food resources.

Keywords: Feeding ecology, thread fin bream, demersal fish, Gulf of Thailand, fish biology.

Introduction

Trophic ecology knowledge is crucial to understand functional role of fish species in a particular ecosystem (Blaber, 1997; Wotton, 1998; Cruz-Escalona, Abitia-Cardenes, Campos-Davila, & Galvan-Magana, 2000; Linke, Platell, & Potter, 2001; Almeida, 2003; Hajisamae, Yeesin, & Ibrahim, 2006; Hajisamae, 2009). It is one of the most appropriate factors that provides help to define the success of a species in the habitat (Almeida, 2003) and understand food web dynamics (Trueman, Johnston, O'Hea, & MacKenzie, 2014; Espinoza, Samantha, Tayler, Aaron, & Ingo, 2015). Community structure of co-existing species can be described by the position of these species along different resource dimensions of space and time (Pianka, 1969; Ross, 1986; Bohorquez-Herrera, Cruz-Escalona, Adams, & Peterson, 2015). Understanding the factors affecting species co-existence is very important in ecological studies (Baeta & Ramon, 2013). In marine community, body sizes of both fish and its prey have been related directly to foraging success (Persson, 1990; Juanes, 1994; Hughes, 1997; Scharf et al., 2000; Karpouzi & Stergious, 2003). Diets of most fishes change with growth, but the timing of changes varies from species to species and is often associated with changes in lifestyle, habitats (Blaber, 2000) and morphological characteristics (Labropoulou & Papadopoulou-Smith, 1999). The ultimate objective of dietary change is to maximize energy intake, enhance growth rate and minimize the risk of predation in competing for food with bigger predators (Brown, 1985). Many studies reported relationship between prey size and fish morphology or fish behavior including mouth dimension, visual acuity, digestive capacity and swimming performance (Keast & Webb, 1966; Galis, 1990; Kaiser & Hughes, 1993; Juanes, 1994; Juanes & Conover, 1994; Hart, 1997). Intra-specific and inter-specific food partitioning is a strategy for a survival of the species within the ecosystem and has been recognized as an important factor structuring fish community in a particular habitat (Carrete, 2010). Diet composition of a particular species has an important application to the sympatric and co-existing species. Nemipteridae or threadfin breams are important fish resources for both artisanal and commercial fisheries (Russell, 1990). They are extensively found in tropical indo-pacific regions (Russell, 1993), and have become important target species in many countries including India (Joshi, 2005), Japan, Taiwan (Russell, 1993), Indonesia, China (Ping, Rensie, & Jing, 2011) and others (ElHaweet, 2013). In Thailand, various species of threadfin fin breams contribute greatly to the trawl fisheries with the possible consequence of a depletion of resources (Stobutzki et al., 2006). Careful management is therefore highly required. However, feeding ecology and interspecific relationships among nemipterid species is poorly understood. This study therefore aims to investigate diet composition and trophic relationships of eight nemipterid species residing in the southern part of the South China Sea including *Nemipterus mesoprion* (Bleeker, 1853), *Nemipterus hexodon* (Quoy & Gaimard, 1824), *Nemipterus nemurus* (Bleeker, 1857), *Nemipterus nematophorus* (Bleeker, 1854), *Nemipterus tambuloides* (Bleeker, 1853), *Nemipterus peronii* (Valenciennes, 1830), *Nemipterus furcosus* (Valenciennes, 1830) and *Scolopsis taeniopterus* (Cuvier, 1830). This information will be useful for the understanding of natural phenomenon and may serve as useful data for future management of these fishery resources.

Materials and Methods

Study Site and Sample Collection

The study area was located between 6° 41' 42" to 9° 18' 10.8"N and 100° 2' 13.2" to 102° 3' 7.2"E in the lower part of the South China Sea (Figure 1). A total of 22 sampling stations were set based on four depth contours (15-25 m, 25-35 m, 35-45 m, 45-55 m). Three replicated bottom trawling cruises were conducted at each station by the MV PRAMONG 9 research vessel during 22-30 April 2015, 26 May-4 June 2015 and 19–29 July 2015. The bottom-trawl net used was made by nylon with the headline of 39 m, mesh size of 40 mm and mesh size at the cod-end of 25 mm. The duration of trawl hauls was 60 minutes. Data such as longitude, latitude, depth of water, trawl duration and towing distance were recorded. From eight target fish species including *N. mesoprion*, *N. hexodon*, *N. nemurus*, *N. nematophorus*, *N. tambuloides*, *N. peronii*, *N. furcosus* and *S. taeniopterus*, a total of 476 specimens, were sorted from the whole catches, identified, counted, weighted, frozen and brought back to laboratory for further analysis. Additional samples containing 430 fishes were collected from bottom gill net fisheries at five main fishing ports nearby trawling areas including Surattani, Nakornsritammarat, Songkhla, Pattani and Narathiwas provinces covering the lower part of the South China Sea.

Laboratory Analysis

Frozen fish samples were thawed, length and weight were measured using a caliper and weight balance to the nearest centimeter and gram, respectively. The fish samples were classified into four different size classes (S1 = ≤7.1 cm, S2 = 7.1-14 cm, S3 = 14.1-21.0 cm, and S4 >21.0 cm). They were gutted open by a surgical ocular scissors. Sexes were identified by gonad observation (Dan, 1977) and maturity stages (immature, maturing, early matured and fully matured stages) were recorded (modified from Raje, 1996 and Dan, 1977). Fish stomachs were removed and immediately preserved with 10% buffer formalin for a week, drenched overnight with freshwater and preserved in 70% ethanol separately (Hajisamae, 2009). Stomach was cut-open in a petri dish by a corneal scissor. An OLYMPUS SZ61 microscope was used to examine and identify food contents. Each dietary item was identified to the

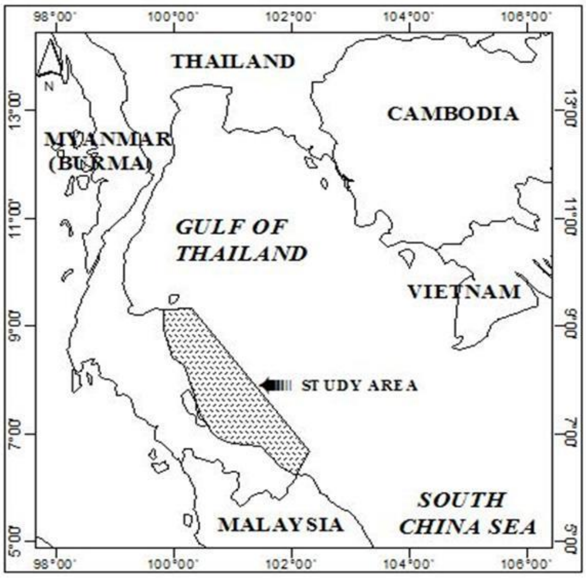

Figure 1. Study area along the lower part of the South China Sea.

lowest taxonomic level as possible. Prior to stomach content analysis, stomach fullness (FL) was visually estimated at a scale of 0-10, where 0 was empty and 10 represented completely full with food (modified from Hajisamae, 2009). Prey item weight was taken by using a microbalance with an accuracy of 0.001 g (Sartorius TE 214S).

Data Analysis

The Percentage of Index of Relative Importance (%IRI) was applied to analyze diet composition, attributes and overlap. %IRI was calculated by the following formula (Cortes 1997):

$$\%IRI = \frac{IRI}{\sum IRI} \times 100$$

The Index of Relative Importance (IRI) is calculated by the following formula (Hyslop, 1980):

$$IRI = (\%N + \%W) \times \%FO$$

Where %N is the percentage composition by number, %W is percentage composition by weight and %FO is percentage frequency of occurrence of each prey.

Vacuity index (VI) was calculated using the following formula:

$$VI = \frac{\text{Total number of empty stomach}}{\text{Total number of stomach examined}} \times 100$$

Average number of food items (AF) was an average number of prey items in each stomach.

Diet breadth (Bi) was calculated using Levin's standardized index (Labropoulou & Papadopoulou-Smith, 1999).

$$Bi = \left(\frac{1}{n-1}\right)\left(\left(\frac{1}{\sum_{i,j=1}^{n} P_{ij}^{2}}\right) - 1\right)$$

Where Bi = Levin's standardized index for predator, "i"; "Pij" = proportion of diet of predator "i" that is made up of prey "j"; "n" = number of prey categories

Diet overlap (C_H) was calculated by Simplified Morisita index or Morisita-Horn index (Horn, 1966)

$$C_H = \frac{2(\sum p_{ij} p_{ik})}{\sum p_{ij}^2 + \sum p_{ik}^2}$$

Where C_H= Morisita-Horn index of overlap between species *'i'* and *'k'*; p_{ij}= proportion food 'i' of the total food quantity by species *'j'*; p_{ik}= proportion food *'i'* of the total food used by species *'k'* and n = total number of food item. The rate of overlap was classified as low overlap = 0.0-0.29, moderately overlap = 0.30-0.59 and high overlap (to be biologically significant) = 0.60-1.00 (Langton, 1982).

Statistical Analysis

One-way analysis of variance (ANOVA) was used to analyze stomach fullness (FL) and average number of food item (AF) for fish of different size classes, stages of maturity and sexes. Log (X+1) transformation of raw data was applied prior to statistical analysis to reduce non-normality. To assess inter-specific trophic relationship, cluster analysis was used. Prior to analysis, the dietary samples were square-rooted transformed. The Bray-Curtis similarity was constructed to form a cluster dendogram by using a PRIMER statistical package 5.0 (Clarke & Gorley 2001). A one-way analysis of similarities (ANOSIM) was performed to test a significant difference of the grouping on the dendogram. A similarity percentage (SIMPER) was applied to assess what dietary items make the greatest contribution to the grouping.

Results

Food and Dominant Food Items

Shrimp, fish, crab, echinoderm and mollusk were common food items for all species examined. Due to a great portion of shrimp and fish in the diet, they were considered the most important food for these fishes (Table 1). However, levels of contribution of each food items in the diet for each species were different. Shrimp largely dominated the diets of *N. mesoprion* (% IRI = 88.9) but fish highly contributed to the diets of *N. nemurus* (% IRI = 89.9%) and *N. tambuloides* (% IRI = 80.8%). Five species including *N. nametaophorus, N. peronii, S. taenipoterus, N. hexodon* and *N. furcosus* ingested almost equal proportion of shrimp and fish with slightly greater value in favour of shrimp. Very small contribution of shrimp was found in the diet of *N. nemurus* (% IRI = 2.8%).

Dietary Attributes

Trophic attributes, including stomach fullness (FL), total number of food item (TLF), average number of food item (AF), vacuity index (VI) and diet breadth (Bi) are shown in Table 2. It was found that FL ranged from 3.34 for *N. nematophorus* to 8.08 for *N. tambuloides*. Analysis of variance (ANOVA) detected a highly significant difference between FL of eight fish species (P<0.01) (Table 3). TLF ranged from 11 items for *N. peronii* to 37 items for *S. taenopterus*. AF was highest in the diet of *N. tambuloides* (4.87) and lowest in *N. nematopterus*

Table 1. Mean abundance (ind/50 m/12 h) of species caught inside the strata (St1–St6) around the gas platform Barbara NW and at the open-sea control site (St7). P = pelagic; NB = nekto-benthic; B = benthic; 1st: 1st year after construction; 2nd: 2nd year after construction; 3rd: 3rd year after construction; No. of hauls inside each stratum = 11

Food items	*S. taeniopterus*				*N. hexodon*				*N. furcosus*				*N. tambuloides*			
	%N	%FO	%W	%IRI	%N	%FO	%W	%IRI	%N	%FO	%W	%IRI	%N	%FO	%W	%IRI
Crab	3.0	10.8	2.7	0.9	17.4	27.0	27.7	8.7	5.7	14.9	7.2	1.6	18.9	38.3	6.8	5.1
Unidentified crab	1.9	7.8	1.2	0.6	2.8	8.1	2.4	1.0	2.8	7.5	1.9	0.6	7.7	13.3	2.2	2.9
Charybdis sp.	-	-	-	-	-	-	-	-	-	-	-	-	2	1.7	1.6	0.1
Charybdis anisodon	-	-	-	-	-	-	-	-	-	-	-	-	1.3	5.1	0.5	0.2
Parapanope sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	5.1	0.8	0.2
Portunus pelagicus	1.1	3.1	1.5	0.2	12.4	10.8	13.1	6.3	2.8	7.5	5.2	1.0	6.1	10.0	0.4	1.4
Thenus orientalis	-	-	-	-	1.1	2.8	3	0.3	-	-	-	-	-	-	-	-
Shrimp	37.8	55.2	24.8	50.8	42.1	51.4	25.8	43.1	51.9	55.0	26.3	47.9	22.2	31.7	4	13.0
Mantis shrimp	0.9	3.7	1.8	0.3	3.9	5.4	1.2	0.6	1.9	5.0	6.6	0.7	0.3	1.7	0.2	0.0
Oratosquilla solicitans	0.3	1.0	0.8	0.0	0.6	2.8	0.4	0.1	-	-	-	-	-	-	-	-
Penaeus indicus	0.7	2.4	4.5	0.3	0.6	2.8	10.4	0.7	1.9	5.0	8	0.9	1	5.1	2	0.3
Other shrimps	28.5	39.9	17.1	48.4	36.5	37.9	11.5	41.5	48.1	45.0	11.8	46.4	20.9	25.0	1.9	12.7
Other crustaceans	7.4	8.2	0.7	1.8	0.6	2.8	2.3	0.2	-	-	-	-	-	-	-	-
Echinoderm	1.3	4.5	7.1	0.6	-	-	-	-	-	-	-	-	-	-	-	-
Holothuria fuscogilva	0.2	0.6	0.6	0.0	-	-	-	-	-	-	-	-	-	-	-	-
Holothuria scabra	0.9	2.7	6.4	0.5	-	-	-	-	-	-	-	-	-	-	-	-
Starfish	0.2	1.0	0.1	0.0	-	-	-	-	-	-	-	-	-	-	-	-
Fish	49.5	39.6	57.9	46.8	37.6	45.9	28.3	46.9	34.9	45.0	38.8	47.4	53.5	68.4	81.7	80.8
Caranx sexfasciatus	-	-	-	-	-	-	-	-	-	-	-	-	13.8	11.7	11.9	6.7
Carangidae	11.5	8.2	36.8	10.5	1.7	5.4	2.1	0.5	0.9	2.5	1.3	0.1	31	38.3	48.7	67.9
Kurtus sp.	0.2	0.6	0.6	0.0	1.1	5.4	4	0.6	0.9	2.5	1.9	0.1	-	-	-	-
Selaroides leptolepsis	1.9	1.4	8.7	0.4	-	-	-	-	-	-	-	-	5.7	10.0	16.2	4.8
Other fishes	35.7	28.5	11.7	35.9	34.8	35.1	22.3	45.8	33.0	40.1	35.5	47.2	3	8.3	4.8	1.4
Mollusk	7.1	12.5	3.5	0.8	2.2	10.8	14.3	1.1	7.5	7.5	27.8	3.0	2.7	8.3	5.8	0.5
Bivalvia	3.8	4.7	0.3	0.5	0.6	2.8	0.2	0.1	-	-	-	-	-	-	-	-
Charonia variegata	-		-	-	0.6	2.8	1.8	0.2	-	-	-	-	0.3	1.7	0.1	0.0
Loliginidae	0.2	0.4	0.3	0.0	-	-	-	-	6.6	5.0	27.3	2.9	1.0	1.7	-	0.0
Monoplex intermedius	-		-		-	-	-	-	0.9	2.5	0.5	0.1	-	-	-	-
Uroteuthis (P) chinensis	0.5	1.0	1.2	0.0	-	-	-	-	-	-	-	-	0.7	3.4	4	0.4
Uroteuthis (P) duvaucelii	-	-	-	-	-	-	-	-	-	-	-	-	0.7	1.7	1.7	0.1
Sepioteuthis lessoniana	-	-	-	-	0.6	2.8	10.5	0.7	-	-	-	-	-	-	-	-
Sepia sp.	0.1	0.4	1.4	0.0	-	-	-	0.0	-	-	-	-	-	-	-	-
Veneridae	1	2.0	0.1	0.1	-	-	-	0.0	-	-	-	-	-	-	-	-
Other mollusks	1.4	4.1	0.3	0.2	0.6	2.8	1.8	0.2	-	-	-	-	-	-	-	-
Urechidae	1.5	1.2	3.9	0.2	0.6	2.8	3.9	0.3	-	-	-	-	2.7	6.6	1.7	0.6

Table 1. (continued)

Food items	*S. taeniopterus*				*N. hexodon*				*N. furcosus*				*N. tambuloides*			
	%N	%FO	%W	%IRI	%N	%FO	%W	%IRI	%N	%FO	%W	%IRI	%N	%FO	%W	%IRI
Crab	3.0	10.8	2.7	0.9	17.4	27.0	27.7	8.7	5.7	14.9	7.2	1.6	18.9	38.3	6.8	5.1
Unidentified crab	1.9	7.8	1.2	0.6	2.8	8.1	2.4	1.0	2.8	7.5	1.9	0.6	7.7	13.3	2.2	2.9
Charybdis sp.	-	-	-	-	-	-	-	-	-	-	-	-	2	1.7	1.6	0.1
Charybdis anisodon	-	-	-	-	-	-	-	-	-	-	-	-	1.3	5.1	0.5	0.2
Parapanope sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	5.1	0.8	0.2
Portunus pelagicus	1.1	3.1	1.5	0.2	12.4	10.8	13.1	6.3	2.8	7.5	5.2	1.0	6.1	10.0	0.4	1.4
Thenus orientalis	-	-	-	-	1.1	2.8	3	0.3	-	-	-	-	-	-	-	-
Shrimp	37.8	55.2	24.8	50.8	42.1	51.4	25.8	43.1	51.9	55.0	26.3	47.9	22.2	31.7	4	13.0
Mantis shrimp	0.9	3.7	1.8	0.3	3.9	5.4	1.2	0.6	1.9	5.0	6.6	0.7	0.3	1.7	0.2	0.0
Oratosquilla solicitans	0.3	1.0	0.8	0.0	0.6	2.8	0.4	0.1	-	-	-	-	-	-	-	-
Penaeus indicus	0.7	2.4	4.5	0.3	0.6	2.8	10.4	0.7	1.9	5.0	8	0.9	1	5.1	2	0.3
Other shrimps	28.5	39.9	17.1	48.4	36.5	37.9	11.5	41.5	48.1	45.0	11.8	46.4	20.9	25.0	1.9	12.7
Other crustaceans	7.4	8.2	0.7	1.8	0.6	2.8	2.3	0.2	-	-	-	-	-	-	-	-
Echinoderm	1.3	4.5	7.1	0.6	-	-	-	-	-	-	-	-	-	-	-	-
Holothuria fuscogilva	0.2	0.6	0.6	0.0	-	-	-	-	-	-	-	-	-	-	-	-
Holothuria scabra	0.9	2.7	6.4	0.5	-	-	-	-	-	-	-	-	-	-	-	-
Starfish	0.2	1.0	0.1	0.0	-	-	-	-	-	-	-	-	-	-	-	-
Fish	49.5	39.6	57.9	46.8	37.6	45.9	28.3	46.9	34.9	45.0	38.8	47.4	53.5	68.4	81.7	80.8
Caranx sexfasciatus	-	-	-	-	-	-	-	-	-	-	-	-	13.8	11.7	11.9	6.7
Carangidae	11.5	8.2	36.8	10.5	1.7	5.4	2.1	0.5	0.9	2.5	1.3	0.1	31	38.3	48.7	67.9
Kurtus sp.	0.2	0.6	0.6	0.0	1.1	5.4	4	0.6	0.9	2.5	1.9	0.1	-	-	-	-
Selaroides leptolepsis	1.9	1.4	8.7	0.4	-	-	-	-	-	-	-	-	5.7	10.0	16.2	4.8
Other fishes	35.7	28.5	11.7	35.9	34.8	35.1	22.3	45.8	33.0	40.1	35.5	47.2	3	8.3	4.8	1.4
Mollusk	7.1	12.5	3.5	0.8	2.2	10.8	14.3	1.1	7.5	7.5	27.8	3.0	2.7	8.3	5.8	0.5
Bivalvia	3.8	4.7	0.3	0.5	0.6	2.8	0.2	0.1	-	-	-	-	-	-	-	-
Charonia variegata	-		-	-	0.6	2.8	1.8	0.2	-	-	-	-	0.3	1.7	0.1	0.0
Loliginidae	0.2	0.4	0.3	0.0	-	-	-	-	6.6	5.0	27.3	2.9	1.0	1.7	-	0.0
Monoplex intermedius	-		-		-	-	-	-	0.9	2.5	0.5	0.1	-	-	-	-
Uroteuthis (P) chinensis	0.5	1.0	1.2	0.0	-	-	-	-	-	-	-	-	0.7	3.4	4	0.4
Uroteuthis (P) duvaucelii	-	-	-	-	-	-	-	-	-	-	-	-	0.7	1.7	1.7	0.1
Sepioteuthis lessoniana	-	-	-	-	0.6	2.8	10.5	0.7	-	-	-	-	-	-	-	-
Sepia sp.	0.1	0.4	1.4	0.0	-	-	-	0.0	-	-	-	-	-	-	-	-
Veneridae	1	2.0	0.1	0.1	-	-	-	0.0	-	-	-	-	-	-	-	-
Other mollusks	1.4	4.1	0.3	0.2	0.6	2.8	1.8	0.2	-	-	-	-	-	-	-	-
Urechidae	1.5	1.2	3.9	0.2	0.6	2.8	3.9	0.3	-	-	-	-	2.7	6.6	1.7	0.6

Table 2. Trophic attribute of eight nemipterid fishes of different ecological and biological conditions collected from the lower part of the South China Sea. (n = number of stomach analyzed; FL= fullness index; SD= standard deviation; TLF = total number of food item; AF= average number of food item; VI = vacuity index; Bi= diet breadth**;** S1 = <7cm, S2 = 7.1-14.0cm, S3 = 14.1-21.0cm, S4 = >21cm.**)**

Species	n	Size Range (cm)	FL± SD	TLF	AF	VI	Bi
N. nematophorus	198	All	4.24±2.98	32	2.05	21.21	0.04
	44	S1	3.36±3.29	8	1.16	36.36	0.21
	148	S2	4.35±2.78	29	2.28	17.57	0.04
	6	S3	8.00±2.45	5	2.67	0.00	0.60
N. mesoprion	171	All	3.34±2.73	20	2.20	22.22	0.01
	7	S1	0.86±1.57	-	-	71.43	D
	127	S2	3.46±2.73	15	1.96	21.26	0.05
	37	S3	3.41±2.74	11	3.30	16.22	0.01
N. nemurus	22	All	5.55±3.95	18	3.41	22.73	0.07
	9	S2	5.11±3.89	8	1.67	22.22	0.68
	13	S3	5.85±4.12	16	4.62	23.08	0.05
N. peronei	23	All	4.39±2.79	11	3.26	8.70	0.17
	13	S2	4.92±2.10	7	2.92	0.00	0.25
	10	S3	3.70±3.50	7	3.70	20.00	0.23
S. taeniopterus	345	All	4.09±2.75	37	3.65	14.49	0.04
	39	S2	4.08±2.25	14	4.97	10.26	0.09
	253	S3	3.47±2.38	28	2.91	17.39	0.03
	53	S4	7.06±2.84	21	6.17	3.77	0.04
N. hexodon	42	All	6.00±3.71	22.00	4.24	11.90	0.07
	8	S2	3.63±2.83	4	2.50	25.00	0.51
	27	S3	6.11±3.79	17	5.44	11.11	0.09
	5	S4	10.00±0.00	9	2.40	0.00	0.85
N. furcosus	44	All	4.89±2.92	14.00	2.41	9.09	0.09
	11	S2	5.82±3.06	6	1.91	9.09	0.13
	33	S3	4.58±2.85	13	2.58	9.09	0.13
N. tambuloides	61	All	8.08±2.48	20.00	4.87	1.67	0.05
	6	S2	4.33±2.66	5	1.67	16.67	0.47
	36	S3	8.64±1.96	15	5.56	0.00	0.08
	19	S4	8.21±2.33	10	4.58	0.00	0.10

Table 3. Statistical results for the effects size, sex and maturity stage on stomach fullness index and number of food items in the stomachs of eight nemipterid fishes collected from the lower part of the South China Sea

Factors	Species	No. of sample	df	Fullness index	No. of food items
Species	All	906	7	P<0.01	P<0.01
Size	*N. nematophorus*	198	2	P<0.01	P>0.05
	N. mesoprion	171	2	P<0.05	P>0.05
	N. nemurus	22	-	P<0.05	P<0.05
	N. tambuloides	61	2	P<0.01	P<0.05
	S. taeniopterus	345	2	P<0.01	P>0.05
	N. hexodon	42	2	P>0.05	P>0.05
	N. furcosus	44	-	P>0.05	P<0.05
	N. peronii	23	-	P>0.05	P<0.05
Sex	*N. nematophorus*	198	2	P>0.05	P>0.05
	N. mesoprion	171	2	P<0.01	P>0.05
	N. nemurus	22	2	P>0.05	P>0.05
	N. tambuloides	61	-	P>0.05	P>0.05
	S. taeniopterus	345	-	P>0.05	P>0.05
	N. hexodon	42	2	P>0.05	P<0.05
	N. furcosus	44	2	P>0.05	P>0.05
	N. peronii	23	-	P<0.05	P<0.05
Maturity stage	*N. nematophorus*	198	3	P>0.05	P>0.05
	N. mesoprion	171	3	P<0.01	P>0.05
	N. nemurus	22	3	P>0.05	P>0.05
	N. tambuloides	61	3	P>0.05	P>0.05
	S. taeniopterus	345	3	P<0.05	P>0.05
	N. hexodon	42	3	P>0.05	P>0.05
	N. furcosus	44	2	P>0.05	P>0.05
	N. peronii	23	2	P>0.05	P>0.05

(2.05). A highly significant difference between AF of the eight fish species was recorded (P<0.01). VI varied from 1.67 for *N. tambuloides* to 22.73 for *N. nemurus*. *Bi* ranged from 0.01 for *N. mesoprion* to 0.17 for *N. peronii*.

Impacts of Size, sex and Maturity Stage on FL and Number of Food Items

It was found that FL varied significantly between different size classes of five species including *N. nematophorus*, *N. mesoprion*, *N. nemurus*, *N. tamboloides* and *S. taeniopterus* (P<0.05). Sexes of fish; identified as male, female and unidentified sex, significantly influenced FL of *N. mesoprion* (P<0.01) and *N. preonii* (P<0.05). Maturity stages significantly affected FL in the diets of two species, *N. mesoprion* (P<0.01) and *S. taeniopterus* (P<0.05). Fish size class significantly affected AF of four species including *N. nemurus, S. taeniopterus, N. hexodon* and *N. Peronii*. Sexes also showed significant impacts on AF of *N. hexodon* (P<0.05) and *N. peronii* (P<0.05). There was no impact of maturity stage on AF of all species (P>0.05). Details of statistical results are in Table 3.

Diet Overlap and Inter-Specific Relationship

Out of 28 pairs of dietary overlap for eight fish species, 16 pairs or 57.5% had the values >0.6, considered to be biologically significant (Table 4). Very low value of overlaps was found between *N. nemurus* with *N. mesoprion* and *N. tambuloides* with all other seven species. It was confirmed with a clustering dendogram that *N. nemurus* and *N. tambuloides* formed a separate group (Figure 2). Four species formed the cluster G1 on the dendogram including *N. hexodon, S. taeniopterus, N. mesoprion* and *N. nematophorous* indicating their preference over similar suite of food items. *N. peronii* and *N. furcosus* formed the cluster G2 on the dendogram. Analysis of similarity (ANOSIM) indicated that classification significantly separated the dietary samples of these species into two distinct groups (Global R = 0.786, P <0.005). Similarity percentage (SIMPER) showed that unidentified shrimp (26.4% contribution), unidentified fish (23.8%), mantis shrimp (11.2%) and *Leiognathus* spp. (9.1%) were the greatest contributors to the formation of cluster G1. Unidentified shrimp, unidentified fish and crab were the major contributors to cluster G2 with the

Table 4. Morisita-Horn indices for the diets of different nemipterid fishes collected from the lower part of the South China Sea. The value >0.60 are highlighted in bold indicating significant overlap

Species	Species							
	Sp1	Sp2	Sp3	Sp4	Sp5	Sp6	Sp7	Sp8
N. nematophorus (Sp1)	-							
N. mesoprion (Sp2)	0.75	-						
N. nemurus (Sp3)	0.59	0.11	-					
N. tambuloides (Sp4)	0.15	0.18	0.14	-				
S. taeniopterus (Sp5)	0.98	0.83	0.54	0.33	-			
N. hexodon (Sp6)	1.00	0.79	0.63	0.16	0.98	-		
N. furcosus (Sp7)	0.99	0.88	0.48	0.17	0.98	0.98	-	
N. peronii (Sp8)	0.98	0.82	0.52	0.16	0.97	0.98	0.99	-

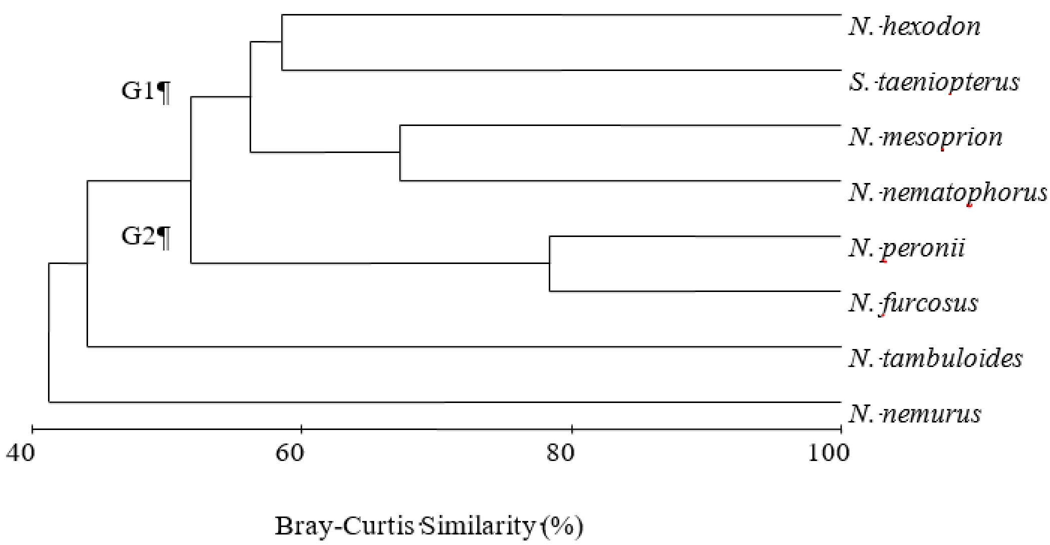

Figure 2. Cluster dendogram indicating inter-specific relationship between eight sympatric nemipterid fish species collected from the lower part of the South China Sea. (G1 = group 1 and G2 = group 2)

contributions of 29.6%, 21.3% and 12.6%, respectively. For dietary overlap between each size classes of eight species, out of 210 pairs examined, 79 pairs had the value > 0.6, indicating significant overlaps. Details of diet overlaps between fishes of different size classes of all species are in Table 5.

Discussion

This is considered the first work dealing directly with feeding habits of eight nemipterid species residing in the same habitat. With the exception of *N. mesoprion* (Manojkumar, 2008) and *S. taeniopterus* (Hajisamae, 2009), no existing reference for other six species is available. Results from this study indicated that nemipterid fishes or thread fin breams feed on a wide range of food items but with high preference over fish and shrimp. Based on very low value of the overall Bi and feeding mainly on aquatic animals, they were considered as specific carnivorous fishes. It was also observed that many species were considered piscivorous, feeding on fishes, but the ratio of fishes contributing to the diet was different among species. *N. numurus* and *N. tambuloides* were the most piscivorous species as their diet largely dominated by fishes. *N. mesoprion* was the only species which can be defined as a specific crustacean predator as it fed mainly on mantis shrimp, shrimp and other crustaceans. This finding is coincident with those reported by Rao (1989), Joshi (2005) and Manojkumar (2008) that the main food of *N. mesoprion* was crustaceans. In coastal waters off Visakhapatnam, Rao (1989) reported that *N. mesoprion* fed mainly on crustaceans especially *Parapanope euagora* and teleosts especially *Leognathus* sp. Joshi (2005) observed a large portion of *Stolephorus* spp. and *Leiognathus* spp. in the diet of *N. mesoprion* off Cochin, India. Raje (1996) noticed that *N. mesoprion* off Veraval, India was a carnivorous species, and its diet composed of crustaceans, fish, mollusks and annelids. Similar observations for the diet of this species were reported by Zacharia and Nataraja (2003) and Manojkumar (2008). Historically, feeding habits of *N. mesoprion* was long described by Krishnamoorthy (1971) that it was highly predaceous and possibly a sight feeder of crustaceans, mollusks, annelids and echinoderms. For *S. taeniopterus*, Hajisamae (2009) found that polychaete, crab and shrimp were its main food items. However, slightly different observation was made in this study where shrimp and fish were the major component with small contribution of crab. Additionally, some studies reported on diet composition of other nemipterid fishes. Boaden and Kingsford (2012) found a variety of benthic invertebrates in the diets of *S. bilineatus* and observed an ontogenetic shift in prey size. Studies on *N. japonicas* and *N. randalli* indicated that they were predators feeding on benthic organisms (Vinci, 1982 and Rao & Rao, 1991). Thangavelu et al. (2012) found that *N. japonicus* fed mainly on crustaceans including *Acetes* spp., penaeid prawns, crabs, squid, juvenile fishes such as flathead, lizard fish and some fish larvae. Gurlek et al. (2010) found that crustacean, fish, polychaete and mollusk were the main food for *N. randalli*. Apart from these reports, no reference was found on diets for other nemipterid species.

Generally, diets of most fishes change with sizes (Blaber, 1997). This study confirmed this assumption as it was found that FL of fish samples increased with the increasing of predator body size. Results from this study also indicated that larger fishes seemed to be more active and successful predators than the smaller of the same species. It is postulated that the discrete shift in diet with increasing body size is related to morphological limitations. When nemipterid fishes reach an optimum body size, they may access to a higher trophic resources. There was no relationship between maturity stage and FL of fish, but a decrease of FL was observed at fully matured stage in this study. A small contribution of nylon and plastic materials in the diets of *N. nematophorus* and *N. nemurus* was probably due to incidental ingestion while capturing targeted preys rather than intentional selection.

Dietary overlap is a tool to compare partitioning of food resources consumed between animal species co-existing in the same habitat (Ross, 1986). According to the niche theory, when sympatric animals overlap in the use of shared resources along one dimension, they must differentiate along another resource to co-exist (Hutchinson 1959, MacArthur 1958). Food overlap among different species or different sizes of the same species is one of the important directions to understand fish community organization (Krebs 1989). Results from this study indicated that food overlap between species was high with the exception of the overlap between *N. tambuloides* with other co-existing species.

In conclusion, the eight nemipterid fish species from the lower part of the South China Sea are specific predators feeding mainly on shrimp and fish. The co-existence of these species in the bottom waters of this habitat requires partitioning of available food resources. This information is useful for an understanding of natural phenomena occurring in the ocean and can be useful for future management of these fishery resources.

Acknowledgement

Financial support for this study was granted by the Graduate School, Prince of Songkla University, Thailand and research vessel was provided by Southern Marine Fisheries & Development Center, Songkhla, Thailand. Authors would love to thank Mrs. Sriwita Chaibundit, Mr. Thanate Sritakon and all crew members of MV Pramong 9 for helping in research vessel and laboratory works. Special thanks to Dr. Fazrul Hisam, and Dr. Prawit Towattana.

Table 5. Morisita-Horn indices for the diets of different size class of nemipterid fishes collected from the lower part of the South China Sea. (S1 = <7cm, S2 = 7.1-14.0cm, S3 = 14.1-21.0cm, S4 = >21cm. The value >0.60 are highlighted in bold indicating significant overlap

Species	Size	*N. nematophorus*			*N. mesoprion*		*N. nemurus*		*N. tambuloides*			*S. taeniopterus*			*N. hexodon*				*N. furcosus*		*N. peronii*	
		S1	S2	S3	S2	S3	S2	S3	S2	S3	S4	S2	S3	S4	S1	S2	S3	S4	S2	S3	S2	S3
N. nematophorus	S1	-																				
	S2	1.0	-																			
	S3	0.4	0.4	-																		
N. mesoprion	S2	0.9	0.9	0.4	-																	
	S3	0.8	0.8	0.3	0.2	-																
N. nemurus	S2	0.4	0.3	0.1	0.2	0.1	-															
	S3	0.5	0.6	0.2	0.3	0.0	0.4	-														
N. tambuloides	S2	0.7	0.7	0.3	0.5	0.3	0.4	0.9	-													
	S3	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.0	-												
	S4	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.0	1.0	-											
S. taeniopterus	S2	0.9	0.9	0.3	0.7	0.5	0.4	0.8	0.9	0.1	0.1	-										
	S3	1.0	1.0	0.4	1.0	0.9	0.2	0.4	0.6	0.2	0.2	0.8	-									
	S4	0.2	0.2	0.1	0.2	0.1	0.3	0.2	0.1	1.0	1.0	0.2	0.2	-								
N. hexodon	S1	0.2	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-							
	S2	0.9	1.0	0.4	0.8	0.6	0.4	0.7	0.8	0.3	0.3	1.0	0.9	0.3	0.0	-						
	S3	1.0	1.0	0.4	0.9	0.7	0.3	0.6	0.8	0.1	0.1	0.9	0.9	0.2	0.0	1.0	-					
	S4	0.2	0.2	0.3	0.2	0.1	0.1	0.2	0.2	0.0	0.0	0.2	0.2	0.0	0.0	0.2	0.2	-				
N. furcosus	S2	0.9	0.9	0.3	1.0	1.0	0.1	0.2	0.4	0.2	0.2	0.7	1.0	0.1	0.0	0.8	0.9	0.2	-			
	S3	1.0	1.0	0.4	0.9	0.8	0.3	0.6	0.8	0.1	0.1	0.9	1.0	0.2	0.0	1.0	1.0	0.2	0.9	-		
N. peronii	S2	0.8	0.9	0.3	0.7	0.4	0.4	0.9	0.9	0.1	0.1	1.0	0.7	0.2	0.0	0.9	0.9	0.2	0.6	0.9	-	
	S3	0.8	0.8	0.4	0.9	0.9	0.1	0.1	0.4	0.1	0.1	0.6	0.9	0.1	0.0	0.7	0.8	0.2	0.9	0.8	0.5	-

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