Diet composition and trophic niche similarities of engraulid fishes in Pabean bay, Indramayu, Indonesia

L S Syafei1,3 R S Siregar2, M F Rahardjo2,3 and C P H Simanjuntak2,3*

1 Department of Fishery Extension, Jakarta Fisheries University, Indonesia
2 Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University (IPB University), Bogor, Indonesia
3 Indonesian Ichthyological Society, Indonesia

*E-mail: charles_phs@apps.ipb.ac.id

Abstract. A study on the trophic ecology of fishes is one of the approaches to acquire a better understanding of fish feeding strategies, prey inclinations, niche competition and increase knowledge on the working of marine biological system. The present work aims to determine diet composition and trophic niche overlap among species of engraulid fishes in the coastal area of Pabean. Sampling was performed monthly from April 2016 to March 2017 and fishes were captured using gill nets and guiding barriers. During research period, seven species of engraulid were collected, namely Thryssa hamiltonii (with total length ranged from 47-186 mm), Thryssa mystax (53-151 mm), Thryssa kaminalensis (66-112 mm), Thryssa setirostris (106-132 mm), Stolephorus indicus (54-133 mm), Stolephorus dubiosus (56-75 mm) and Stolephorus tri (66-91 mm). Prey of fishes were classified into four taxonomic groups i.e., Bacillariophyceae, Polychaeta, Crustacea and Pisces. Crustacea was the most consumed category (IRI>90%), recorded for all species of engraulid fishes, followed by Bacillariophyceae (<10%), polychaeta and fish juveniles (<5%). This finding indicates that all engraulid fishes in Pabean waters are crustasivore. Inter-specific feeding overlap was high, indicates that feeding competition among engraulid fishes tends to be high when food resources is decreased.

Keywords: crustasivore, engraulid fishes, feeding ecology, guilds, resource partitioning

1. Introduction

A better knowledge of fish diet, niche breeding and overlap, predator interactions is important to describe the working of marine biological system (Elliott et al 2002, Metcalf et al 2008). Moreover, understanding the trophic ecology of fishes and food web structure are an essential prerequisite for ecosystem-based fishery management (Garcia et al 2003, Gascuel et al 2011, Egan et al 2017). Since tropical coastal ecosystem is an essential habitat for many marine fish species (Blaber 1997), it is necessary to describe resources partitioning among fish assemblages rather than a single-species approach. Studies on the trophic ecology of coastal fish assemblages in Indonesian waters are limited (Zahid et al 2015) and mostly are concentrated on single species or fish family (Annisa et al 2018, Santi et al 2017, Sulistiono et al 2010, Simanjuntak and Zahid 2009, Simanjuntak and Rahardjo 2001, Rahardjo and Simanjuntak 2002).
Pabean is situated in northern part of Indramayu, west Java, Indonesia. Studies on the trophic ecology of fishes in Pabean waters have been conducting since 2016. About 78 fish species from 39 families are occurring in this area (Rahardjo and Affandi 2016) and some of them already studied in terms of feeding ecology, such as terapontid grunters (Tambunan et al, 2017), clupeid fishes (Bukit et al, 2017), scalloped perchlet (Santi et al, 2017), javelin grunt (Annisa et al, 2018), gobiid fishes (Konchara et al, 2018), and mullet fishes (Al Ghiffary et al, 2018).

Engraulid fishes are commercially important small pelagic fish inhabit coastal waters of Java Sea (Widodo and Burhanuddin, 1995). Members of this family may play an important role as secondary consumer that feeds on zooplankton or micro crustacean in coastal ecosystem (Chaves and Vendel, 2008, Sulistiono et al, 2010, Kumar et al, 2015, El Qendouci et al, 2018). However, little is known about the feeding ecology of this family in terms of resource partitioning among species. Most of previous studies focused on the single species such as Engraulis encrasicolus (Plounevez and Champalbert, 1999, El Qendouci et al, 2018) and Thryssa kammalensis (Baek et al, 2014). The study aimed to determine diet composition and trophic niche overlap among species of engraulid fishes in coastal area of Pabean, Indramayu, Indonesia.

2. Materials and methods

2.1. Study area

Research was conducted in Pabean waters, Indramayu, west Java, Indonesia (coordinates between 6°14’ S 108°18’ E - 6°17’ S 108°18’ E and 6°17’ S 108°20’ E - 6°14’ S 108°21’ E) (figure 1). The shoreline of Pabean is cover by fringe mangroves and since many rivers input into Pabean Bay, such as Cimanuk River, the waters of this bay is estuarine waters. Small scale aquacultures are carried out in this area and the bay is the major fishing ground for small scale fishery.

![Figure 1. Map of the study sites in Pabean bay, Indramayu, West Java, Indonesia.](image-url)
2.2. Sampling collection and analysis
Samples were obtained monthly between April 2016 and March 2017 at three fixed zones in Pabean Bay using gill nets (mesh size: 1-1.75 inches) and guiding barrier (sero) (mesh size: 0.04 inch) during ebb and low tides. All fish specimens were immediately preserved in 10% formaldehyde-seawater solution. At each sampling station, environmental parameters such as temperature (ºC), salinity (ppt), dissolved oxygen (mgL⁻¹), pH and transparency (m) were measured.

In laboratory, all fish specimens were identified to species level using fish identification book (Carpenter and Niem 1999) and fish number per species were counted. Fish total length (mm) and body weight (g) were measured and documented. The stomachs and intestines were removed and preserved in 4% formaldehyde solution for further food item analysis. All food items present in the gut were identified to the lowest possible taxa refers to Carpenter and Niem (1998), Chihara and Murano (1997), and Yamaji (1979) using a stereomicroscope (10×) and a binocular microscope (40-100×). All prey items were counted and its volume was measured (V).

Diet composition was determined as a percentage of each food item in the stomach contents and expressed as numerical abundance (%N). The percentage frequency of occurrence (%F) of each food item in the stomach and the percentage volume (%V) of each prey item was calculated as well. The main food items of each fish species were identified using the index of relative importance (IRI) (Pinkas et al 1971):

\[ IRI = F \times (N + V) \]  

where \( IRI \) is index of relative importance, \( F \) is percentage frequency of occurrence, \( N \) is percentage of numerical abundance, \( V \) is percentage volume of each prey item. IRI values ranging from 0-20,000.

Diet breadth of each species was quantified using the Levin’s measure (Krebs 2014). Hurlbert’s formula was applied to standardize the trophic niche measure (ranging from 0 to 1) (Krebs 2014), according to the formula:

\[ B_a = \left( \frac{1}{\sum_{i=1}^{n} p_{ij}} \right) - 1 \times \left( \frac{1}{(n-1)} \right) \]  

where \( B_a \) is standardized trophic niche breadth; \( p_{ij} \) is proportion of food category i in the diet of species j; \( n \) is total number of food categories. Trophic niche breadth was categorized low (0-0.39), intermediate (0.4-0.6) or high (0.61-1) (modified of Grossman 1986).

Feeding overlap between species of engraulid fishes was quantified using simplified Morisita index (Krebs 2014):

\[ C_H = \frac{2 \sum_{i=1}^{n} p_{ij} \times p_{ik}}{\sum_{i=1}^{n} p_{ij}^2 + \sum_{i=1}^{n} p_{ik}^2} \]  

where \( C_H \) is feeding overlap of simplified Morisita, \( p_{ij} \) is proportion of food category i in the diet of species j, \( p_{ik} \) is proportion of food category i in the diet of species k, \( n \) is total number of food categories. Species feeding overlap varies in a scale from 0 to 1, with 1 indicating a complete overlap.
3. Results and discussion

3.1. Environmental conditions
There was a significant difference in temperature, salinity, Secchi depth transparency, and dissolved oxygen readings of three sampling sites (p<0.05). During the study period, temperature ranged from 28-32.5°C, salinity from 20.3-35 ppt, transparency 0.1 to 1.8 m; and dissolved oxygen ranged from 3.9-8.6 mg L⁻¹. Fluctuation of environmental condition was due to climatic conditions i.e., dry and wet seasons. The hot and dry period occurs between June to August, while wet season occurs between November to February. Pabean water as the estuary ecosystem is characterized by environmental fluctuations. Variation in temperature, salinity, oxygen is caused by tides dynamic, mixing of freshwater from rivers and marine waters (McLusky and Elliott 2004).

3.2. Prey item and diet composition
A total of 414 individuals of seven engraulid fishes were caught in the study, viz. *Thryssa hamiltonii* (with total length and body weight ranged from 47-186 mm, 0.47-45.37 g), *T. mystax* (53-151 mm; 0.61-24.92 g), *T. kammalensis* (66-112 mm; 1.54-10.4), *T. setirostris* (106-132 mm; 6.47-14.97 g), *Stolephorus indicus* (54-133 mm; 0.81-15.93 g), *S. dubiosus* (56-75 mm; 0.89-2.77 g) and *S. tri* (66-91 mm, 1.60-5.00 g (fig. 2). All fish species were grouped into five-length groups, namely I (total length ranges from 41-70 mm), II (71-100 mm), III (101-130 mm), IV (131-160 mm) and V (161-190 mm). Most of the fish samples were in the group II, while the least amount was the group V. The majority of fish individuals were juveniles and all of fish stomachs contained food. Since the large number of engraulid fishes were captured in juvenile stage, it shows that estuarine waters of Pabean Bay may play an important role as a nursery ground for engraulid fishes. Some previous studies reported similar findings such as Vidy (2000) in estuary of Sine Saloum, Senegal; Vendel and Chaves (2006) in Barra do Sai lagoon, Santa Catarina State, Brazil; and Sichum *et al* (2013) in Talet Noi Bay, Gulf of Thailand.

![Fish species](image)

**Figure 2.** Engraulid fish species collected in Pabean bay, Indramayu, West Java, Indonesia.
Overall, the prey items consumed by engraulid fishes in Pabean bay is shown in table 1. A total of 19 prey items were determined and classified into four taxonomic groups, namely Bacillariophyceae, Polychaeta, Crustacea and Pisces. Crustacean group was more diverse than other types of food. It comprises of seven and six micro and macro crustaceans, respectively. Micro crustacean consists of Polychaeta, Crustacea and Pisces. Crustacean group was more diverse than other types of food. It comprises of Bacillariophyceae, Pleurosigma, Nitzschia, Coscinodiscus, Nereis, Acartia, Calanus, Chantocalanus, Copilia, Oithona, Sapphirina, and Temora; while macro crustacean comprises of Acetes, Metapenaeus, Mysis, Luciferidae, nauplius, and Squilla. Rajan (2018) stated that the food of family Engraulidae (anchovies) mainly comprises copepods, crustaceans, ostracods, amphipods, larvae and juveniles of fishes.

| Group of prey items | Taxa                          | Remarks            |
|---------------------|-------------------------------|--------------------|
| Bacillariophyceae   | *Pleurosigma*, Nitzschia,     |                    |
|                     | *Coscinodiscus*               |                    |
| Polychaeta          | *Nereis*                      |                    |
| Crustacea           | *Acartia*, *Calanus*,         | Micro and macro    |
|                     | *Chantocalanus*, *Copilia*,   | crustacea          |
|                     | *Oithona*, *Sapphirina*,     |                    |
|                     | *Temora*, *Acetes*,           |                    |
|                     | *Metapenaeus*, *Mysis*,       |                    |
|                     | *Luciferidae*, nauplius,      |                    |
|                     | *Squilla*                     |                    |
| Pisces              | *Leiognathus* spp., Teleostei | Juvenile, fish     |

Diet composition of all species of engraulid fishes during the study period are presented in figure 3. Crustaceans (micro and macro crustacean) were the most important prey item for *Thysya hamiltonii*, *T. mystax*, *T. kammalensis*, *T. setirostris*, *Stolephorus indicus*, *Stolephorus dubiosus* and *Stolephorus tri* in Pabean Bay. *T. hamiltonii* and *T. mystax* is mainly crustacea (i.e., Acetes, Metapenaeus, Luciferidae, Mysis, nauplius, *Copilia*, *Calanus*, *Chantocalanus*, *Oithona*, *Temora*), while other prey items such as Bacillariophyceae (*Pleurosigma*, Nitzschia, Coscinodiscus), Pisces (fish juveniles and Leiognathidae) and Polychaeta (*Nereis*) are categorized as the complementary diet (~10%) (figure 3). Thus, *T. hamiltonii* and *T. mystax* in Pabean waters are listed as crustacivore. Hajisamae et al (2003) categorized *T. hamiltonii* in Johor Strait, Singapore as carnivore with the main prey item was crustacean. Sulistiono et al (2010) reported that the main menu of *T. mystax* in estuary of Ujung Pangkah, east Java is crustacean. An ontogenetic change in trophic ecology was recorded for *T. hamiltonii*. The smaller fish (group I) feeds mostly on phytoplankton (Bacillariophyceae), while the bigger one (~ group II) feeds largely on crustacean and polychaeta. Putri (2012) also found the similar result that *T. hamiltonii* had an ontogenetic diet shifts in Mayangan coast, west Java, Indonesia.

*T. kammalensis* consumes crustaceans (viz. *Acetes*, *Metapenaeus*, Luciferidae, *Mysis*, nauplius, *Acartia*, *Calanus*, *Chantocalanus*, *Oithona*, *Sapphirina*, and *Temora*), Bacillariophyceae and pisces with the main diet was crustacean in Pabean waters (figure 3). This species is grouped as crustacivore. Baek et al (2014) stated that *T. kammalensis* in the coastal waters of Gadeok-do, Korea is a carnivorous fish that consumes *Sagitta*, copepods, crab larvae, shrimps, and fish eggs. However, the main food is *Sagitta*. The difference in main food item may occur due to differences in composition and abundance of food resources. Rahardjo et al (2011) stated that habitat different would cause differences in food resources, therefore food composition of one fish species might be differ than the same species in other locations.

*T. setirostris* is crustacivore which feeds on crustaceans (i.e., *Acetes* and *Metapenaeus*) in Pabean Bay (fig. 3). Hajisamae et al (2003) found that *T. setirostris* in eastern of Johor Strait, Singapore as predator which mainly prey on crustaceans. The small individuals of this species in some coastal areas of Taiwan is designated as zooplanktivore that eats zooplankton for the most part and other prey items such as crustacea nekton, eggs, phytoplankton and algae as additional diet (Egan et al 2017).
The presence of a large number of crustaceans such as Acetes, Metapenaeus, Luciferidae, nauplius, Chantocalanus, Oithona, and Temora in the gut contents of three species of Stolephorus indicate that these species are classified as crustacivore in Pabean Bay (figure 3). Phytoplankton (Bacillariophyceae) in very limited number (1-2% of fish diet) also identified from stomachs of S. indicus, S. tri and S. dubiosus. Horinouchi et al (2012) stated that the main food items of S. indicus comprised planktonic copepods, planktonic salpids and shrimps. Gopal et al (2018) observed that the main food item of S.
indicus was crustaceans, which comprised copepods, lucifers, mysids, Acetes and amphipods. Venkataraman (1960) reported that the food of Stolephorus tri in Malabar coast, India was mainly copepods and small crustaceans. Another congeneric fish such as Stolephorus commersonnii from South Andaman is labelled as a planktonivorous carnivore which primarily eats planktonic crustaceans, bivalves, and gastropods (Kumar et al 2015).

3.3. Trophic guild
Trophic guilds are groups of fish species utilizing similar prey (Garrison and Link 2000). There are nine trophic guilds in marine fishes based upon prey types consumed, namely herbivores, omnivores, zooplanktivores, insectivores, piscivores, detritivores, crustacivores, annelidivores and molluscivores (Hajisamae et al 2003, Nakamura et al 2003, de Medeiros et al 2017). In this study, only Thryssa hamiltonii undergo ontogenetic diet shift, from phytoplanktivore (herbivores) become crustacivore. Generally, all species of engraulid fishes in Pabean Bay are considered as crustacivores. de Medeiros et al (2017) reported that engraulid fishes in the Mamanguape River estuary, Brazil feeds mainly on micro crustaceans and belongs to zooplanktivores.

3.4. Niche breadth and niche trophic overlap
The results of the Levin’s measure of niche breadth showed that generally dietary breadth values were very low ($B_a<0.5$) for all engraulid fish species in Pabean Bay (table 2). Thryssa hamiltonii had generally broad ranges of diet breadth within engraulid fishes in Pabean Bay ($B_a=0.19$), followed by T. mystax (0.15) and T. kammalensis (0.10). There are two possibilities why low dietary expansiveness estimations of engraulid fishes happened in Pabean Bay, first because of diminishing of food resources as an impact of trawl fishery; and the subsequent one is the specialization mechanism of every species toward the ideal states (Ramírez-Luna et al 2008).

Generally, the feeding niche overlap among species of engraulid fishes in Pabean Bay was high indicating that food resources partitioning was very tight among them (table 2). The highest niche trophic overlaps were recorded between Thryssa kamalensis and Stolephorus indicus; T. kamalensis and S. tri; S. indicus and S. tri (each with $C_H=0.99$), followed by S. indicus and S. dubiosus (0.97), T. hamiltonii and T. mystax (0.95), T. kamalensis and S. dubiosus (0.94), S. dubiosus and S. tri (0.93), T. mystax and T. kamalensis (0.74). High trophic overlap between fish species indicates similarity of prey item they utilized (Grossman 1996). Trophic overlap values which exceed 0.6 indicates that biologically overlap in utilizing food resources is occurs and further leads to competition when food resources are limited in the marine environment (Wallace 1981).

| T. hamiltonii | T. mystax | T. kamalensis | T. setirostris | S. indicus | S. dubiosus | S. tri |
|--------------|-----------|---------------|---------------|-----------|------------|-------|
| T. hamiltonii | 1.00      | 0.95          | 0.66          | 0.67      | 0.59       | 0.51  |
| T. mystax    | 1.00      | 0.77          | 0.74          | 0.72      | 0.63       | 0.74  |
| T. kamalensis | 1.00      | 0.60          | 0.99          | 0.94      | 0.99       | 0.99  |
| T. setirostris | 1.00    | 0.58          | 0.44          | 0.44      | 0.44       | 0.44  |
| S. indicus   | 1.00      | 0.97          | 0.99          | 0.99      | 0.99       | 0.99  |
| S. dubiosus  | 1.00      | 1.00          | 1.00          | 1.00      | 1.00       | 1.00  |
| S. tri       | 1.00      | 1.00          | 1.00          | 1.00      | 1.00       | 1.00  |

| Niche breadth ($B_a$) | 0.19 | 0.15 | 0.10 | 0.01 | 0.09 | 0.10 | 0.07 |

Tabel 2. Niche breadth and niche trophic overlap of engraulid fishes in Pabean Bay.
4. Conclusion

In summary, our study suggests that the seven species of engraulid fishes, namely *Thryssa hamiltonii*, *T. mystax*, *T. kammalensis*, *T. setirostris*, *Stolephorus indicus*, *S. dubiosus* and *S. tri* in Pabean Bay, Indramayu, Indonesia are grouped into the same guild as crustacivore due to the similarity of the resources they consumed. We also revealed that feeding niche overlap among species of engraulid fishes in Pabean Bay is high, indicating that inter-specific competition will occur when food resources are limited. Our study could contribute to a better understanding about the trophic ecology of small pelagic fish family in Indonesian coastal waters.

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