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**Abstract.** The use of fairy shrimp (*Streptocephalus* spp.) as a live feed for aquaculture is not well-known in Indonesia. On top of that, fairy shrimp mostly portrayed incorrectly in Indonesia as an unwanted creature and should be prevented in fish ponds. This review highlights the importance of fairy shrimp *Streptocephalus* spp. as an alternative live feed as well as explore the potential application and suitability for its future implementation in Indonesian aquaculture industry.

**Keywords:** Fairy shrimps, *Streptocephalus*, microalgae, *Macrobrachium rosenbergii*

## 1. Introduction

Fairy shrimp (*Streptocephalus* spp.) is a freshwater crustacean from order Anostraca, one of four order of crustacea in the class Branchiopoda. They are commonly found in vernal pool, a type of seasonal water catchment or basin which temporarily dry in one period and wet in other period. Their distribution remarkably ranged from temperate to tropical zones across the world. Since the last two decades, their demands gradually increased as live food in aquaculture. They have high nutritional value such as crude protein and lipid that are similar to *Artemia*, and even higher amino acids value than *Artemia*. They also have high amount of polyunsaturated fatty acids, which are very useful for their predators to gain metabolism energy and size growth in the form of triglycerides [1-7].

Of all species under *Streptocephalus* genus that have been validated, as many as nine species can be found in Asia with only four of them occurred in South East Asia to date: *S. dichotomus* in Myanmar, *S. javanensis* in Indonesia, *S. sirindhornae* and *S. siamensis* in Thailand [4,8,9]. Recent studies by [10-12], although not specifically mentioned which species it belongs, confirmed the existence of *Streptocephalus* spp. in Cisadea River, Lake Cangkuang, and Lake Situ Gede, all of them in West Java, Indonesia. Furthermore, [13] and [14] indicated that *S. javanensis*, or “Huhurangan” in Sundanese language, were considered by local fish farmers as a pest as well as competitor in fishponds. Since then, numerous books and literatures related to inland aquaculture written in Indonesia have mostly portrayed this species incorrectly as an unwanted creature and should be prevented in aquaculture [10, 15-18].

In this review, we provide some aspects related to the biology and behavior of fairy shrimp *Streptocephalus* spp. including their life cycle, nutritional value, reproductive biology, mating pattern, cyst morphology, food preference, and feeding habit, which can help to achieve continuous productivity in mass culture. These aspects were then examined and compared with other existing live feed.

## 2. Taxonomy and distribution

The genus *Streptocephalus* is a small freshwater crustacean in the order Anostraca, which along with other genera in the same order such as *Artemia* and *Branchinella*, are commonly identified as fairy shrimp. However, concerning differences in habitat between them, the term brine shrimp usually applied to saltwater Anostracans in order to distinguish them from freshwater Anostracans. Furthermore, the order Anostraca is separated into two suborders, which are Artemiina and Anostracina. The suborder Artemiina consists of two genera in families Artemiidae and Parartemiidae, which live in saltwater. The suborder Anostracina consist of 21 genera in six families, which mostly live in freshwater. The genus *Streptocephalus* is in the suborder Anostracinain the family Streptocephalidae [9, 19-21].

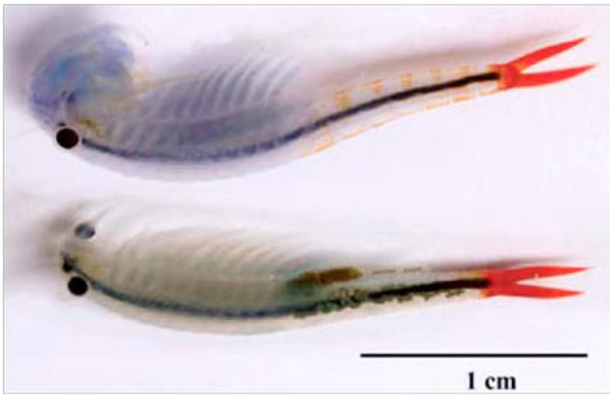


**Figure 1.** Samples of fairy shrimp *Streptocephalus sirindhornae* [9]

Mostly found in vernal ponds as well as freshwater lakes, *Streptocephalus* distributions remarkably ranged from temperate to tropical zones across Central and North America, Africa, Eurasia, and Australia. Their natural habitat predominantly is in a tropical region and further extended to temperate region as far as northern Volga River, Russia (*S. torvicornis*) in the northern latitude, to Cape Town, South Africa (*S. dendyi* and *S. gracilis*) and central west New South Wales Australia (*S. archeri*) in the southern latitude [8, 19, 21-23]. Particularly in the South East Asia region, their distribution ranged from Yunnan Province in southern China to West Java in Indonesia [7, 24].

## 3. Morphology and behavior

The body size of *Streptocephalus* ranged between 6 and 25 mm, which consists of three parts: head, thorax, and abdomen. The head part has a pair of compound eyes on stalks, unpaired median eye, two pairs of antenna, and a pair of mandibles. The thorax part consists of around 11 segments with a pair of appendages on each segment called phyllopodia. The abdomen part has eight segments with no appendage and a telson plate with a pair of caudal rami [25-27]. The main identification to characterise each species apart is on the male second antennae and frontal appendage. Although it usually only has minor roles in identification effort, the complex distal part can provide a substantial indication for further detailed taxonomical identification [21, 28-30].

The cysts of *Streptocephalus* are drought-resistant with polygonal ridges surface which might help them to avoid predation as well as slightly beneficial for species identification. The cyst can keep the embryo remain viable for many years. They hatch after about 12 - 48 hours in the water, able to reach maturity in 1 to 3 weeks after hatch, and could start to reproduce within 2 to 3 months period during their lifetime [21,30,31]. When they reach maturity, the males will actively detects and chases the females, start copulation, and fertilized the eggs. One male can fertilize as many as 15 females, and sometimes more than one male is required to fertilize a female. The females are able to reproduce a new clutch of eggs every 2 days [32-34].

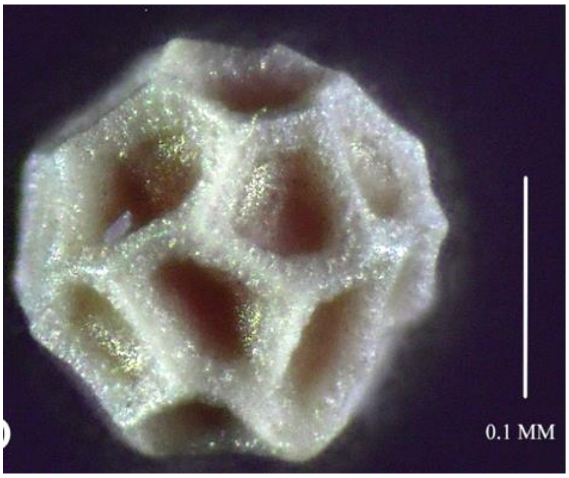


**Figure 2.** Samples of the cyst of *Streptocephalus shinsawbuae* [35]

The natural lifespan of *Streptocephalus* ranged between 4 and 6 months, with some species can reach up to 12 months under laboratory condition. Generally, males have a longer lifetime than females. Their main food sources mostly are microalgae and phytoplankton, especially for the juvenile, with zooplankton and other small crustacean also as an additional food source as they grow. Their optimum water temperature in their habitat range from 24 to 31°C, with pH 5-7 and dissolved oxygen 1.1-13.0 mg/l[36-40].

The fairy shrimp *Streptocephalus* have relatively high mortality rate especially at early stages of their lifespan as a result of their extremely unstable environment which temporarily dry in one period and wet in another period, predation by another organism, and cannibalism by adults. Consequently, they develop the ability to reproduce massively, grow rapidly, and produce robust and enduring cyst [27, 34, 41,42]. In a controlled and maintained environment, these capabilities make them highly potential as an alternative live feed in aquaculture industry, which could assure the continuous vast amount of food supplies especially for the early larval stages of aquatic freshwater creatures such as fish, prawns, and ornamental shrimp [43].

## 4. Fairy shrimp *Streptocephalus* as live feed in aquaculture

A number of studies have observed the suitability of fairy shrimp *Streptocephalus* as a live feed in aquaculture industry, especially for feeding the larvae of fish and shrimp. For example, [44] and [45] reported the successful culture of tilapia (*Oreochromis* sp.) at larval stages by feeding them with fairy shrimp nauplii of species *S. proboscideus*. The study conducted by [3] resulted in considerable improvement in weight gain and growth of angelfish *Pterophylum scalare* larvae by using decapsulated cyst of *S. dichotomus* as live feed. Additionally, study conducted by [43] proposed the use of mass cultured *S. proboscideus* cyst as a suitable candidate for feeding the Persian sturgeon, *Acipenser persicus* larvae. Furthermore, [46-48] confirmed the high nutritional value of *S. dichotomus* and *S. Sirindhornae* nauplii which resulted in improvement of growth, survival rate, and carotenoid content of giant freshwater shrimp *Macrobrachium rosenbergii*.

Several studies have also pointed out some advantages of using fairy shrimp *Streptocephalus* compared to formulated feeds and artemia as the most popular live food source in aquaculture. For example, when using artemia to feed freshwater animals, they have to be delivered frequently since artemia can only live in saline water, and they will die soon after they were transferred to freshwater. Consequently, similar to formulated feeds, the uneaten artemia will accumulate at the bottom of the pond and affects negatively to water quality. This will leads to toxic build-up, generate some diseases, and increase the mortality rate of the cultured species, especially in a farm with low water exchange.

Therefore, in freshwater aquaculture, using freshwater live feed instead of saltwater one significantly reduce the frequency of feeding as well as water toxicity [37,39]

Fairy shrimp *Streptocephalus* nauplii have high nutritional value (in g $kg^{-1}$ dry weight) such as protein, lipid, essential amino acids (EAA), total amino acids (TAA), polyunsaturated fatty acids (PUFA), and carotenoid. For instance, the comparison is shown in Table 1. They have high value of protein (546 ±5) and lipid (255 ±2) which is quite similar to Artemia with crude protein 538±4 and lipid 187 ±0.3, but higher than commercial formulated feeds (protein 414 ±2; lipid 64 ±0). They also have higher TAA (458.96 ±2.32) and EAA (66.63%) than Artemia (451.12 ±2.13; 39.32%) and formulated feeds (289.93 ±1.54; 31.79%). They also have higher amount of PUFA (105.02 ±0.27) than Artemia (43.86 ±1.92) and formulated feeds (28.42 ±1.56), which are very useful for their predators to gain metabolism energy and size growth in the form of triglycerides. Moreover, they have high-level content of total carotenoid complex (114- 323 µg $g^{-1}$) which can improve the body coloration of ornamental fish fed with them as well as reproductive function, immune system, and stress tolerance [5,6,51-55].

**Table 1.** Comparison of nutritional content of *Streptocephalus*, Formulated Feeds, and Artemia

| Nutritional Content | Streptocephalus | Commercial Formulated Feeds | Artemia |
|---|---|---|---|
| **Protein** | 546 ± 5 [a]* | 414 ± 2 [a]* | 538 ± 4 [a]* |
| | 64.65 - 74.41[b]** | - | 56.25[b]** |
| **Lipid** | 255 ± 2 [a]* | 64 ± 0 [a]* | 187 ± 0.3 [a]* |
| | 6.23 - 9.34 [b]** | - | 13.49 [b]** |
| **Essential Amino Acids (EAA)** | 66.63 [a]** | 31.79 [a]** | 39.32 [a]** |
| | 63.76 - 65.64 [b]** | - | 31.1 [b]** |
| **Total Amino Acids (TAA)** | 458.96 ± 2.32 [a]* | 289.93 ± 1.54 [a]* | 451.12 ± 2.13 [a]* |
| | 784.92 [b]* | - | - |
| **Polyunsaturated Fatty Acids (PUFA)** | 105.02 ± 0.27 [a]* | 28.42 ± 1.56 [a]* | 43.86 ± 1.92 [a]* |
| | 5.47 - 44.34 [b]** | - | 16.8 [b]** |

*Notes:*
[a] [55] * g kg-1 dry weight
[b] [6] ** percentage

The production of the cyst of *Streptocephalus* can be done in both indoor and outdoor culture system. In the tropical climate region, the cyst can be produced throughout the entire year. However, unlike *Artemia*, the cyst of *Streptocephalus* naturally sink to the bottom of the water. Consequently, it is much easier to execute the production of their cyst in a small indoor tank rather than in a large outdoor pond, since the effort to harvest it at the bottom of the outdoor pond are much more challenging and time-consuming than at the indoor tank [26,43]. It also worth noting that the cyst production of *Streptocephalus*is varied between species. Their cyst production is also affected by the type and amount of diets as well as environmental conditions (pH, DO, salinity, and temperature) in both quantity and quality, which is in identical circumstances as Artemia except in salinity. Subsequently, their number of cysts per female is also relatively similar, with average number of cysts per female per brood of *Streptocephalus* range between around 40 and 200 [29,39,43,56,57] and *Artemia* between 30 and 265 [58-60].

## 5. Live feed in Indonesian aquaculture

Indonesia currently is the world third largest aquaculture producers (not including aquatic plants and non-food products) after China and India, with total number of production reached 6.15 million tonnes and valued USD 11.9 billion in 2017 [61]. Aquaculture in Indonesia is separated into 3 categories based on water salinity: marine, brackishwater, and freshwater. The marine aquaculture mostly operated in coastal areas with grouper and red snapper as the main commodities. The brackishwater aquaculture most commonly situated in estuarine with commodities mainly shrimp and milkfish. The freshwater aquaculture typically conducted in inland water such as lake, swamp, pond, and paddy field, with tilapia and catfish as the highest volume products [62].

The aquaculture hatchery in Indonesia predominantly uses *Artemia* as live feed, while few of them use others such as *Tubifex*, *Moina*, and *Daphnia*. The dependency on *Artemia* is excessive that its import number reached 40 tonnes and valued around USD 4 million a year in 2016 [63]. Various efforts are needed in order to be able to deal with this incredibly high demand for *Artemia* in Indonesia while aiming to reduce the import quantity. Some of the efforts include an attempt by the government of Indonesia to increase the number of Artemia production locally by commencing a pilot project which encourages the salt farmers to allocate a portion of their farmland to run the Artemia farming as well [63]. Some other efforts involve the use of alternative live feeds such as *Moina*, *Daphnia,* and *Tubifex* to substitute *Artemia* [64-68].

However, a number of studies also showed the superiority of *Artemia* compared to other existing entities as a live feed in aquaculture, particularly in Indonesia. Although the price of *Artemia* cyst is relatively higher than other stated live feed, the superiority of *Artemia* is not only on its nutritional content but also on its simple application, market availability, and continuous supply [65,67-69]. In contrast, the use of *Streptocephalus* as an aquaculture live feed in Indonesia is perhaps almost non-existence. Considering the biological and morphological characteristics of fairy shrimp *Streptocephalus,* which has strong resemblance with *Artemia,* especially on their cysts, as well as the tropical climate of Indonesia, the opportunity of fairy shrimp *Streptocephalus* as a live feed in this country is highly prospective for continuous production. Regarding the mass production and market availability, the use of alternative live feed besides *Artemia* is challenging. It is mainly suggested to utilize the intensive and small-scale culture of *Streptocephalus* in order to get good results [26,34,43].

For many decades, the fairy shrimp *Streptocephalus*has been inaccurately regarded by many fish farmers in Indonesia as a pest as well as food competitor [13,14,70]. This is most likely the cause of its near-absence in aquaculture activities in Indonesia to date. There are only a few literature in Indonesia which have been found noting these creatures related to aquaculture, and most, if not all, of them, have continued to depicts *Streptocephalus* as an unsolicited being in aquaculture activities [10,15-18]. On the contrary, in many other countries, the fairy shrimp *Streptocephalus* has been studied, examined, and successfully implemented as an alternative live feed in aquaculture [3,26,42,43,48].

Several studies have mentioned the vulnerability of fairy shrimp *Streptocephalus* to black disease, a bacterial pathogen predominantly of *Aeromonas* spp., occurs visibly by black spots at some parts of the body which caused mortality as well as reduced life span [29,34,71,72]. However, this situation is not only limited to fairy shrimp but also to brine shrimp as well as many other aquatic animals. Infections caused by *Aeromonas* spp. are normally occurs in many aquatic species, especially when they are in relatively stressful environments which includes fluctuation of water quality, overpopulation, and lack of food. It requires strict water quality management to reduce stress as well as applied some treatments such as probiotics to deal with the disease [34,71-74].

## 6. Conclusion

The use of fairy shrimp *Streptocephalus* as a live feed in Indonesia, as a country located in the tropical region, is really prospective for continuous production throughout the year. Although it is difficult to acquire the massive, extensive, and large-scale production similar to *Artemia*, the intensive and small-scale production of *Streptocephalus* is highly achievable. With their high nutritional value which is relatively higher than *Artemia*, their suitability as aquaculture live feed in some other countries, their reproductive ability, and their advantages as a freshwater creature, fairy shrimp *Streptocephalus* are potential to develop as an alternative and sustainable live feed in Indonesia, especially for local and small scale fish farmer.

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