Enrichment of commercial feed for striped snakehead fry 
(*Channa striata*) with golden snail (*Pomacea* sp.) flour

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**Abstract.** The striped snakehead *Channa striata* is a highly nutritious and economically valuable food fish. Wild populations are declining due to habitat degradation and conversion as well as overexploitation. To promote sustainable use of this resource, a striped snakehead domestication program was initiated in 2013. Earlier research found that golden snail (*Pomacea* sp.) was suitable as a natural feed for the grow-out of striped snakehead juveniles. This study focused on the formulation of feed for fry, applying a fully randomised experimental method with 5 replicates. Each experimental unit (aquarium with aeration) contained four striped snakehead fry (total length 3.42 ± 0.21 mm). The feed treatments used commercial HI-PRO-VITE 782 feed, with golden snail flour added in 4 doses: A (0%), B (20%), C (25%), D (30%). Total length and weight were measured weekly; water quality and survival were monitored. Overall, the length-weight relation was allometric negative. In terms of both length and weight, growth was highest under treatment C and lowest under treatment A. Growth was significantly different between treatments: A and C for length and weight (analysis of variance with Tukey post-hoc test, α=0.05). Growth patterns and condition factor varied between treatments, with treatment C yielding better balanced growth compared to B (slower increase in length) and D (slower weight gain). Survival rate did not differ significantly between treatments. We conclude that enrichment of commercial feed (HI-PRO-VITE 782) with golden snail flour can improve striped snakehead fry growth, with 25% the most effective dose.

1. Introduction

The striped snakehead *Channa striata* is considered a valuable native freshwater food fish in many Asian countries [1,2], including Indonesia [3,4]. The flesh of *C. striata* is highly nutritious. In addition to exceptionally high albumin content [5], a growing body of research on other bioactive substances extracted from *C. striata* is increasing the range of substances and products with considerable benefits for human health. One example is the wound-healing effect of the *C. striata* striatin protein fraction [6]. Awareness of the health benefits to be derived from snakeheads, consumed directly or in the form of processed nutraceutical and medicinal products, is driving an increase in demand for *C. striata* [2–6].

Wild *C. striata* populations are vulnerable to land-use change [7], likely to be a growing threat as wetlands around the world come under increasing pressure from direct anthropogenic pressures and climate change [8,9]. Concerns over declining populations are reported from a growing number of...
regions across the species distribution [2], with declines mostly attributed to fishing pressure combined with habitat degradation or conversion [2,4,7]. To promote sustainable use of this resource, a domestication program for the striped snakehead (local name ikan gabus) was initiated in Central Sulawesi in 2013 [4,10]. Feed plays a key role in aquaculture. For sustainability, feed formulations must not only fulfil the dietary requirements of cultured organisms at all stages of the life-cycle, but must also take into account the source and environmental impact of the feed ingredients [11]. Feed ingredients also need to be readily available at an economically viable price.

In the wild, C. striata appears to be an opportunist, with a varied but predominantly carnivorous diet comprising nekton, zooplankton, zoobenthos, and detritus [12]. Reported food items include fish, insects including chironomid larvae; larval and adult amphibians; molluscs (slug and snails); crustacea (crabs, shrimp, crayfish); reptiles (snakes, turtles); worms; nematodes; and even plant debris [12–14]. The golden snail Pomacea canaliculata has been found in the guts of sub-adult and adult C. striata (standard length SL ≥ 24 cm) [14], and has also been used as bait for catching C. striata [12].

In Asia, the golden snail is an invasive alien species [14,15] which has become a common paddy field pest, in particular in the Philippines [15] and Indonesia [4,16]. In many areas where golden snails are currently a pest with little if any value, their collection as natural feed or as an ingredient in cultured fish feed could benefit both rice agriculture and aquaculture [4,15,16]. The use of golden snail as an alternative source of protein could reduce the need for commonly-used feeds or feed ingredients, in particular those whose use may have negative socio-economic and/or environmental impacts.

Golden snail flour has been used in feed formulations for several cultured species including the mud crab Scylla paramamosain [17] and the rabbitfish Siganus guttatus [15]. Reported golden snail protein content varies from around 30% (wet weight) [16] to around 50-60% (dry weight) [18]. The high protein content suggests that golden snail could be suitable as a feed or feed component for carnivorous fish, and golden snail has been found suitable as a natural feed for the grow-out of C. striata fingerlings [16] and juveniles [4].

Availability of fresh golden snails as natural feed is likely to vary, in particular with irrigated rice farming cycles. Furthermore, preparation can be labour-intensive, especially if intended as feed for younger (small) fish. One solution is to process golden snails as flour when they are abundant. This flour can then be incorporated into feed formulations, including pelleted artificial feed. This study focused on the formulation of feed for C. striata fry. The research objective was to evaluate the suitability and determine the optimal proportion of golden snail flour to enrich a widely available artificial feed during the early life-stages of C. striata seed grow-out.

2. Materials and Methods

2.1. Experimental set-up and materials

This study applied a fully randomised experimental method with four treatments and five replicates. Each of the 20 experimental units comprised an aquarium (equipped with aeration) containing four striped snakehead (Channa striata) fry (total length 3.42±0.21 mm). The C. striata fry were obtained from a fish farmer in Pendolo, Poso District, Central Sulawesi Province, Indonesia and acclimated for three days prior to the start of the experimental treatments. Throughout the 30 day experimental period, the fry were fed three times a day at 08:00, 12:00 and 16:00 local time (GMT+8).

Water quality was monitored to ensure the parameters measured remained within the ranges considered appropriate for the husbandry of tropical freshwater fish such as C. striata. Temperature and pH were measured daily, while dissolved oxygen (DO) and ammonia (NH3) were measured at the beginning and end of the experiment.

Golden snail flour was produced in-house. Golden snails were obtained live, then boiled and removed from their shells. The intestines and other internal organs were removed and the meat was oven-dried for 3 days. The dried meat was weighed and ground to produce golden snail flour.

The golden snail flour was added as a partial replacement for a base feed (high-protein commercial pelleted artificial feed, brand-name HI-PRO-VITE 782). This feed had been used successfully for
rearing *C. striata* fry, and could be considered as a control. The commercial pelleted feed was also crushed to enable homogenous mixing of the two feed ingredients. For each experimental feed formulation, appropriate quantities of snail flour and crushed pellets were weighed and the dry ingredients were thoroughly mixed. Water was added to produce a suitable firm consistency and a pelleting machine was used to produce pellets of a size suitable for *C. striata* fry. The pellets were oven-dried and stored in dark, dry conditions.

### 2.2. Experimental treatments

The four experimental feed treatments (% golden snail flour in the feed formulation) were: A (0%, control), B (20%), C (25%), D (30%). The nutritional content (protein and lipids) of each feed formulation (treatment) is shown in Table 1.

#### Table 1. Nutritional content (wet weight) of the four experimental treatments (feed formulations)

| Treatment | % Golden Snail Flour | Lipids (%) | Protein (%) |
|-----------|----------------------|------------|-------------|
| A         | 0                    | 6          | 40          |
| B         | 20                   | 5.03       | 36.09       |
| C         | 25                   | 11.36      | 39          |
| D         | 30                   | 13.90      | 43.70       |

1Manufacturer’s data (feed label); 2Proximate analysis by the Livestock Technology Laboratory, Faculty of Animal Husbandry and Fisheries, Tadulako University, Palu

### 2.3. Parameters and data analysis

Total length (TL, in mm) and body weight (W) of each *C. striata* fry were measured weekly and survival was monitored daily. Data were tabulated in Microsoft Excel (Microsoft Office 2010) and analysed using R for Windows v.3.4.2 [19], implemented in RStudio v.1.1.456 [20].

The mean growth in total length (GL), the mean increase in body weight (GW), and the survival rate (SR) for each experimental unit were calculated as:

\[
\begin{align*}
GL &= L_t - L_0 \\
GW &= W_t - W_0 \\
SR(\%) &= \frac{100 \cdot N_0 - N_t}{N_t - 1}
\end{align*}
\]

where: 

- \(L_0\) and \(W_0\) are the mean initial length and weight of the fry 
- \(L_t\) and \(W_t\) are the mean final length and weight of the fry 
- \(N_0\) and \(N_t\) are the initial and final number of live fry in the unit

Growth pattern was determined for each treatment and for all surviving fry based on the parameter \(b\) of the length–weight relation \(W = a \cdot L^b\) (Keys 1928 in [21]), where \(W\) is the wet weight in g and \(L\) is the total length in mm. Growth pattern was considered isometric if \(b \approx 3\), allometric positive/negative for \(b > 3\) and \(b < 3\) respectively. The value of \(b\) was determined from a linear regression of the log-transformed variables (L and W), leading to an equation of the form \(\log(W) = \log(a) + b \cdot \log(L)\).

Fulton’s condition factor \(K\) [21] was calculated for each fry in each treatment as:

\[
K = \frac{100 \cdot W \cdot (L^3)^{1/3}}{(L^3)^{1/3}}
\]

where: 

- \(W\) (g) and \(L\) (cm) are the length and weight of the fry

The results were analysed descriptively and compared with other studies. Analysis of variance (ANOVA) was conducted (aov function in R) to compare the values of GL, GW, SR, and K between treatments, followed by the Tukey honestly significant difference (HSD) post-hoc test (TukeyHSD function in R) if differences were significant (at \(\alpha=0.05\)).
3. Results

3.1. Growth (increase in length, weight gain)
In terms of both length and weight, growth was highest under treatment C and lowest under treatment A (Table 2). Growth was significantly different between treatments (ANOVA, \( p < 0.05 \)). The post-hoc Tukey test rejected the null hypothesis (equal mean values) for growth in both length and weight for treatments A and C.

Table 2. Growth (mean and standard deviation SD) in total length (TL) and body weight (W) for \( C. striata \) fry under four feed treatments

| Code | Treatment | Growth in TL (mm) mean | SD | Growth in W (g) mean | SD |
|------|-----------|------------------------|----|----------------------|----|
| A    | 0         | 0.72                   | 0.15| 0.12                 | 0.03|
| B    | 20        | 0.82                   | 0.06| 0.16                 | 0.03|
| C    | 25        | 1.02                   | 0.13| 0.20                 | 0.05|
| D    | 30        | 0.86                   | 0.16| 0.14                 | 0.02|

3.2. Growth pattern and condition factor
Length-weight parameters (Table 3) show allometric negative growth patterns (\( b < 3 \)) overall and for each treatment. Condition factor \( K \) varied significantly between treatments. The lm function in R showed a significant difference between A and D (\( p < 0.05 \)) and highly significant difference between C and A (\( p < 0.01 \)) but not between B and A. The null hypothesis rejected (Tukey post-hoc test, \( \alpha = 0.05 \)) for treatments A and C and treatments B and C (Table 4). The mean value of \( K \) was lowest for the fry under treatment C (mean 0.62, SD 0.05), intermediate for treatment D (mean 0.64, SD 0.08) and highest for treatments A and B (mean 0.70, SD 0.13 and 0.08, respectively).

Table 3. Length-weight relation (\( L=aL^b \)) parameter \( a \), parameter \( b \) with standard error (SE) and coefficient of determination (\( r^2 \)), and growth pattern for \( C. striata \) fry (end of trial length-weight data)

| Code | Treatment | \( a \) value | \( b \) SE | \( r^2 \) | Growth pattern |
|------|-----------|---------------|------------|---------|----------------|
| A    | 0         | 0.000386      | 1.918      | 0.586   | 0.433          | Allometric negative |
| B    | 20        | 0.000066      | 2.404      | 0.410   | 0.696          | Allometric negative |
| C    | 25        | 0.000047      | 2.466      | 0.301   | 0.817          | Allometric negative |
| D    | 30        | 0.000181      | 2.111      | 0.425   | 0.638          | Allometric negative |
| All treatments combined | | 0.000178 | 2.124 | 0.201 | 0.635 | Allometric negative |

Table 4. Condition factor \( K \) pairwise Tukey post-hoc test significance levels (p values above the diagonal, significance levels at \( \alpha = 0.05 \) below the diagonal)

| Treatment code | A | B | C | D |
|----------------|---|---|---|---|
| A              | **|   | * |   |
| B              | ns| **|   |   |
| C              | * | ns| **| ns|
| D              | ns| ns| ns| **|

* = significant at \( \alpha = 0.05 \) (\( p < 0.05 \)); ns = not significant at \( \alpha = 0.05 \) (\( p < 0.05 \))

3.3. Survival rate
Survival rate (SR) was over 80% for all treatments (Table 4). Although SR was slightly lower for treatment D than for treatments A, B and C, SR did not differ significantly between treatments.
Table 5. Survival rate (SR) with standard deviation (SD) for C. striata fry

| Code | % golden snail flour | SR (%) | SD  |
|------|----------------------|--------|-----|
| A    | 0                    | 88     | 11  |
| B    | 20                   | 88     | 18  |
| C    | 25                   | 88     | 18  |
| D    | 30                   | 84     | 9   |
|      | All treatments combined | 87 | 13 |

4. Discussion

4.1. Growth and survival of C. striata fry

The survival of C. striata fry was high under all treatments. As the commercial feed (treatment A, control) was known to have been used to successfully rear C. striata fry, this indicates that all treatments provide adequate (although not necessarily optimal) nutrition. Compared to the control (A), C. striata fry growth (length and weight) was significantly higher under treatment C, and higher (albeit not significant at α = 0.05) under treatments B and D, indicates that enrichment of commercial feed with golden snail flour has a positive effect. The addition of golden snail flour can be considered to enrich the feed formulation, with an optimum dose or proportion around 25%.

The proximate analysis (Table 1) indicates one possible reason for these results. Although both lipid and protein content increased with the proportion of golden snail flour from treatment B to D, protein content was similar to the control in all treatments but lipid content was not. In terms of protein content, all feed formulations used in this study were below the optimum range of circa 45-50% [22]. Thus, further protein enrichment could potentially increase growth compared to the best-performing feed formulation (C) in this study.

With respect to lipids, the treatment producing the highest growth in both length and weight (C) had a lipid content (≈11%) approximately twice that of treatments A (control) and B (5-6%). Dietary lipid content is reported to have a significant influence on the growth of C. striata fry, and above optimal levels circa 7-11.5% growth tends to decrease in line with lipid content up to an upper tolerance level of around 19% [22]. Based on [22], the lipid content of feed treatments A and C was sub-optimal, while treatment D lipid content (≈14%) was markedly above the optimum range. Thus, treatment C was the only treatment within a lipid content within (albeit close to the upper limit) of the optimal range for C. striata fry feed in [22].

There are indications that C. striata flesh quality may be higher with feed lipid content closer to the upper limit (≈11%) as in treatment C than the lower limit (≈7%) under the feed formulations in [22], however further research would be necessary to determine the effect (if any) of lipid content from feed enrichment with golden snail flour.

4.2. Growth patterns and fry condition

The length-weight parameter b values from our study (all treatments combined) and other studies (Table 6) show that growth patterns in C. striata can vary greatly, from allometric negative to allometric positive. The low value of b in this study provides additional support for the suggestion in [23] that the growth pattern of C. striata may vary with life-stage. When plotting the growth curve, [23] found a discontinuity at around 60-70 mm TL and poor support (low r²) for a length-weight relation obtained through regression based on all size classes; separate analysis of two size classes resulted in allometric negative growth pattern for fry and fingerlings and an isometric or allometric positive pattern for larger juveniles and adults.
Table 6. Length-weight parameter $b$ values from this study and other studies on $C. striata$

| Origin            | Sample          | $n$ | TL (mm)    | value | b     | SE  | $R^2$ | Growth pattern | Reference/remarks |
|-------------------|-----------------|-----|------------|-------|-------|-----|-------|----------------|------------------|
| Indonesia, Central Sulawesi | 66              | 36-50 | 2.12       | 0.20  | 0.64  |     |       | A-             | This study       |
|                   |                 |     | (1.92-2.47)|       |       |     |       | (4 treatments) |                  |
|                   | 90              | 38-63 | 2.62       | 0.11  | 0.96  |     |       | A-             | [23]             |
|                   | 90              | 64-143| 2.99       | 0.06  | 0.98  |     |       | I              | [23]             |
|                   | 492             | 38-231| 3.05       | -     | 0.99  |     |       | I              | [4]              |
| Indonesia, Kalimantan | 180             | 75-280| 2.69       | -     | 0.91  |     |       | A-             | [24] male        |
|                   | 150             | 120-335| 2.91      | -     | 0.97  |     |       | I              | [24] female      |
|                   | 330             | 75-335| 2.92       | -     | 0.97  |     |       | I              | [24] both sexes |
| India             | 100             | 35-45 | 3.89-4.11  | -     | 0.806 |     |       | A+             | [25]             |
|                   | 126             | 109-424| 3.0-3.96  | 0.89-0.93 | 0.99 |     |       | I to A+        | [25]             |
|                   | 772             | 20-306| 2.88       | 0.013 | 0.99  |     |       | A-             | [26]             |
| China             | 13              | 106-393| 2.99      | -     | 0.98  |     |       | I              | [27]             |
| Various           | -               | -    | 2.72-2.95  | -     | 0.86-0.96 |     |       | A- to I        | [1]              |

$^1$I = Isometric; A- = Allometric negative; - = no data. $^2$ mean of 6 values; - = no data

Growth pattern and condition factor varied between treatments. Although the post-hoc Tukey tests on length and weight gain only indicated significant differences between treatments A and C, the values obtained for the length-weight parameter $b$ indicate differences in growth pattern between all four treatments. The higher coefficient of determination ($r^2$) for treatment C indicates less variability, and thus more consistent growth. Based on the net growth in weight and length (Table 2), the growth in fry under treatments B and D was similar; however the fry under treatment D grew more in length but less in weight than those under treatment B, as reflected in the $b$ values. This difference corresponded to longer thinner fry in treatment D and shorter plumper fry in treatment B.

The condition factor K takes into account the relation between L and W. Factors influencing K can include age/life-stage, health, nutritional status and sex [24]. Counter-intuitively, the mean value of K was lowest for the fry under treatment C, which had the highest $b$ value and the highest average growth (length and weight). The much lower value of the parameter $a$ could explain this result, despite the higher value of $b$ and the higher growth in both length and weight. Combined with the higher growth, lower between replicate and between individual variability in growth and growth patterns under treatment C indicate an optimal level of enrichment with golden snail flour circa 25%.

5. Conclusion
We conclude that enrichment of commercial feed (HI-PRO-VITE 782) with golden snail flour can improve striped snakehead ($Channa striata$) fry growth, with 25% the most effective dose. We recommend further research on $C. striata$ feed formulation using golden snail flour, including different $C. striata$ life-stages, a variety of different base ingredients and/or additives, and the effects on flesh quality as well as growth.

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References
[1] Froese R and Pauly D 2019 FishBase, The Global Database of Fishes. http://www.fishbase.org (version 04/2019) [Accessed 05 April 2019]
[2] Rahman M A and Awal S 2016 Development of Captive Breeding, Seed Production and Culture Techniques of Snakehead Fish for Species Conservation and Sustainable Aquaculture *Int. J.*
Pomacea canaliculata – on the growth and imitate change: The role of wetland restoration in a

Amilhat E and Lorenzen K 2005 Habitat use, population dynamics and migration pattern of chevron snakehead Channa striata in a rainfed rice farming landscape J. Fish Biol. 67 23–34

Dudgeon D, Arthington A H, Gessner M O, Kawabata Z I, Kolar C S, Naiman R J, Prieur-Richard A H, Soto D, Stiassny M L J and Sullivan C A 2006 Freshwater biodiversity: Importance, threats, status and conservation challenges Biol. Rev. Camb. Philos. Soc. 81 163–82

Erwin K L 2009 Wetlands and global climate change: The role of wetland restoration in a changing world Wetl. Ecol. Manag. 17 71–84

Ndobe S, Madinawati, Serdiati N, Syukri and Moore A 2017 Pertumbuhan Benih Ikan Gabus Channa striata dengan Pakan Cacing Darah Beku [Growth of snakeheads (Channa striata) with frozen bloodworm feed] J. Sains Teknol. Akuakultur 1 104–10

Pahlow M, van Oel P R, Mekonnen M M and Hoekstra A Y 2015 Increasing pressure on freshwater resources due to terrestrial feed ingredients for aquaculture production Sci. Total Environ. 536 847–57

Talde C M, Mamaril SR A C and Palomares M L D 2004 The diet composition of some economically important fishes in the three floodplain lakes in Agusan Marsh wildlife sanctuary in the Philippines Asian Pac. J. Aquat. Sci. 9 45

Lee P G and Ng P K L 1994 The systematics and ecology of snakeheads (Pisces: Channidae) in Peninsular Malaysia and Singapore Hydrobiologia 285 59–74

Kuan-Chung L, Bao-Sen S, Yuh-Wen C, Da-Ji H and Shih-Hsiung L 2016 Growth, diet composition and reproductive biology of the invasive freshwater fish Chevron snakehead Channa striata on a subtropical Island Zool. Stud. 55 1–11

Visca M D and Palla S Q 2018 Golden apple snail, Pomacea canaliculata meal as protein source for rabbitfish, siganus guttatus culture AACL Bioflux 11 533–42

Ditari K D, Alamshaj M A and Luqman E M 2013 Substitution effect of Artemia spp. with golden snail (Pomacea canaliculata) and worm (Lumbricus rubellus) on the growth and protein retention of snakehead seed (Channa striata). J. Ilm. Perikan. dan Kelaut. 5 157–61

Sadinar B, Samidjan I and Rachmawati D 2013 Pengaruh Perbedaan Dosis Pakan Keong Mas Dan Ikan Rucah Pada Kejiting Bakau (Scylla paramamosain) Terhadap Pertumbuhan dan Kelulushidupan Dengan Sistem Battery di Tambak Tugu, Semarang [The effect of golden snail and trash fish dose in feed on mangrove crab (Scylla paramamosain) growth and survival with a battery system in Tugu pond, Semarang J. Aquac. Manag. Technol. 2 84–93

Adebayo-Tayo B C, Onilude A A and Etuk F I 2011 Studies on microbiological, proximate mineral and heavy metal composition of freshwater snails from Niger Delta Creek in Nigeria. Adv. Agric. Environ. Eng. 3 10–3

Kottelat M, Whitten A J, Kartikasari S and Wirjoatmodjo S 1996 Freshwater fishes of Western Indonesia and Sulawesi (Singapore: Periplus TD)

Ndobe S, Serdiati N and Moore A 2014 Domestication and Length-Weight Relationship of Striped Snakehead Channa striata (Bloch) Proceedings of International Conference of Aquaculture Indonesia (ICAI) (Bandung: Masyarakat Akuakultur Indonesia (MAI)) pp 165–72

Mustafa A, Widodo M A and Kristianto Y 2012 Albumin And Zinc Content Of Snakehead Fish (Channa striata) Extract And Its Role In Health IEESE Int. J. Sci. Technol. 1 1–8

Rahayu P, Marcelline F, Sulistyaningrum E, Suhartono M T and Tjandrawinata R R 2016 Potential effect of striatin (DLBS0333), a bioactive protein fraction isolated from Channa striata for wound treatment Asian Pac. J. Trop. Biomed. 6 1001–7

Amilhat E and Lorenzen K 2005 Habitat use, population dynamics and migration pattern of chevron snakehead Channa striata in a rainfed rice farming landscape J. Fish Biol. 67 23–34

Dudgeon D, Arthington A H, Gessner M O, Kawabata Z I, Knowler D J, Lévêque C, Naiman R J, Prieur-Richard A H, Soto D, Stiassny M L J and Sullivan C A 2006 Freshwater biodiversity: Importance, threats, status and conservation challenges Biol. Rev. Camb. Philos. Soc. 81 163–82

Erwin K L 2009 Wetlands and global climate change: The role of wetland restoration in a changing world Wetl. Ecol. Manag. 17 71–84

Ndobe S, Madinawati, Serdiati N, Syukri and Moore A 2017 Pertumbuhan Benih Ikan Gabus Channa striata dengan Pakan Cacing Darah Beku [Growth of snakeheads (Channa striata) with frozen bloodworm feed] J. Sains Teknol. Akuakultur 1 104–10

Pahlow M, van Oel P R, Mekonnen M M and Hoekstra A Y 2015 Increasing pressure on freshwater resources due to terrestrial feed ingredients for aquaculture production Sci. Total Environ. 536 847–57

Talde C M, Mamaril SR A C and Palomares M L D 2004 The diet composition of some economically important fishes in the three floodplain lakes in Agusan Marsh wildlife sanctuary in the Philippines Asian Pac. J. Aquat. Sci. 9 45

Lee P G and Ng P K L 1994 The systematics and ecology of snakeheads (Pisces: Channidae) in Peninsular Malaysia and Singapore Hydrobiologia 285 59–74

Kuan-Chung L, Bao-Sen S, Yuh-Wen C, Da-Ji H and Shih-Hsiung L 2016 Growth, diet composition and reproductive biology of the invasive freshwater fish Chevron snakehead Channa striata on a subtropical Island Zool. Stud. 55 1–11

Visca M D and Palla S Q 2018 Golden apple snail, Pomacea canaliculata meal as protein source for rabbitfish, siganus guttatus culture AACL Bioflux 11 533–42

Ditari K D, Alamshaj M A and Luqman E M 2013 Substitution effect of Artemia spp. with golden snail (Pomacea canaliculata) and worm (Lumbricus rubellus) on the growth and protein retention of snakehead seed (Channa striata). J. Ilm. Perikan. dan Kelaut. 5 157–61

Sadinar B, Samidjan I and Rachmawati D 2013 Pengaruh Perbedaan Dosis Pakan Keong Mas Dan Ikan Rucah Pada Kejiting Bakau (Scylla paramamosain) Terhadap Pertumbuhan dan Kelulushidupan Dengan Sistem Battery di Tambak Tugu, Semarang [The effect of golden snail and trash fish dose in feed on mangrove crab (Scylla paramamosain) growth and survival with a battery system in Tugu pond, Semarang J. Aquac. Manag. Technol. 2 84–93

Adebayo-Tayo B C, Onilude A A and Etuk F I 2011 Studies on microbiological, proximate mineral and heavy metal composition of freshwater snails from Niger Delta Creek in Nigeria. Adv. Agric. Environ. Eng. 3 10–3
[22] Hua K, Koppe W and Fontanillas R 2019 Effects of dietary protein and lipid levels on growth, body composition and nutrient utilization of *Channa striata* *Aquaculture* **501** 368–73

[23] Ndobe S, Serdiati N and Moore A 2013 Upaya Domestikasi Melalui Pembesaran Ikan Gabus (*Channa striata*) di Dalam Wadah Terkontrol [Early domestication of the striped snakehead (*Channa striata*) in a controlled environment] *Proceedings of Konperensi Akuakultur Indonesia 2013* (Masyarakat Akuakultur Indonesia (MAI)) pp 165–75

[24] Ahmadi A 2018 The length-weight relationship and condition factor of the threatened snakehead (*Channa Striata*) from Sungai Batang River, Indonesia *Polish J. Nat. Sci.* **33** 607–23

[25] Dayal R, Srivastava P P, Bhatnagar A, Chowdhary S, Lakra W S, Raizada S and Yadav A K 2014 Comparative Study of WLR of *Channa striatus* Fry- Fingerling, Grow-Outs and Adults of Gangetic Plains *Online J. Anim. Feed Res.* **2** 174–6

[26] Kumar D, Marimuthu K, Haniffa M A and Sethuramalingam T A 2008 Effect of Different Live Feed on Growth and Survival of Striped Murrel *Channa striatus* larvae *Ege Univ. J. Fish. Aquat. Sci.* **25** 105–10

[27] Li Q, Xu R and Huang J 2013 Length-weight relations for 20 fish species from the Pearl River, China *Acta Ichthyol. Piscat.* **43** 65–9