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**Proceeding:**

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**Thesis, Dissertation:**

Sugiyarto. 2004. Soil Macro-invertebrates Diversity and Inter-Cropping Plants Productivity in Agroforestry System based on Sengon. [Dissertation]. Universitas Brawijaya, Malang. [Indonesian]

**Information from internet:** Balagadde FK, Song H, Ozaki J, Collins CH, Barnet M, Arnold FH, Quake SR, You L. 2008. A synthetic Escherichia coli predator-prey ecosystem. Mol Syst Biol 4:187. www.molecularsystembiology.com


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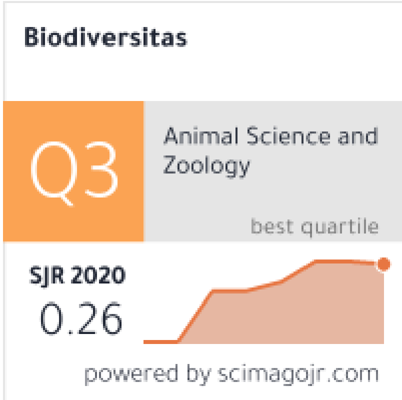


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# Feeding ecology of *Neoarius leptaspis* in the Rawa Biru Lake, Merauke, Indonesia

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**Abstract.** *Wibowo DN, Rukayah S, Wahayu NL, Mote N. 2022. Feeding ecology of* Neoarius leptaspis *in the Rawa Biru Lake, Merauke, Indonesia. Biodiversitas 23: 1327-1335.* A few studies have been carried out on *Neoarius leptaspis* (Bleeker, 1862), however, its feeding ecology was not examined, especially for the sample from Rawa Biru Lake, Merauke, Papua, Indonesia. Therefore, this study aims to analyze the feeding ecology of *N. leptaspis* at 8 sampling sites in the lake, which were sampled in the morning and evening. The parameters observed were natural food diversity, mouth width ratio, intestine length ratio, stomach fullness and content, preponderance index, and electivity index. The result showed that 25 plankton species were observed in the waters. *Neoarius leptaspis* has a mouth width ratio of approximately 75% of head width. The full stomach was observed in the samples collected in the evening, where the diets were dominated by animal materials as indicated by the indexes of preponderance and electivity. The mouth width ratio, feeding periodicity, intestine length, and dominant diets were similar to the previous reports on the same species from other regions. This showed that *N. leptaspis* is a predatory fish species based on the feeding ecology data, which provides essential information for fisheries and conservation.

**Keywords:** Ariidae, catfish, food habit, lake, trophic level

## INTRODUCTION

The availability and distribution of fish food in the water system are essential for their growth and fisheries. Meanwhile, different food availability and distribution can alter the feeding ecology of fish species living in the various water system. Feeding ecology can be assessed through the analysis of feeding periodicity (Dypvik and Kaartvedt 2013; Schneider et al. 2014), food habit (Johnson et al. 2012; Day et al. 2014), mouth width (Faye et al. 2012), and natural food availability (Albertson et al. 2018; Pusey et al. 2020; Thoral et al. 2021). Feeding periodicity provides information about foraging time, whether diurnal or nocturnal (Johnson et al. 2012; Dypvik and Kaartvedt 2013), while food habits and availability give information on food selection and nutritional shift (Thoral et al. 2021). Fish are classified into herbivorous, omnivorous, carnivorous, planktivorous, and detritivorous (Henriques et al. 2017; Edem and 2018), which described their trophic level (Henriques et al. 2017). The food habit of a fish species is determined by stomach contents (Gupta and Banerjee 2014) because their consumption varies according to body size (Babut et al. 2017; Edem and Opeh 2018; Jacobson et al. 2018). Moreover, Huang et al. (2021) and Tesfahun and Temesgen (2018) also stated that after increasing the body size, the fish change and adapt to food needs, mouth opening capability, and food availability in nature.

The catfish from the Ariidae family belongs to Siluriformes, with members widely distributed in the tropics and temperate (Marceniuk et al. 2017), including Southeast Asia and East Asia (Isa et al. 2012). It has a relatively high economic value (Kottelat et al. 1993), no scales, adipose fins, forked caudal fin, spine in both pectoral and dorsal fins, short anal fin, wide nostrils that are behind with one tentacle nose, and ceiling jagged (Salini et al. 1990; Froese and Pauly 2021).

Rawa Biru Lake is located in the Wasur National Park area, Merauke, Papua, Indonesia, with 413.810 hectares (Figure 1). It is the largest wetland in Papua (Mote and Wibowo 2016) and is used as a water source of Merauke city and for artisanal fisheries. The geographic position of Rawa Biru Lake is at 8°03' to 9°06'S, and 140°30' to 14°00'E (Wasur National Park Institute 2009). Previous studies reported fish diversity in Rawa Biru Lake (Mote and Wibowo 2016). Feeding ecology study of fish from Rawa Biru Lake has also been conducted on Nile Tilapia, *Oreochromis niloticus* (Setiawati and Pangaribuan 2017). The food habit of *Arius (Neoarius) leptaspis* was also determined in the Australian waters (Salini et al. 1990; Blaber et al. 1994; Salini et al. 1998). However, there is no study about the feeding ecology of *N. leptaspis* from Rawa Biru Lake, Merauke, Papua, Indonesia. According to Froese and Pauly (2021), *N. leptaspis* is an opportunistic feeder that consumes small animals, plants, and detritus, which are dominated mainly by animal materials.

Moreover, this species was classified as carnivorous species, specifically piscivorous (Salini et al. 1990; Blaber et al. 1994). Nevertheless, previous studies reported nutritional shifts in several fish species due to food availability (Dhanker et al. 2012; Sanchez-Hernandez and Cobo 2015; Thoral et al. 2021). Therefore, to test the possibility of nutritional shifts on *N. leptaspis*, it is important to study its feeding ecology.

This study aims to determine the feeding ecology of *N. leptaspis* in the Rawa Biru Lake, Merauke, Papua. Meanwhile, the information is essential for *N. leptaspis* conservation and the domestication effort of the species.

## MATERIALS AND METHODS

### Sampling location

The samples of *N. leptaspis* were collected in the central parts of Rawa Biru Lake, Merauke, Papua, Indonesia (Figure 1). Sampling was carried out at 8 sites (Figure 1) and the geographic position of each site is shown in Table 1.

### Procedures

*Sampling effort*

Fish samples were collected at the predetermined sampling sites by the fishers operating in the Rawa Biru Lake, using a fishnet with a mesh size of 0.5, 1, 2, and 3 inches and a total diameter of 6 meters. The samples were collected three times (August, September, and October 2015) with replications at an interval of a month in the morning (05.00-08.00 am) and evening (04.00-07.00 pm). Subsequently, the fish was sorted according to their general morphology and were preserved in 10% formalin.

*Fish identification and body measurement*

Identification is a vital step in ecological study to provide accurate information about the species. In this study, fish identification was carried out at the Laboratory of Fisheries Management, Faculty of Agriculture Universitas Musamus Merauke, Papua. Stomach content analysis and plankton identification were conducted at the Ecology Laboratory and Environmental Laboratory of Faculty of Biology Jenderal Soedirman University Purwokerto. Subsequently, the identification process was completed based on morphological characteristics according to Kottelat et al. (1993), and names validity was checked by comparing the result to the information available in FishBase (Froese and Pauly 2021).

**Table 1.** The geographic position of sampling sites in the Rawa Biru Lake, Merauke, Papua, Indonesia

| Station | Coordinates |
|---|---|
| 1 | S 08⁰41’53,5’’ E 140⁰51’050” |
| 2 | S 08⁰41’24,7’’ E 140⁰51’202” |
| 3 | S 08⁰40’51,0’’ E 140⁰51’17,7” |
| 4 | S 08⁰45’28,8’’ E 140⁰57’16,7” |
| 5 | S 08⁰40’12,7’’ E 140⁰52’54,1” |
| 6 | S 08⁰39’33,5’’ E 140⁰53’07,6” |
| 7 | S 08⁰39’32,4’’ E 140⁰53’23,1” |
| 8 | S 08⁰29’22,0’’ E 140⁰53’25,8” |

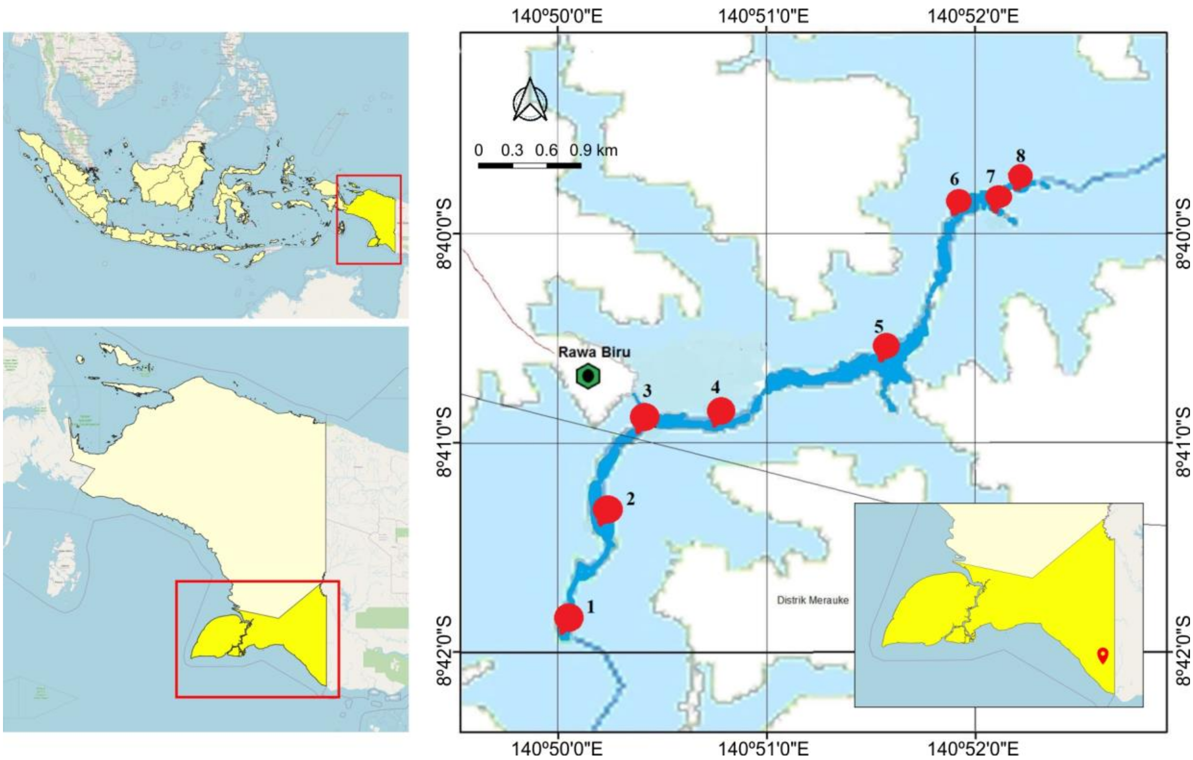


**Figure 1.** Map of Rawa Biru Lake, Merauke, Papua, Indonesia indicating the sampling sites of *Neoarius leptaspis*

The specimen of valid species was subjected to the standards length measurement, which was estimated using a millimeter block and ruler with a precision of 0.1 centimeters (cm). During the measurement, the head of the fish was positioned on the left side (Figure 2).

*Feeding ecology*

Several parameters related to the feeding ecology of *N. leptaspis* were measured and estimated. These parameters included plankton diversity in the water samples, mouth position and width, feeding periodicity, relative gut length (RGL), and stomach content. The analysis of stomach content was carried out to calculate the index of preponderance (IP) and index of electivity (Ei).

*Plankton sampling and identification.* The plankton net used has a mesh size specification of 25, a mouth diameter of 30 cm, and a trapezium height of 75 cm. At each sampling point, water was taken using a bucket that has a volume of 10 liters. The water was filtered 10 times, so the total volume of filtered water was approximately 100 liters. Next, the 50 µL collection bottle was removed from the plankton net. The mixtures of collected plankton were transferred into a new collection bottle and preserved using formalin until the final concentration of formalin became 4% and added 2 drops of pure lugol (Sastranegara et al. 2020). Observations and identification of plankton were carried out under a binocular microscope with a magnification of 10x40. The stages of plankton identification were as follows. The water sample was homogenized by slowly inverting the sample bottle. One drop of a water sample is placed on an object-glass, then the cover glass is blown and the plankton is observed under a light microscope (Sachlan 1982). The plankton obtained were identified using the key of determination from Sachlan (1982) and Davis (1995). Observations were made in 20 fields of view by sliding the glass object ten steps to the right direction, one step-up, and then ten steps to the left direction. Plankton abundance was calculated using the following formula (Sachlan 1982).

Abundance = [(A/B) x (C/D) x (E/F)] individu/litre

Where:
A : water volume in bottle sample (ml)
B : water volume observed (ml)
C : cover glass width ($mm^2$)
D : view field number (20)
E : number of plankton individual
F : total volume of filtered water (100L)

*Mouth position and width*. The mouth position determination was based on its relative position to the snout tip. The mouth width was determined by measuring the distance between the left and right sides of the maxilla when the mouth was opened. The measurement was also conducted using a millimeter block and ruler with the precision 0f 0.1 cm.

*Feeding periodicity*. Feeding periodicity was determined based on stomach fullness. Fish samples were grouped based on sampling times (morning at 05.00 -08.00 and evening 16.00-19.000 East Indonesia Time). The stomach fullness was determined for each group fish sample and estimated using the modified formula from:

SF= [DW (gram)/EW (gram)] x 100%

Where:
SF : stomach fullness
DW : stomach content
EW : body weight without viscera

*The relative gut length (RGL) measurement*. The relative gut length was calculated by dividing gut length (GL) by standard body length (SL). The calculation was performed using the following formula (Gupta and Banerjee 2014; and Alabssawy et al. 2019).

**Figure 2.** Body and intestine length of *Neoarius leptaspis*

**Table 2.** The method for water quality parameter measurement in the Rawa Biru Lake Merauke, Papua, Indonesia

| Parameter | Unit | Method | References |
|---|---|---|---|
| Water acidity (pH) | - | Universal pH paper 1-14 | APHA 2005 |
| Dissolved oxygen (DO) | mg/L | Winkler method | APHA 2005 |
| Dissolved carbon dioxide ($CO_2$) | mg/L | Titration method | APHA 2005 |
| Temperature | °C | Mercury thermometer | APHA 2005 |

RGL= [GL (cm)/SL (cm)] x 100%

Where:
RGL : relative gut length
GL : gut length
SL : standard length

*Stomach content analysis*. Stomach content analysis was initiated by dissecting all *N. leptaspis* specimens, which was conducted to remove the digestive organ from the abdominal cavity. Fish dissection started from the anus to the rear of the operculum. The surgery was carried out by placing blunt scissors in the body cavity to avoid damage to the digestive organs. The volume of digestive organs was measured by putting them into a measuring cup filled up with specific volume. Moreover, the digestive organs volumes are in different forms between the initial and the final volume of water after the organs are inserted into the measuring cup. The digestive organs (feed) contents are removed and collected in a sample bottle labeled, while a formalin solution of 4% was added until the entire feed was submerged.

In the microscope observation, the stomach content was homogenized and the large feed was identified under loops, while small ones were observed under a binocular microscope. Subsequently, a drop of homogenized stomach content was put on the object-glass. The feed observations were carried out at 20 view fields with five replications for each sample and were identified based on Sachlan (1982) and Davis (1955). According to Sachlan (1982) and Davis (1955), natural food that mainly consisted of plankton was also identified. The feeding habit of the fish was determined based on the preponderance (IP) index and electivity (Ei) index.

The index of preponderance was used to estimate stomach fullness and was calculated using the formula below (Natarajan and Jhingran after Gupta and Banerjee 2014).

$$IP = (Vi \times Oi) / (\Sigma(Vi \times Oi)) \times 100\%$$

Where:
IP : index of preponderance
Vi : percentage of $i^{th}$ plankton
Oi : frequency of $i^{th}$ plankton

Index of electivity was used to determine the most preferred food items by the species. This index was calculated using the following formula (Ageili et al. 2013).

$$Ei = (ri - pi) / (ri + pi)$$

Where:
Ei : electivity index
ri : relative number of organisms that are eaten
pi : relative number of organisms in the water

*Water quality measurement*

The feasibility of water quality as a fish habitat was estimated by measuring four vital parameters; water acidity (pH), dissolved oxygen (DO), dissolved carbon dioxide ($CO_2$), and water temperature. Meanwhile, the water quality parameters are shown in Table 2.

### Data analysis

The data on mouth type was analyzed descriptively by comparing observation results and information available in the literature. Similarly, feeding periodicity was analyzed based on the stomach fullness, while feeding habits data were determined descriptively according to the literature.

## RESULTS AND DISCUSSION

### Fish identification and body measurement

A total of 16 fish species were found during biodiversity surveys in the Rawa Biru Lake Merauke, Papua in 2015 (Table 3). The total species obtained was categorized as high species diversity even though even though it is at the lowest value for the high category. According to NCDENR (2006) An ecosystem is said to have high fish diversity if it is inhabited by more than or equal to 16 species.

Thirty-eight fish specimens were identified as a member of Ariidae. Careful and detailed identification placed two specimens as *Arius spatula* and 36 specimens as *Neoarius leptaspis*. The specimens of *A. spatula* were obtained from sampling station number 1. Moreover, most part of the samples (25 individuals) of *N. leptaspis* were obtained from sampling station 1, less from station 4 (7 individuals) and 6 (4 individuals). Fish samples were not obtained from stations 2, 3, 5, 7, and 8. *N. leptaspis* is a catfish species that lives mostly in the lower reaches of river to brackish water, but it could also be found in the upper stream areas (Froese and Pauly 2021). Therefore, it was a logical reason that we found more specimens at station 1 because that station is located in downstream of the Rawa Biru Lake.

The collected *N. leptaspis* had a standard body length, ranging from 11.2 cm to 43.5 cm (25.357±8.179 cm). The maximum length was shorter than the 48.0 cm of the results obtained from the Australian region (Blaber et al., 1994) and those summarized by Froese and Pauly (2021), which is 60.0 cm. Although the maximum size of 43.5 cm was less than the Australian water, it was assumed to have passed the first reproductive cycle. The assumption was that gonad maturity reached level 5 during sampling in September and October. The *N. leptaspis* samples had gonad maturity levels ranging from 1 (8%) to 5 (25%). The majority of samples collected in September and October had reached the gonad maturity level ranging between 4 (19%) and 5 (25%). These two highest gonad maturity levels indicated that *N. leptaspis* were ready to spawn and the phase was already reached at the standard body size of 25.7 cm.

The *N leptaspis* population from Rawa Biru Lake was smaller than reported in the previous study by Blaber et al. (1994) in the Gulf of Carpentaria Australia. It could be due to its potential extreme pH condition in Rawa Biru Lake Merauke. Meanwhile, a pH value of 5 (Table 2) is an inhibiting factor for optimum growth of *N. leptaspis* since the value was below the standard for fish life. The effect of low pH on fish growth operates via physiological and cytological disturbances, including increasing blood viscosity (Srineetha et al. 2013; Kwong et al. 2014; Mota et al. 2018) and lowering appetite and food intake (Abbink et al. 2012; Kennedy and Picard 2012). Those physiological and cytological disturbances result in reducing growth fish growth rate (Abbink et al. 2012; Kennedy and Picard 2012).

## Water quality parameter

Water quality of Rawa Biru Lake was estimated based on the measurement of four parameters; water acidity (pH), dissolved oxygen (DO), dissolved carbon dioxide ($CO_2$), and water temperature. The average values of four water quality parameters are presented in Table 4. Based on the water quality standard class 3, the mean values of three water quality parameters were in an allowable value for fisheries (Governmental Law of the Republic of Indonesia No. 82 Year 2021). Theses parameters were dissolved oxygen, dissolved carbon dioxide, and temperature. In contrast, the pH value was slightly below standard values (pH 6-9) for fisheries. Even though fish could cope environment with pH ranging between 5-9, but pH 5 was not optimum and might become a limiting factor for fish growth (Abbink et al. 2012; Kennedy and Picard 2012).

## Feeding ecology

*Plankton diversity*

Microscopic observation and plankton identification that were collected from Rawa Biru Lake placed samples into phytoplankton and zooplankton. Out of the 25 species of plankton that were identified, 19 species belong to phytoplankton and 6 from the zooplankton (Table 5). The phytoplankton consisted of 4 classes, while only 2 classes composed zooplankton group.

We observed a higher number of plankton species than Santosa and Satria (2015), who was also sampled plankton from the wetland ecosystem in Merauke, Papua. We found 25 plankton species from Rawa Biru Lake, Merauke consisted of 19 phytoplankton and six zooplankton, while Santosa and Satria (2015) obtained 15 phytoplankton and five zooplankton. However, the present study and the study by Santosa and Satria (2015) both obtained a low plankton diversity compared to other studies (Satria and Santosa 2016). Low plankton diversity of both current and study by Santosa and Satria (2015) be because similar water characteristics were observed between both studies, particularly in waters' pH. The Rawa Biru Lake had waters' pH of 5, and other wetland areas of Merauke (Santosa and Satria 2015) has pH values ranging between 4.64 and 5.64. Both pH values indicate that the water in the Merauke wetlands tends to acid. Comparison to another study in Kumbe River Merauke (Satria and Santosa 2016) proved that the present study obtained a lower plankton diversity. Satria and Santosa (2016) observed 57 plankton genera.

**Table 3.** Fish species found during biodiversity surveys in the Rawa Biru Lake Merauke, Papua, Indonesia

| Lokal name (Merauke) | Scientific name | Collection time | |
|---|---|---|---|
| | | Morning | Evening |
| Kakap rawa | *Lates calcarifer* | - | +++ |
| Gabus Irian | *Channa* | - | + |
| Pelangi | *Iriatherina* sp. | +++ | - |
| Sumpit | *Strongylura krefftii* | +++ | - |
| Neon | *Craterocephalus randi* | + | - |
| Ton tobi | *Pingalla lorentzi* | +++ | + |
| Duri mata kecil | *Arius spatula* | - | + |
| Musin | *Glossamia sandei* | + | ++ |
| Arwana | *Scleropages jardinii* | - | + |
| Duri mata besar | *Neoarius leptaspis* | + | +++ |
| Loreng | *Toxotes chatareus* | + | ++ |
| Loreng bersuara | *Amniataba affinis* | ++ | ++ |
| Mata bulan | *Megalops cyprinoides* | + | + |
| Musin kuning | *Glossamia* sp. | + | + |
| Sembilang hitam | *Porochilus meraukensis* | + | ++ |
| Sembilang kuning | *Plotosus papuensis* | + | + |

Note: +: low number; ++: moderate number; +++: abundant (high number); -: absent

**Table 4.** Average values of four water quality parameters in the Rawa Biru Lake Merauke, Papua, Indonesia

| Parameter | Unit | Sampling station | | | | | | | | Mean±SD |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| Water acidity (pH) | - | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5.00 ±0.00 |
| Dissolved oxygen (DO) | mg/L | 3.19 | 3.20 | 2.46 | 3.00 | 2.78 | 3.47 | 2.55 | 7.10 | 3.47 ± 1.51 |
| Dissolved carbon dioxide ($CO_2$) | mg/L | 4.36 | 3.10 | 2.83 | 1.07 | 5.17 | 6.23 | 6.63 | 6.24 | 4.45 ± 1.98 |
| Temperature | °C | 26 | 27 | 27 | 28 | 29 | 26.5 | 27 | 27 | 27.19 ± 0.92 |

**Table 5.** Plankton diversity and abundance in the Rawa Biru Lake during the study.

| Classis/species | Abundance (cell/L) | | | | | | | | Mean±SD |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| **Phytoplankton** | | | | | | | | | |
| **Cyanophyta** | | | | | | | | | |
| *Dactyloccocopsis raphidioides* | 437 | 0 | 874 | 2,185 | 2,622 | 2,185 | 3,059 | 3,933 | 1,911.875±1,360.778 |
| *Microcystis aeruginosa* | 1,748 | 2,185 | 3,496 | 5,244 | 3,059 | 1,748 | 1,311 | 2,622 | 2,676.625±1,267.354 |
| *Anabaena circularis* | 2,622 | 3,496 | 3,933 | 5,244 | 874 | 3,059 | 1,311 | 3,496 | 3,004.375±1,410.008 |
| *Anabaena hallensis* | 2,185 | 3,059 | 4,807 | 6,118 | 5,244 | 3,496 | 2,622 | 2,185 | 3,714.500±1,495.682 |
| *Oscillatoria sancta* | 3,059 | 3,496 | 2,622 | 3,933 | 2,185 | 2,622 | 3,059 | 4,807 | 3,222.875±840.181 |
| *Oscillatoria limosa* | 2,185 | 3,933 | 1,748 | 2,185 | 3,933 | 3,059 | 3,059 | 4,370 | 3,059.000±963.101 |
| *Trichodesmium erythraeum* | 874 | 1,748 | 874 | 874 | 874 | 1,748 | 2,185 | 2,622 | 1,474.875±698.322 |
| *Merismopedia* sp. | 3,059 | 1,748 | 1,311 | 1,311 | 1,748 | 874 | 437 | 0 | 1,311.000±934.345 |
| **Chlorophyta** | | | | | | | | | |
| *Oocytus naegelii* | 2,622 | 3,059 | 4,807 | 3,933 | 3,059 | 874 | 437 | 874 | 2,458.125±1,583.183 |
| *Kirchneriella lunaris* | 874 | 0 | 874 | 2,185 | 1,311 | 1,748 | 2,622 | 874 | 1,311.000±842.208 |
| *Raphidium polymorphum* | 874 | 1,748 | 2,185 | 3,496 | 3,496 | 2,622 | 1,748 | 874 | 2,130.375±1,029.835 |
| *Scenedesmus quadricauda* | 3,059 | 3,496 | 2,185 | 1,748 | 1,311 | 0 | 0 | 874 | 1,584.125±1,299.242 |
| **Chrysophyta** | | | | | | | | | |
| *Micrasterias foliacea* | 5,244 | 3,933 | 3,059 | 2,185 | 1,311 | 2,185 | 874 | 437 | 2,403.500±1,618.334 |
| *Straurastrum* sp. | 1,748 | 2,185 | 2,622 | 3,933 | 874 | 1,748 | 1,311 | 874 | 1,911.875±1,016.503 |
| *Cyclotella* sp. | 0 | 0 | 2,185 | 3,059 | 2,185 | 1,311 | 874 | 2,185 | 1,474.875±1,118.718 |
| **Phyrophyta** | | | | | | | | | |
| *Peridinium inconspicuum* | 3,059 | 1,748 | 2,622 | 3,933 | 2,622 | 2,185 | 1311 | 874 | 2,294.250±984.117 |
| *Peridinium globulus* | 3,496 | 2,185 | 5,681 | 6,118 | 3,933 | 6,992 | 4807 | 874 | 4,260.750±2,059.670 |
| *Gonyaulax oatenata* | 437 | 1,311 | 1,748 | 2,622 | 3,496 | 874 | 1748 | 1,311 | 1,693.375±975,415 |
| *Ceratium tripos* | 874 | 1,311 | 3,059 | 3,933 | 2,622 | 1,748 | 2622 | 1,311 | 2,185.000±1,044.630 |
| **Zooplankton** | | | | | | | | | |
| **Rotatoria** | | | | | | | | | |
| *Brachionus angularis* | 0 | 437 | 4,807 | 5,244 | 2,622 | 3,059 | 3496 | 3,933 | 2,949,750±1,894.067 |
| *Schizocerea diversicornis* | 0 | 874 | 437 | 874 | 437 | 1,748 | 2622 | 1,311 | 1,037.875±840.181 |
| *Asplanchna herricki* | 1,311 | 2,185 | 2,622 | 3,933 | 1,311 | 874 | 2622 | 3,059 | 2,239.625±1,029.835 |
| **Entomostraca** | | | | | | | | | |
| *Ceriodaphnia quadrangula* | 0 | 0 | 4,807 | 3,933 | 2,185 | 437 | 1311 | 1,311 | 1,748.000±1,794.211 |
| *Diaptomus gracilis* | 0 | 2,185 | 0 | 437 | 0 | 0 | 0 | 0 | 327.750±765.864 |
| *Cyclops* sp. | 437 | 1,311 | 3,933 | 3,059 | 437 | 874 | 0 | 0 | 1,256.375±1,466.905 |

The difference between our study and the study by Satria and Santosa (2016) was also caused by water characteristics. Water pH in Maro River Merauke ranged from 4 to 6.5 (acid to neutral), while the current study observed water pH in Rawa Biru Lake was 5. The difference of water pH between Maro River and Rawa Biru Lake indicates that the plankton community is strongly affected by water quality, especially phytoplankton. It was also reported that phytoplankton was more sensitive to water quality alteration than zooplankton (Meng et al. 2017; Borics et al. 2021), including water velocity and nutrients (Wu et al. 2019). Therefore, it was reasonable that we found lower phytoplankton diversity because acidic water in the Rawa Biru Lake is hazardous for living organisms and a limiting factor for several aquatic organisms, including phytoplankton.

Comparing between plankton identified from the water (Table 3) and from the stomach (Table 4) seems only two out of 16 phytoplankton genera (19 species) were consumed by *N. leptaspis*, i.e., *Anabaena* and *Oscillatoria*. The data was reasonable because *N. leptaspis* is a carnivore species that consume more animals than plant materials, including phytoplankton (Salini et al. 1990; Blaber et al. 1994; Salini et al. 1998). The statement was supported by a higher IP value for animal materials (66.34 to 78.50%) than for plant materials (21.5 to 33.60%). However, we could not compare between zooplankton in the water and inside the stomach because we could not identify the zooplankton into species level. According to Manko (2016), it is frequently that we are unable to identify stomach content at the species level because the food component has been digested, and only particular food remaining are left in the stomach.

*Mouth type*

Visual observation on the mouth position showed that the mouth of *N. leptaspis* is slightly below the snout tip, which indicates that the species has a subterminal mouth. A previous study by Oliveira et al. (2018) reported that a fish's mouth could be inferior, subterminal, terminal, or superior. Moreover, the subterminal mouth position is among catfish characteristics (Wright and Bailey 2012), including a member of Siluriformes (Marceniuk et al. 2017), which consists mainly of carnivore species (Chattopadhyay et al. 2014). The discovered subterminal mouth of *N. leptaspis* was because they belong to Siluriformes (Marceniuk et al. 2017).

The current discovery and a report by Blaber et al. (1994) stated that the width of the mouth opening *N.*

*leptaspis* is a stable morphological character, where the increase in body size increases the mouth openings. Based on the individual body size, the maximum mouth width was between 1.5 cm and 5.1 cm, approximately 75% of head width. The observed mouth opening width was similar to the previous report by Blaber et al. (1994), showing that the environment did not affect the mouth width of *N. leptaspis*.

*Feeding periodicity*

This study obtained more *N. leptaspis* samples in the evening than in the morning sampling. Based on the measurement of stomach content volume, the evening sample group has a full stomach with maximum fullness of 100%. Meanwhile, maximum stomach fullness in individuals collected in the morning was 50%. These values indicated that *N. leptaspis* is a nocturnal forager species. Previous studies also showed that nocturnal fish has a maximum stomach fullness in the evening until night (Dypvik and Kaartvedt 2013; Schneider et al. 2014). The present finding in line with the characteristic of catfish that this fish group is a nocturnal forager.

*Stomach content*

The relative gut length (RGL) values were ranged from 0.6 to 1.2. The values showed that *N. leptaspis* has a shorter to slightly longer stomach than its standard body length (SL). Therefore, it was categorized as short gut because the ratio values were between 0.5 to 2.4 for carnivorous fish (Gupta and Banerjee 2014; Idrus et al. 2021). According to the observed values of relative gut length, *Neoarius leptaspis* can be categorized as carnivorous species. It was also reported that herbivorous fish have RGL, ranging from 3.6 to 6.0. Furthermore, the RGL values of omnivorous fish ranged from 1.3 to 4.3, while carnivorous fish varied between 0.5 and 2.4 (Gupta and Banerjee 2014; dos Santos et al. 2015).

After dissection, it was discovered that, out of 36 individuals, the stomachs of 35 fish contained food, while the remaining individuals had an empty stomach. The food items observed inside the stomach were phytoplankton, zooplankton, plant litter, and animal fragments. Meanwhile, a detailed food identified from *N. leptaspis* is shown in Table 6. This result showed that *N. leptaspis* had a broad range of food types, which is similar to the previous studies in the Australian region (Salini et al. 1990; Blaber et al. 1994; Salini et al. 1998) that *N. leptaspis* has a broad range of food items.

Based on the primary food component observed inside the stomach, *N. leptaspis* has a similar index of preponderance (IP) during sampling periods. The IP values of the animal compound were ranged from 66.34 to 78.50%, while that of plant materials varied between 21.5 and 33.66%. This showed that *N. leptaspis* food was dominated by animal materials and can be categorized as carnivore fish species. Previous studies showed that fish with dominant food components from animal materials could be classified as carnivore species (Chattopadhyay et al. 2014; Gupta and Banerjee 2014; Alabssawy et al. 2019). Moreover, Salini et al. (1998) has also stated that *N. leptaspis* is predator fish, which indicates that the species is carnivorous.

**Table 6.** Food items observed in the stomach of *Neoarius leptaspis*

| Group | Food item |
|---|---|
| Animal | Shrimp, fish, worm, fish fragments, insect, zooplankton |
| Plant | Plant fragments and phytoplankton (*Anabaena, Lyngbya, Nitzschia, Synedra, Tabellaria, Volvox, Spirogyra, Navicula, Oscillatoria, Cymbella, Fragilaria*) |

**Table 7.** Index of electivity of food item of *Neoarius leptaspis* from Rawa Biru Lake, Merauke, Papua

| Food item | Ei value |
|---|---|
| **Chlorophyta** | |
| *Cylindrocystis brebisonii* | -1 |
| **Cyanophyta** | |
| *Lyngbya spirulinoides* | -0.2 |
| *Spirogyra prolifica* | 0.48 |
| **Chrysophyta** | |
| *Achnanthes brevipes* | -0.3 |
| *Asterionella formosa* | - |
| *Fragilaria crotonensis* | 1 |
| *Mastogloia elliptica* | -1 |
| *Navicula insuta* | -0.6 |
| *Nitzschia vermicularis* | -0.2 |
| **Xanthophyta** | |
| *Botryococcus braunii* | 0.41 |
| **Zooplankton** | |
| *Keratella aculeata* | 0.72 |
| *K.cochlearis* | -0.30 |
| *K.quadrata* | 0.42 |
| Nauplius *(Euphausia brevis)* | 0.79 |
| Nauplius *(Cyclops strenuus)* | 0.94 |
| *Rotifer neptunius* | 0.80 |

The food habit of *N. leptaspis* from Rawa Biru Lake, Merauke was also analyzed based on an index of electivity (Ei). The Ei values were negative for phytoplankton, except for some species, while positive for most zooplankton, except for *Keratella cochlearis* (Table 7). The index showed that *N. leptaspis* preferred animal materials to plant. This is in line with a previous study, which stated that *N. leptaspis* is carnivore species. According to Ageili et al. (2013), fish with positive electivity to phytoplankton and zooplankton were categorized as omnivorous species. This indicated that fish with positive election to zooplankton but negative to phytoplankton is categorized as carnivore or predator species.

In conclusion, mouth position, feeding periodicity, relative gut length, food, and feeding habits of *N. leptaspis* were substantial clues that this Ariidae (Siluriformes) species from Rawa Biru Lake, Merauke, Papua, Indonesia is carnivore species. Animal components were dominant in the stomach with positive electivity.

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