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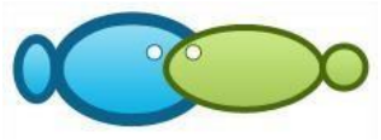

Diel catch of marine life stage of "nike" in Gorontalo waters: daily growth and morphometric body ratios

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Abstract. Nike is a Gorontalo local name for the marine life stages of amphidromous goby fish. The study compared Nike's daily growth trend and morphometric body ratio in diel times. Sampling was conducted at 7 points for 7 consecutive days during the waning crescent of Hijri Year (22 Sha'ban to 28 Sha'ban 1439), which coincides with the Gregorian Calendar of 8 to 14 May 2018. The fish were collected twice per day, representing period of the day (07.00-08.00 am) and the night (7.00-8.00 pm). 2100 larvae were gathered from Gorontalo waters using circular net fishing gear, then placed in ziplock bags and preserved with ice cubes. The total length (TL), standard length (SL), head length (HL), body depth (BD), body width (BW), and body weight (W) as morphometric aspects of samples were measured. Statistical analysis using t-test assuming equal variance was applied to test significant differences among the ratio of morphometric character values of Nike fish caught from diel time. The results revealed that an alteration in Nike's total length and average body weight did not show a consistent tendency in sync with the increase in the number of appearance days. Hence, there was an indication that the fish population consisted of more than one cohort and confirmed previous findings that the shoal was composed of multi-species. In addition, variation values of morphometric body fish ratio combination: TL/SL, BD/SL, BW/SL, HL/SL, W/SL, SL/TL, BD/TL. BW/TL, HL/TL, and W/TL can potentially be developed and utilized to track species composition and to assess Nike's population dynamics.
Key Words: amphidromous, fish larva, goby, Nike fish, Tomini Bay.

Introduction. Gorontalo waters are located in a tropical area, supporting the life of various aquatic biota. Therefore, some basic applied studies (Kono et al 2021; Padja et al 2021; Kadim et al 2022) supporting the waters' existence and function as a mega biodiversity service area are carried out continuously. The waters are part of Tomini Bay (Kadim et al 2018; Kadim et al 2019) and are situated in the area of the coral triangle initiative (Putri & Raharyo 2019; Yalindua et al 2021). The waters are inhabited by diverse marine creatures, including marine megafauna (Mustika et al 2021), pelagic fishes (Pasisingi et al 2020a; Lawadjo et al 2021; Pasisingi et al 2021a; Pasisingi et al 2021b; Pasisingi et al 2021c; Olii et al 2022), as well as amphidromous fishes called Nike.

Scientific investigation of Nike related to its biological (Pasisingi et al 2020b; Pasisingi et al 2020c) and water quality of its habitat (Salam et al 2016) aspects have been reported. Moreover, recent studies have invalidated some previous research data, such as that the species that compose the Nike was endemic (Pasisingi & Abdullah 2018), or the prediction that the larvae shoal was from a single genus, *Awaous* (Olii et al 2017). Furthermore, Sahami et al (2019a) as well as Sahami & Habibie (2021) succeeded in revealing Nike as a shoaling of goby larvae consisting of more than one species from Eleotridae and Gobiidae families.

Lately, the search for species composition of Nike shoals has been attempted using several methods. Firstly, the genetic approach uses CO1 markers (Olii et al 2019; Sahami et al 2020), which is quite costly and challenging due to limited equipment in several areas and the availability of qualified experts to interpret the results appropriately. In addition, tracing through variations in melanophore patterns to detect

species composition as what Sahami et al (2019b) did is subtle as to this point there are Nike fish with similar species showing distinct melanophore patterns. This weakens the function of the melanophore as the main attribute of a certain species considering that the larvae stage of Nike will experience changes in the melanophore body pattern along with its development and growth in nature. Another inexpensive and potential method that has recently been developed for determining the species of Nike fish in Gorontalo waters is tracing through its morphometric alterations (Sahami et al 2020; Pasisingi et al 2021b).

Nike fish speciation is an essential effort considering that the fish schooling is composed of larvae from various species, and their appearance in nature is inadequate. The first assumption that underlies this research is that there is a possibility that the composition of the Nike appearing during the day and night comes from different species; therefore, the morphometric variations might be diverse. In addition, Nike fish caught during the day and night may come from different cohorts to show various morphometric patterns. Differences in the composition of species and cohort shoaling of Nike fish potentially show variations in the response of the fish toward natural light exposure. This study aimed to compare Nike fish's daily growth trend and morphometric body ratio from Gorontalo waters between night and day capturing times.

Material and Method

Study area and sampling time. Sampling was conducted in Gorontalo waters at several points adapted to the natural appearance of the fish (Figure 1). The samples were collected from the waters in the waning crescent of Sha'ban moon of 1443 Hijri Year which was equivalent to the Gregorian calendar of early May 2018, for seven consecutive days. The sampling was carried out twice per day, representing daytime (07.00–08.00 am) and nighttime (07.00–08.00 pm) periods.

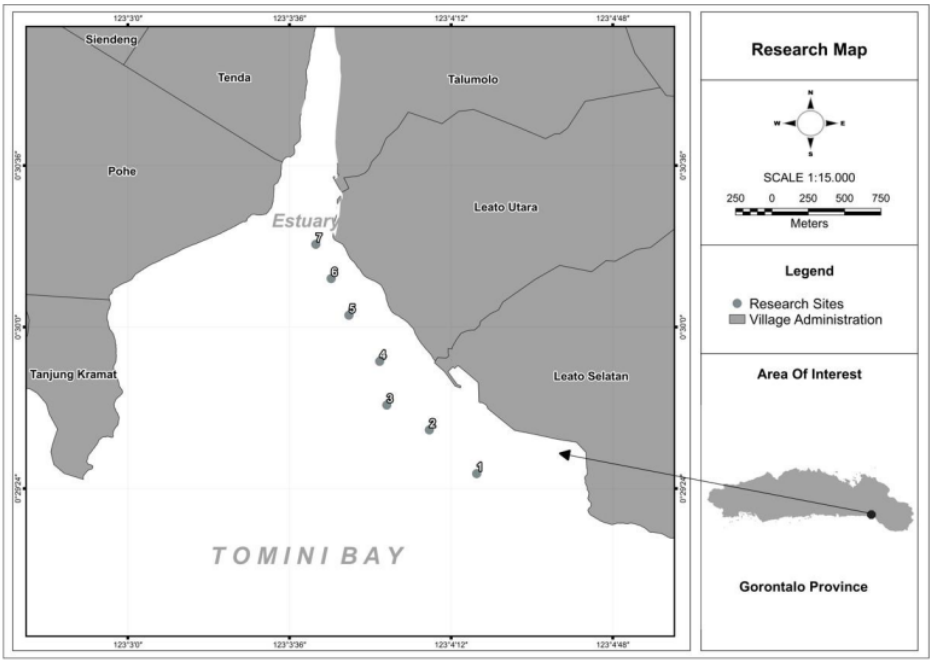

Figure 1. Location of Gorontalo waters and sampling sites; Point 1 (0°29'32.31"N 123° 4'14.66"E); Point 2 (0°29'40.30"N 123°4'6.18"E); Point 3 (0°29'47.99"N 123°3'58.79"E); Point 4 (0°29'57.74"N 123°3'56.10"E); Point 5 (0°30'4.36"N 123°3'50.42"E); Point 6 (0°30'12.41"N 123°3'47.40"E); Point 7 (0°30'19.37"N 123°3'42.33"E).

Procedures. Fish samples were collected directly from Gorontalo waters using circular net fishing gear by the local fishermen. Once a school of Nike fish was surrounded in the net, a number of the fish were gathered and placed ziplock plastic bags, labeled, and preserved using ice cubes to maintain the freshness of the samples. The five morphometric features of 2100 total samples, total length (TL), standard length (SL), head length (HL), body depth (BD), and body width (BW), were measured using a caliper with an accuracy of 0.001 cm. Additionally, the sample weight (W) was measured using a digital scale with an accuracy of 0.01 g.

Data analysis. The length and weight trend data of Nike fish from every appearance day in nature during the study was visualized by a line curve form. The ratio of morphometric characters at each sampling time was also tabulated. Statistical analysis using t-test assuming equal variance was conducted in Microsoft Excel to show whether there was a significant difference in the ratio of morphometric character values of Nike fish caught from diel time.

Results and Discussion

Population growth. Growth is related to the increase in length and body weight of an organism. The growth pattern of Nike caught during the day and night is slightly distinct. At both times, the length and weight gain of fish body were not in lines with the increase of the stage of the lunar phase. Gradually, the aggregate population of Nike in the waters did not show an increase in length (Figure 1) and weight (Figure 2). The longest and heaviest body average during night time sampling were found on the third day of sampling (24 Sha'ban 1439 or 10 May 2018) with 2.518 cm, and on the second appearance day (23 Sha'ban 1439 or 9 May 2018) of 0.172 g, respectively. Meanwhile, data from daytime sampling showed that the highest sample measurement was in the second day (23 Sha'ban 1439 or 9 May 2018) and the highest body weight was displayed in the fourth day (25 Sha'ban or 11 May 2018), with 2.601 cm in length and 0.313 g in weight.

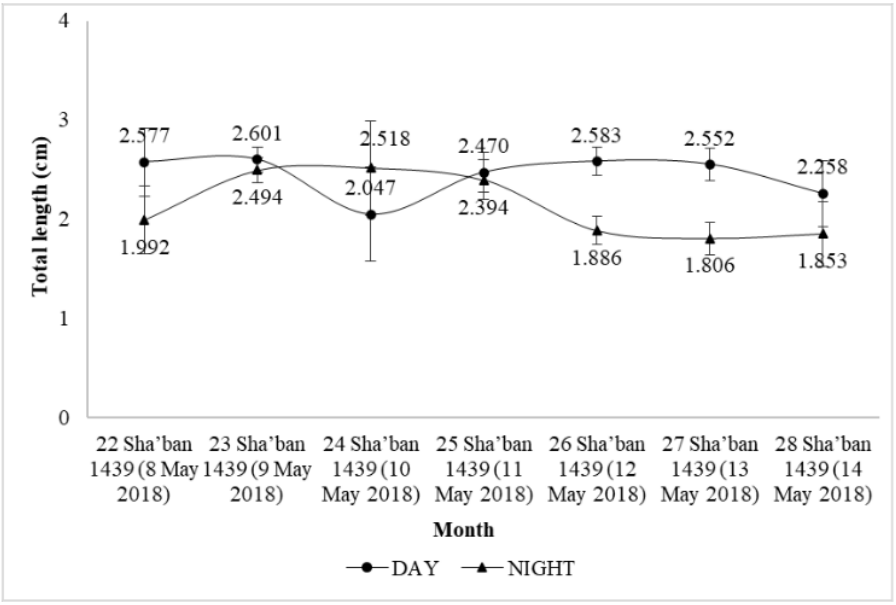

Figure 2. Comparison of total length average of Nike samples among 7 consecutive sampling days in Gorontalo waters.

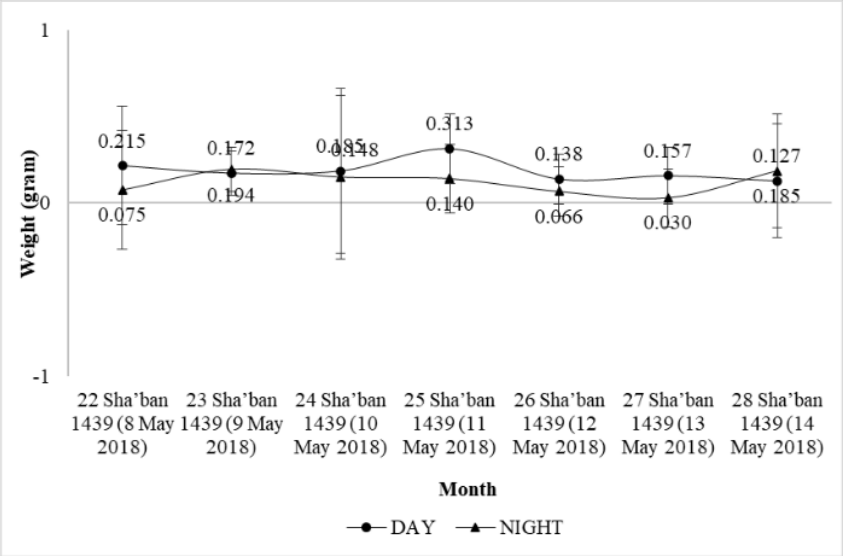

Figure 3. Comparison of body weight average of Nike samples among 7 consecutive sampling days in Gorontalo waters.

Morphometric body features. The size of each morphometric character of Nike catch from day and night times was interpreted relative to the total length and standard-length data. Each proportion showed no consistent trend with the daily order of the natural fish appearance in waters. Nonetheless, the general trend indicated that almost all character proportion values were highest in the second day (23 Sha'ban 1439 or 9 May 2018) and minimum values appeared in the fifth (26 Sha'ban 1439 or 12 May 2018) and sixth (27 Sha'ban 1439 or 13 May 2018) days (Table 1, Table 2).

Table 1

Morphometric characters ratios of Nike fish from nighttime catches for seven consecutive days during waning crescent of lunar phase

Morph. rat.	*Lunar phases*						
	22 Sha'ban (8 May 2018)	*23 Sha'ban (9 May 2018)*	*24 Sha'ban (10 May 2018)*	*25 Sha'ban (11 May 2018)*	*26 Sha'ban (12 May 2018)*	*27 Sha'ban (13 May 2018)*	*28 Sha'ban (14 May 2018)*
TL/SL	1.2384± 0.5537	1.1675± 0.0732^{mx}	1.1472± 0.0793	1.1552± 0.0753	1.1946± 0.1463	1.1552± 0.0693	1.1499± 0.0645^{mn}
BD/SL	0.0757± 0.1613^{mx}	0.0665± 0.0550	0.0172± 0.0227	0.0137± 0.0031	0.0106± 0.0060^{mn}	0.0092± 0.0035	0.0178± 0.0051
BW/SL	0.0400± 0.0669	0.0886± 0.0742^{mx}	0.0134± 0.0141	0.0132± 0.0077	0.0138± 0.0108	0.0085± 0.0032^{mn}	0.0132± 0.0041
HL/SL	0.0307± 0.0419	0.0833± 0.0693^{mx}	0.0165± 0.0119	0.0217± 0.0828	0.0125± 0.0077^{mn}	0.0161± 0.0640	0.0175± 0.0068
W/SL	0.0537± 0.0618	0.0928± 0.0263^{mx}	0.0682± 0.0168	0.0643± 0.0139	0.0302± 0.0150	0.0201± 0.0067	0.0917± 0.0300
SL/TL	0.8429± 0.1132^{mn}	0.8603± 0.0627	0.8767± 0.0749^{mx}	0.8700± 0.0690	0.8492± 0.0150^{mn}	0.8693± 0.0638	0.8722± 0.0469
BD/TL	0.0552± 0.0607	0.0569± 0.0469^{mx}	0.0150± 0.0190	0.0119± 0.0027	0.0089± 0.0050	0.0080± 0.0029^{mn}	0.0155± 0.0043
BW/TL	0.0304± 0.0300	0.0757± 0.0632^{mx}	0.0117± 0.0120	0.0114± 0.0065	0.0115± 0.0090	0.0074± 0.0028	0.0114± 0.0035^{mn}
HL/TL	0.0259± 0.0385	0.0712± 0.0593^{mx}	0.0146± 0.0116	0.0181± 0.0638	0.0105± 0.0065^{mn}	0.0139± 0.0554	0.0152± 0.0056
W/TL	0.0418± 0.0218	0.0795± 0.0219^{mx}	0.0599± 0.0166	0.0560± 0.0129	0.0253± 0.0123	0.0174± 0.0057^{mn}	0.0795± 0.0243^{mx}

Note: morph. rat. - morphometric body ratio; TL - total length; SL - standard length; HL - head length; BD - body depth; BW - body width; W - weight; mx - maximum value; mn - minimum value.

Table 2

Morphometric characters ratio of Nike fish from daytime catches for seven consecutive days during waning crescent of lunar phase

Morph. rat.	Lunar phases						
	22 Sha'ban (8 May 2018)	*23 Sha'ban (9 May 2018)*	*24 Sha'ban (10 May 2018)*	*25 Sha'ban (11 May 2018)*	*26 Sha'ban (12 May 2018)*	*27 Sha'ban (13 May 2018)*	*28 Sha'ban (14 May 2018)*
TL/SL	0.8713± 0.0610	0.8555± 0.0427^{mn}	1.1628± 0.1408	1.1550± 0.0715	1.8142± 3.2964^{mx}	1.1657± 0.0844	1.1699± 0.1230
BD/SL	0.0133± 0.0033	0.0154± 0.0066	0.0187± 0.0054	0.0121± 0.0030^{mn}	0.0206± 0.0411	0.0145± 0.0142	0.0888± 0.0564^{mx}
BW/SL	0.0129± 0.0096	0.0116± 0.0061^{mn}	0.0137± 0.0042	0.0143± 0.0145	0.0191± 0.0364	0.0136± 0.0075	0.0467± 0.0329^{mx}
HL/SL	0.0152± 0.0123	0.0170± 0.0097	0.0182± 0.0063	0.0121± 0.0029^{mn}	0.0229± 0.0424	0.0127± 0.0028	0.0617± 0.0555^{mx}
W/SL	0.0826± 0.0197	0.0508± 0.0159^{mn}	0.0956± 0.0275^{mx}	0.0938± 0.3871	0.0947± 0.1862	0.0702± 0.0154	0.0651± 0.0208
SL/TL	0.8713± 0.0610	0.8555± 0.0427	0.8726± 0.1239^{mx}	0.8693± 0.0575	0.8129± 0.1558^{mn}	0.8639± 0.0851	0.8663± 0.1256
BD/TL	0.0133± 0.0033	0.0132± 0.0057	0.0162± 0.0047	0.0105± 0.0027^{mn}	0.0112± 0.0028	0.0125± 0.0123	0.0767± 0.0480^{mx}
BW/TL	0.0129± 0.0096	0.0099± 0.0053^{mn}	0.0119± 0.0037	0.0124± 0.0125	0.0104± 0.0039	0.0118± 0.0065	0.0404± 0.0285^{mx}
HL/TL	0.0152± 0.0123	0.0146± 0.0084	0.0157± 0.0053	0.0106± 0.0026^{mn}	0.0126± 0.0081	0.0109± 0.0026	0.0529± 0.0469^{mx}
W/TL	0.0826± 0.0197	0.0435± 0.0141^{mn}	0.0828± 0.0239^{mx}	0.0825± 0.3504	0.0507± 0.0111	0.0610± 0.0185	0.0558± 0.0168

Note: Morph. rat. - morphometric body ratio; TL - total length; SL - standard length; HL - head length; BD - body depth; BW - body width; W - weight; mx - maximum value; mn - minimum value.

Morphometric comparison in diel sampling periods. A comparison of the diversity of morphometric characters of Nike fish found during the day and night sampling times was carried out to show the significance of differences between the Nike sample populations found from both collection times. In general, the appearance days of fish in the beginning (first and second days) and at the end (fifth, sixth, seventh days) of the lunar phases indicate that some character ratio values vary significantly. Meanwhile, in the third and fourth days, only morphometric characters ratios of W/SL and W/TL (third day) and BD/SL and BD/TL (fourth day) showed a significant difference between night and day captures (Table 3).

Table 3

Result of t-test of morphometric body ratio of Nike fish between night and day periods of sampling

Lunar phases	*p-value of morphometric body ratio*									
	TL/SL	*BD/SL*	*BW/SL*	*HL/SL*	*W/SL*	*SL/TL*	*BD/TL*	*BW/TL*	*HL/TL*	*W/TL*
22 Sha'ban (8 May 2018)	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0072*	0.0000*	0.6584	0.0013*	0.0000*
23 Sha'ban (9 May 2018)	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.4344	0.0000*	0.0000*	0.0000*	0.0000*
24 Sha'ban (10 May 2018)	0.2407	0.4497	0.8051	0.1293	0.0000*	0.7261	0.4574	0.8417	0.3087	0.0000*
25 Sha'ban (11 May 2018)	0.9820	0.0000*	0.2065	0.0803	0.3520*	0.4598	0.0000*	0.4187	0.1475	0.3542
26 Sha'ban (12 May 2018)	0.0221*	0.0034*	0.0883	0.0031*	0.0000*	0.0235*	0.0000*	0.1554	0.0114*	0.0000*
27 Sha'ban (13 May 2018)	0.2391	0.0000*	0.0000*	0.5129	0.0000*	0.5344	0.0000*	0.0000*	0.5058	0.0000*
28 Sha'ban (14 May 2018)	0.0793	0.0000*	0.0000*	0.0000*	0.0000*	0.5915	0.0000*	0.0000*	0.0000*	0.0000*

Note: TL - total length; SL - standard length; HL - head length; BD - body depth; BW - body width; W - weight; * - *p value* < 0.05 means the ratio is significantly different between night and day.

Bioecology and dynamics of Nike fish are urgently needed due to the exploitation and presence of predators that threaten the sustainability of the species composing the schooling. Larval drift has an essential positive relation with the success of fish recruitment (Tiedemann et al 2021). According to Iida et al (2021), the larval stage is critical due to its size and fragility, and has a low survival rate. Therefore, Nike fish's

biological and ecological aspects, including speciation, must be characterized simply and cheaply.

Amphidromy is a migration habit of island fish. It involves reproduction in freshwater, an abrupt migration of the newly hatched larvae to sea, and migration of small juveniles to freshwater (McDowall 1988). Amphidromous fish are essential for oceanic island freshwater communities (Walter et al 2012) and migrate in order to adapt to the spatial mismatch between larval and adult habitats (Warburton et al 2021). Up to now, Nike has been recognized as a goby fish school categorized as an amphidromous fish. Although Pasisingi & Abdullah (2018) exposed that the movement of the fish started from the sea towards the mouth of the river, it is not yet clear whether all the species composing the schooling have a uniform wandering purpose, whether this group of larvae migrate for spawning or feeding purposes, or whether all the larvae terminate the migration in the same water area. McRae (2007) reported that five amphidromous Hawaiian gobioids have each a different elevation profile of a terminal-estuary stream. Studies on amphidromous fish dispersal and environmental responses are generally species-specific (Smith & Kwak 2014; Urbina & Glover 2015; Pennekamp et al 2018; Iida et al 2021; Oto 2021; Teichert et al 2021). However, a similar search for Nike fish has not been carried out since it has not been fully and clearly reported on which and how many species exist in the migratory schooling.

In this study, changes in Nike fish average TL and BW to the number of days of appearance at diel times that are not patterned indicate the complexity of the larvae population dynamics. Environmental factors and food availability might be the key aspects of determining individual growth in the population. Prey abundance is necessary for recruitment success through its effect on predation rates (Fiksen & Jørgensen 2011). In migratory fish life, temperature, turbulence, drift patterns, food availability, and predation pressure are factors that contribute to the migratory offspring survival and mortality (Langangen et al 2016). Temperature affects many parameters related to fish early life survival. However, the relative importance of such temperature effects is expected to differ substantially in contrasting small pelagic fish habitats (Somarakis et al 2019). Our results cannot reveal in detail to what extent the influence of external and internal factors determine the development of Nike fish in nature.

Body ratio morphological characterization data is used to track differences in similar fish species in diverse populations to establish a conservation program in the future. The relationships among the various morphometric body parts might be used to determine possible distinctions between separated populations of the same species (Gonzalez-Martinez et al 2020). Comparison between wild and farmed specimens of *Clarias gariepinus* showed a correlation difference that may be highly related to feeding trends, plasticity of morphometry, environmental threats, and genetic variations (Solomon et al 2015).

The combined value of the ratio among 6 morphometric characters (TL, SL, BD, BW, HL, and W) of Nike samples showed that the trend of night samples is opposite to the daytime data. In the night sample, the highest morphometric ratio value is generally read on the second day, and the lowest is indicated on the sixth day. On the other hand, the daytime sample data showed that the highest morphometric ratio was found on the seventh day and the lowest on the second day. These results indicate that the sensitivity ratio of morphometric characters can be considered as a basis for Nike fish speciation during a period of emergence. However, this needs to be studied further as the recognition of goby fish species based on morphometric data combined with meristic and genetic records is commonly carried out on the adult phase (Lynch et al 2013; Keith & Hadiaty 2014; Keith et al 2021).

Furthermore, the analysis results show that there is a significant morphometric ratio difference between Nike caught at night and during the day. Although this trend was only apparent on a few days in the middle of the emergence period, this trend supports the notion that the Nike population in the waters consisted of more than one cohort at a natural occurrence period. A group of fish is categorized as originating from one cohort if all the fish in the group are of the same age, and the boundaries of their geographical distribution can be determined (Sparre & Venema 1999). As one Nike population ages, a

new cohort of Nike fish emerges when the previous cohort has been in the waters for several days. However, the results of this study have not been able to estimate when the stock mixing of the different cohorts occurred.

In addition, most of the ratio values of each morphometric feature between Nike fish found during the day and night were significantly different. These results also lead the assumption that diverse species might have various responses to the availability of light in combination with moon phases. Shima et al (2021) confirmed that the daily growth rate of *Thalassoma hardwicke* is strongly influenced by the lunar period and the time of night brightness, where maximum growth occurs when the first half of the night is dark and the second half of the night is brighter due to moonlight. Liedtke et al (2020) also reported that based on light conditions (day and night), the lamprey larval movement rate was significantly faster at night than during light conditions. In addition, Simanjuntak et al (2021) revealed that amphidromous fish in larva and juvenile stages in Cimaja River estuary was commonly preferred to recruit in the early morning and afternoon, based on monthly catches on the 25th of Hijri Year.

Conclusions. Overall, changes in the Nike population's total length and average body weight based on diel catch (day and night) did not show a consistent trend in sync with the increase in the number of appearance days. Hence, there was an indication that the fish population in one natural occurrence period was composed of more than one cohort and reinforced former findings that Nike is composed of multi-species. Moreover, variation in the ratio value of morphometric body characters potentially can be developed and utilized to trace Nike species composition and population dynamics.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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