Amphidromous Nike fish sustainability efforts: the local knowledge and scientific perspective approach

[1]Femy M. Sahami, [1]Sri N. Hamzah, [1]Sitty A. Habibie, [2]Abdul H. Tome, [2]Moh. Rusdiyanto U. Puluhulawa

[1] Faculty of Marine and Fisheries Technology, Universitas Negeri Gorontalo, Gorontalo, Indonesia; [2] Faculty of Law, Universitas Negeri Gorontalo, Gorontalo, Indonesia.
Corresponding author: F. M. Sahami, femysahami@ung.ac.id

Abstract. Nike fish is part of the post-larvae and juvenile amphidromous gobies school. The emergence of this fish species is widely perceived by the local community knowledge to be associated with certain myths. This research aims to analyze the local community knowledge concerning the Nike fish and interpret it through a scientific approach, in order to formulate sustainable management policies. This research was conducted in the waters of Tomini Bay, Gorontalo City, Indonesia. The composition data including fish samples at 150 g were collected in six emergence periods in 2019 and 2021 from the daily catch of fishermen. Meanwhile, the local knowledge data were retrieved in 2022. All data were compiled and analyzed descriptively. The results showed that the local community understand fish taxonomy as indicated by the names provided to several groups of fish such as 'duwo bohu', 'pilodehiyo', 'biluloa', 'piloheluto', and 'taimolo'. It was discovered from a scientific perspective that this local taxonomy has different characteristics and constituent species. For example, duwo bohu and pilodehiyo are the names of the groups dominated by *Sicyopterus longifilis*, while biluloa is a term for groups dominated by *Stiphodon semoni*. Additionally, piloheluto is a group of Nike fish associated with glass eels, while taimolo is the term used for fish that entered river waters to continue their life cycle. Finally, this study can be used to formulate policies needed to ensure the sustainability of these resources by limiting fishing activities to the biluloa and prohibiting the capture of the piloheluto and taimolo groups.
Key Words: amphidromous, folk taxonomy, goby fish, Gorontalo, Tomini Bay.

Introduction. A most unique feature of Earth is the presence of life, while the most remarkable attribute of life is its diversity (Cardinale et al 2012). However, the rates of extinction and decline of species are increasing and this is likely to continue globally unless the major threats to biodiversity are addressed (Caceres-Escobar et al 2019). Humans and their homeland are perceived as the holistic unit supporting all living things and are considered physically and spiritually inseparable parts of the system (Díaz et al 2015). Therefore, the main present and future challenges are to maintain or increase the beneficial contribution of nature to a good quality of life for all (Díaz et al 2018). For example, the recognition of the desired qualities of socio-ecological systems in the local context can assist in the process of strengthening the ecosystem resilience plans (Liu 2014). This can be achieved by ensuring that local communities participate in the process by sharing their experiences (Asmamaw et al 2020). This is necessary because local knowledge systems are a significant resource with the ability to contribute to the increase in efficiency, effectiveness, and sustainability of environmental conservation (Ayaa & Waswa 2016). They are defined as a set of knowledge and good practices passed down from one generation to others. The concept is considered a useful component for studying environmental change (Bart 2006), a source of local community resilience which enables the maintenance of livelihoods and adaptation to environmental changes (Shava et al 2009), and also an important component of human-environment relations and local ecosystems (Díaz et al 2015; Kohsaka & Rogel 2021). Moreover, local knowledge, with a

long-term view and contextual understanding of the local environment, can also be of value in developing new science in biodiversity conservation (UNESCO 2009).

Law Number 32 of 2009 mandated the inclusion of local knowledge as one of the principles in environmental protection and management in Indonesia and this was also confirmed through the Minister of Environment and Forestry Regulation Number 34 of 2017 concerning the recognition and protection of local wisdom in natural resource management and the environment. Some coastal communities observed to have implemented local knowledge to optimize the sustainable use of natural resources include Mane'e in the Talaud Islands (Laira 2016) and Sasi in Maluku Regency (Asrul et al 2017). It is important to note that the management of river fisheries can also benefit significantly from local knowledge (Valbo-Jorgensen & Poulsen 2000). This is necessary because rivers play an important role in the life cycle of amphidromous fish, especially in relation to their reproductive and recruitment phases (Sánchez-Garcés 2017). The post-larva phase of amphidromous fish is the target of traditional fisheries in some areas for intensive fishing, especially when they migrate from seawaters to rivers as observed in Gorontalo.

The schools of small fish called Nike fish (read: nee-K), which is the schooling of post-larvae and juvenile amphidromous gobies, often appear at the last quarter moon phase towards the new moon in the sea waters of Gorontalo City, around the mouth of the Bone River presented in Figure 1 (Sahami et al 2020). Several broods of this species have been reported to be found in the Bone Bolango River (Sahami & Habibie 2020; Sahami & Habibie 2021). It is a consumption fish that is very popular with the people of Gorontalo. However, high demand is observed to be threatening its population and eroding the traditional values believed by local people. This is possible because traditional fisheries can indirectly affect nature as well as its benefits to humans and the quality of life far beyond coastal areas (Díaz et al 2015). The current information on the Nike fish is obtained orally from the local community knowledge, but several recent studies have started to examine the diversity of species that make up the Nike schooling fish using a scientific knowledge approach (Nurjirana et al 2019; Olii et al 2019; Sahami et al 2019b; Sahami et al 2020; Pasisingi et al 2020; Sahami & Habibie 2021). This local knowledge is an interesting concept to be studied and understood as an effort to develop knowledge, maintain biodiversity, and serve as a reference in making policies related to conservation and sustainability. It also needs to be integrated into scientific knowledge in order to achieve sustainable management goals as well as to increase everyone's understanding of ecosystem services and processes (Chalmers & Fabricius 2007). This combination also has the ability to increase the chances of successful environmental management processes (Ulicsni et al 2019).

The integration of local knowledge into scientific knowledge was reported to have the ability to allow the integrated analysis of ecosystems, their functions, factors affecting the whole system, and the response of key species to environmental changes (Periago et al 2017). The local knowledge systems can provide valid and useful knowledge to improve understanding of biodiversity and ecosystem governance for human well-being (Tengö et al 2014). It also has the capacity to discover information required to obtain the preliminary data for scientific research and serve as a source of knowledge to be used as a reference for sustainable natural resource management. Therefore, this research focuses on understanding the local community knowledge concerning Nike fish in the waters of Gorontalo City and interpreting the perspective through a scientific knowledge approach. The findings are expected to help sustainable Nike fish management policies. The research was conducted in the sea waters of Tomini Bay, Gorontalo City between 2019 and 2022.

Material and Method

Location and time of research. Data were collected in the coastal area of Tomini Bay, Gorontalo City, Indonesia, from 2019 to 2022 (Figure 1), while observations and sample analyses were conducted at the Laboratory of the Faculty of Fisheries and Marine Sciences, State University of Gorontalo.

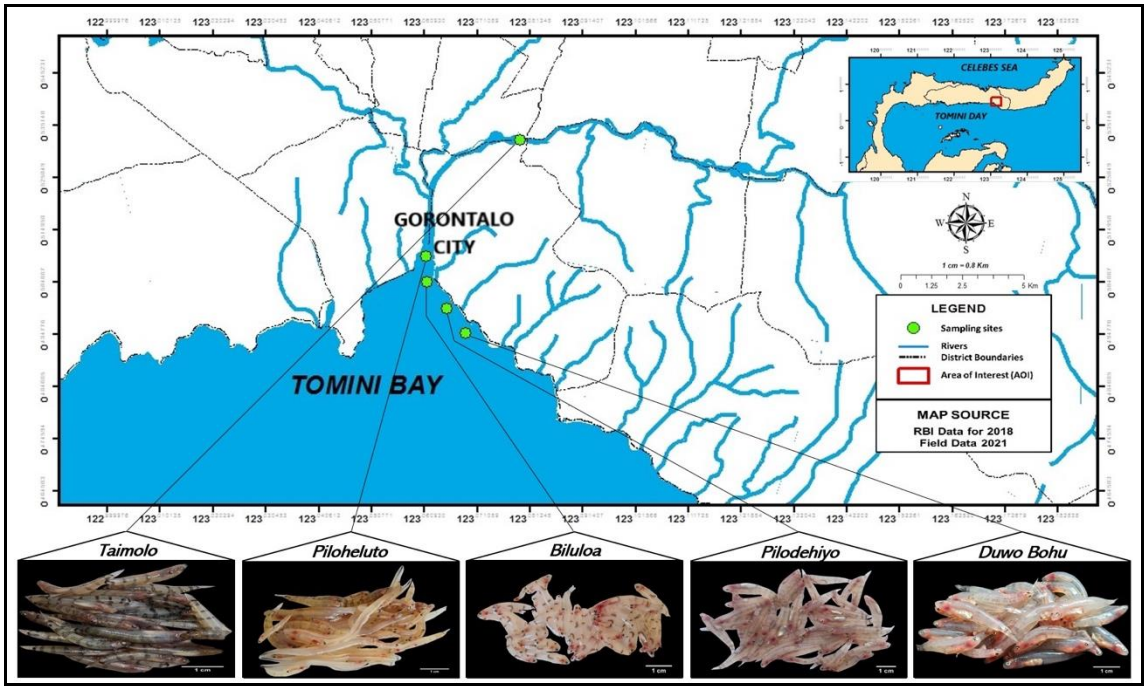

Figure 1. Nike fish sampling locations.

Local knowledge data collection. The information on the local knowledge of the community was retrieved using unstructured interviews in order to allow the respondents to express their insights freely (Shava et al 2009). The 31 respondents were selected using the snowball method and purposive sampling technique (Ulicsni et al 2019), based on the criteria that they are indigenous people of the coastal city of Gorontalo, fishermen, community leaders, and other willing community members. Those observed to have genuine information on the Nike fish were used as key informants and the interview was conducted using open-ended questions based on the direct guidance of the lead researcher. The use of the open-ended questions was intended to avoid limiting the answers and provide freedom of expression for the respondents (Shava et al 2009). Moreover, the methods and instruments used to retrieve the information differ depending on the type of knowledge provided (Nugroho et al 2018) and the respondents were allowed to speak in their language after which all the interviews were recorded and converted into the standard language. It is important to note that this research also explores the level of the government's efforts to conserve Nike fish.

Nike fish composition data collection. Nike fish composition data were collected in six emergence periods from January to June in 2019 and 2021 while data for 2020 was not obtained due to the absence of fishing activity because of the Covid-19 pandemic. A total sample of 150 g was collected from the daily catch of fishermen during the period. The fish were observed and identified to determine the species that comprise each group in line with Sahami et al (2019b) and Sahami et al (2020). Moreover, the number of individuals and species in each identified sample were counted.

Data analysis. The application of cooperative research using more than one knowledge system has the ability to combine the benefits of different ontological and epistemological systems (Ulicsni et al 2019). The extracts of the interviews were analyzed descriptively to understand the local community's knowledge concerning the Nike fish in the waters of Gorontalo City. The findings were integrated into the Nike fish composition analysis in order to produce the results that can be transformed to formulate sustainable fish management policies.

Results and Discussion

Local knowledge of the community concerning the origin of the Nike fish. The original name of Nike fish in the Gorontalo language is 'duwo', however, it is currently more popularly known as Nike because duwo implies Nike in the Gorontalo-Indonesian dictionary (Pateda 2001). According to Lamusu (2022, personal communication), the word duwo originates from 'moloduwo' which denotes 'invite' (Pateda 2001). It was further explained that the name was given because when the people first saw the fish floating in the water they believed and it was blood clots, and they invited community leaders considered to be knowledgeable about natural phenomena to identify them. These leaders did not know the creatures, but needed to provide an appropriate name. This is in line with the concept of local knowledge, which also focuses on the information concerning local contexts or settings such as certain characteristics, circumstances, events, and relationships, as well as important understandings of their meaning (Corburn 2003). Moreover, cultural values and respect are the basis to acquire and transmit customary practices and efforts to conserve nature (Asmamaw et al 2020).

The existence of Nike fish in Gorontalo is often associated with different myths told in several versions by the respondents. For example, Lamusu (2022, personal communication) said that the species is the incarnation of a red lump from the menstrual blood of a girl washed in the river. Meanwhile, Yusuf (2022, personal communication) reported that it originated from a blood clot of a fetus produced through an illicit relationship between a pair of siblings and washed into the river. Meanwhile, Mantu (2022, personal communication) believed the fish came from the relationship between the king of the sea and the queen of the river conducted every full moon in the upper reaches of the river, which drifted into the sea and transformed into Nike fish. These ideas can be incorporated into local myths and oral stories (Turner et al 2000). This simply indicates that people believe that the Nike fish is an incarnation of round lumps resembling balls that drifted from the river to the sea. These clumps are believed to usually drift into the sea at night, but the phenomenon is very difficult to find or see in the present time. Lamusu (2022, personal communication) further explained that the lumps did not automatically become fish when they arrived at the sea but initially turned into caterpillars and then to fish. Therefore, the local people believe that the Nike fish does not have a brood and is a gift from divinity.

There is other local knowledge associated with the existence or appearance of the Nike fish through natural forces controlled by mysticism. This was observed from the direct dialogue with community groups practicing local traditions, like a ritual called 'dayango' often conducted in the past when Nike fish and other fish resources began to reduce or there was an outbreak of disease. Dayango was discovered in the Gorontalo-Indonesian Dictionary to be a type of dance on coals, always associated with supernatural powers (Pateda 2001). It is important to note that there is an inseparable social relation between humans and non-human entities (Berkes et al 1995), with some even considering humans as natural elements (IPBES 2019). However, the ritual has been prohibited by the government. This was confirmed by Djakaria (2022, personal communication) from the Manado Cultural Values Preservation Center. They attempted to record the rituals, but were not permitted by the government and religious leaders. The argument was that the process contains animism, which is contrary to the present religious teachings. This implies old traditions and customs or local wisdom related to nature and environmental conservation are no more relevant, because they violate Islamic religious norms (Nugroho et al 2018). Meanwhile, stories or legends are part of local wisdom because they have meaning (Berkes 2012), as indicated by several taboos associated with the use of Nike fish in Gorontalo waters. This was confirmed by Mantu (2022, personal communication), who told us that fishermen are not allowed to cheat, be stingy, and be greedy to maintain their existence. It was also reported that different taboos, totems, and community experiences are guiding the residents in knowing the appropriate actions to be conducted (Asmamaw et al 2020).

Integration of local knowledge into scientific knowledge. According to Lamato (2022, personal communication), the change in the name from duwo to Nike was first popularized by traders in the early 1970s. Nike fish is actually a term for juvenile payangka fish (*Ophieleotris aporos*) living in Lake Tondano (Susanto et al 2017; Tamanampo & Bataragoa 2017). The fish has several different morphological melanophore patterns, while the molecular analysis showed that it is only a tiller of one species known as *Ophieleotris aporos* (Pangemanan et al 2020). The species that constitute the school of Nike fish in Lake Tondano are different from those in the waters of Gorontalo City as reported by Olii et al (2019), Sahami et al (2019b), and Sahami et al (2020). It was also discovered that some elements of knowledge are truly local, while some were adopted or adapted from outside the community (Nugroho et al 2018). The knowledge gained from the outside includes those maintained and brought by local residents from their own culture and traditions (Shava et al 2009). This is in line with the previous findings noting that linguistic shifts have the ability to continually influence and, in some cases, erode indigenous knowledge (McCarter et al 2014), such as the identification of duwo as Nike.

Most early research in ethnoscience deals with folk taxonomy (Berkes 2012) and found that the local knowledge concerning the taxonomy of Nike fish is based on its morphological form and the time of its appearance. Pateda (2001) states that there are three names for groups of Nike fish based on generations in the period of their appearance. The group of Nike fish that first appeared was called 'duwo bohu', a local name, which means new Nike; the next group was called 'pilodehiyo', a local name, which means the second generation born or subsequent generation; and the last was called 'biluloa', a local name, which means position (Figure 1). According to Lamusu (2022, personal communication), the duwo bohu and pilodehiyo groups have similarities in their transparent and reddish bodies. However, the pilodehiyo has a smaller body size, and the time of appearance is usually two or three days before biluloa. Biluloa is a group with a whiter color and smaller size than pilodehiyo and its appearance is believed by Lamato (2022, personal communication) and Nasaru (2022, personal communication) to indicate the end of the month for the current Nike season.

Observations of the species composition of Nike fish in the waters of Gorontalo City were carried out to reveal similarities in local knowledge from a scientific knowledge perspective. It was reported in previous studies that there are eight species in this school of fish, from families Gobiidae and Eleotridae. They include *Sicyopterus cynocephalus, Bunaka gyrinoides, Belobranchus segura* (Sahami et al 2019a; Sahami et al 2019b), *Sicyopterus longifilis, Sicyopterus parvei, Sicyopterus lagocephalus, Belobranchus belobranchus*, and *Stiphodon semoni* (Sahami et al 2020). The results obtained from the observation of the fish school throughout the six seasons of the Nike fish in 2019 are presented in Figure 2.

Figure 2 shows that the time interval for the appearance of Nike fish in each season varies from 3 to 8 days. It was discovered that the naming of the fish group by the local community provides a scientific explanation for the long emergence season indicated as 8 days. Moreover, the scientific naming of different groups shows that the composition of the constituent species is also different. This was confirmed by the findings that the members of the duwo bohu and pilodehiyo groups are from the *Sicyopterus* genus, which includes *S. longifilis, S. cynocephalus, S. parvei,* and *S. lagocephalus*, while the species in the biluloa group include *Stiphodon semoni, Belobranchus belobranchus*, and *B. segura*. Moreover, the duwo bohu and pilodehiyo groups were observed to be dominated by *S. longifilis* (63.61-87.53%), while the biluloa group is dominated by *S. semoni* (47.99-91.45%). These were further confirmed by the composition of catches in the six fish season periods of 2021 (Figure 3).

Figure 3 shows that the appearance of Nike fish from January to June in 2021 was only for five periods. This data consistently shows that the time interval for the appearance of Nike fish in each season period varies. Likewise, the findings of the constituent species and dominant species in each taxonomic group consistently show that the duwo bohu and pilodehiyo groups are dominated by *S. longifilis* (87.57-98.53%) and the biluloa group by *Stiphodon semoni* (58.64-96.24%). This is possible because

Sicyopterus and *Stiphodon* are the most diverse genera of the subfamily Sicydiinae in the Pacific region, with *Sicyopterus* reported to be the largest genus (Keith et al 2015). Furthermore, *S*. *longifilis* has been found to be the most widely distributed species in the waters around the Bogani Nani Wartabone National Park (TNBNW) (Haryono et al 2002), including the Bone River area which empties into the Gorontalo City sea. This was observed to be in line with the discovery of *S. longifilis* throughout the Nike fish emergence season. It shows that the local knowledge associated with the fish's taxonomy provided an overview of scientific information concerning the constituent species within each group. Therefore, it is possible to integrate the community's local knowledge into scientific knowledge in order to determine unknown natural phenomena. This simply indicates they can both complement and enrich each other (Díaz et al 2015).

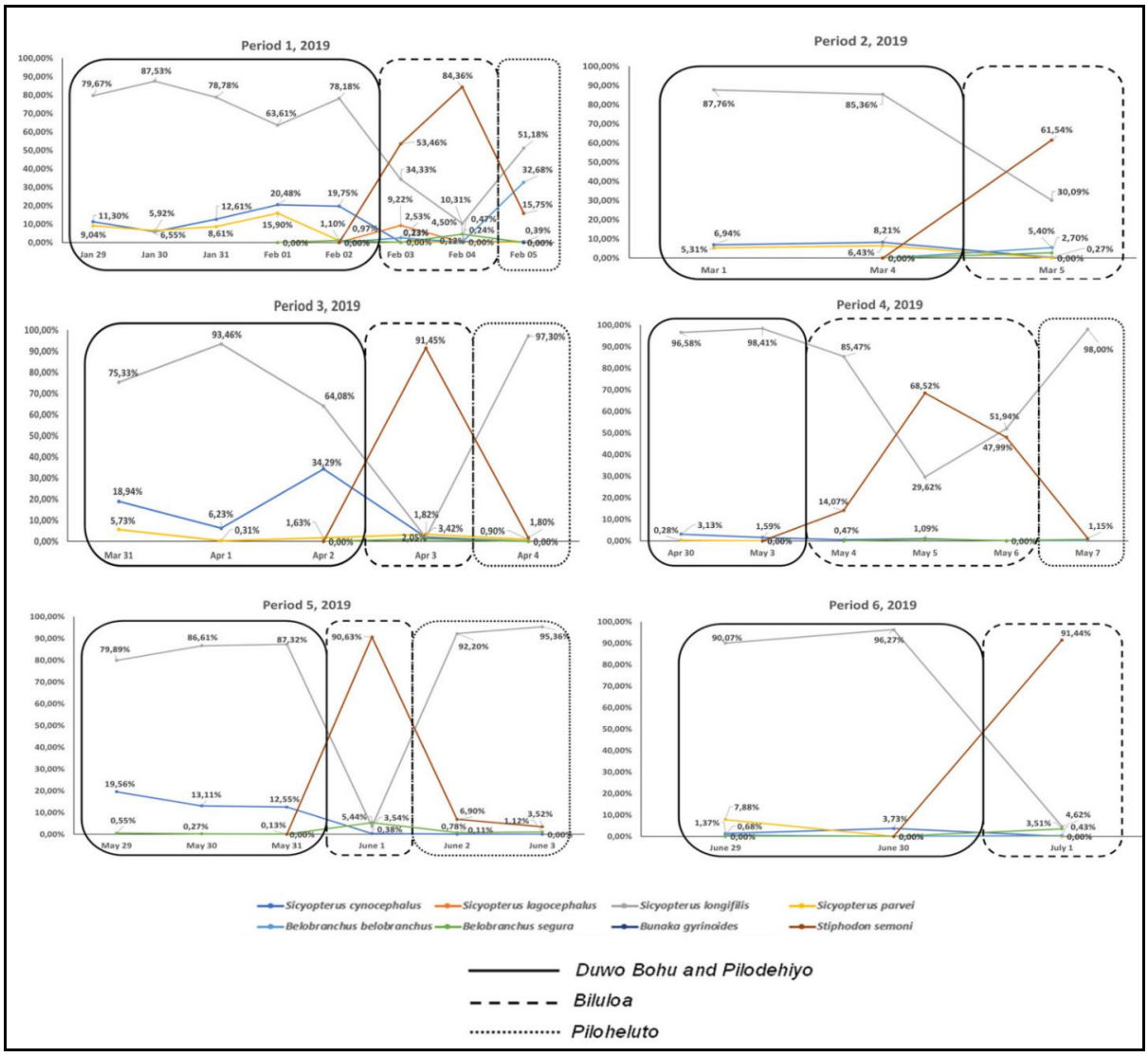

Figure 2. Nike fish schooling composition in the six season periods of 2019.

Some other names were also provided apart from the aforementioned three groups and these include 'piloheluto', a local name, and 'taimolo', a local name, as indicated in Figure 1. Piloheluto was used to represent the Nike fish group that has been mixed with glass eels. It is important to note that this group does not appear every season and, when it appears, it is usually found at the end of the season. It was also observed that piloheluto was only discovered in the first period of 2021 at the end of the season. Based on observations, the piloheluto group was only discovered in 2021, at the end of seasons 1 and 5, as shown in Figure 3. The discovery of this group during the emergence of the

biluloa group in season 5 as presented in Figure 3 makes it clear that its naming is solely based on the inclusion of glass eels in the catch.

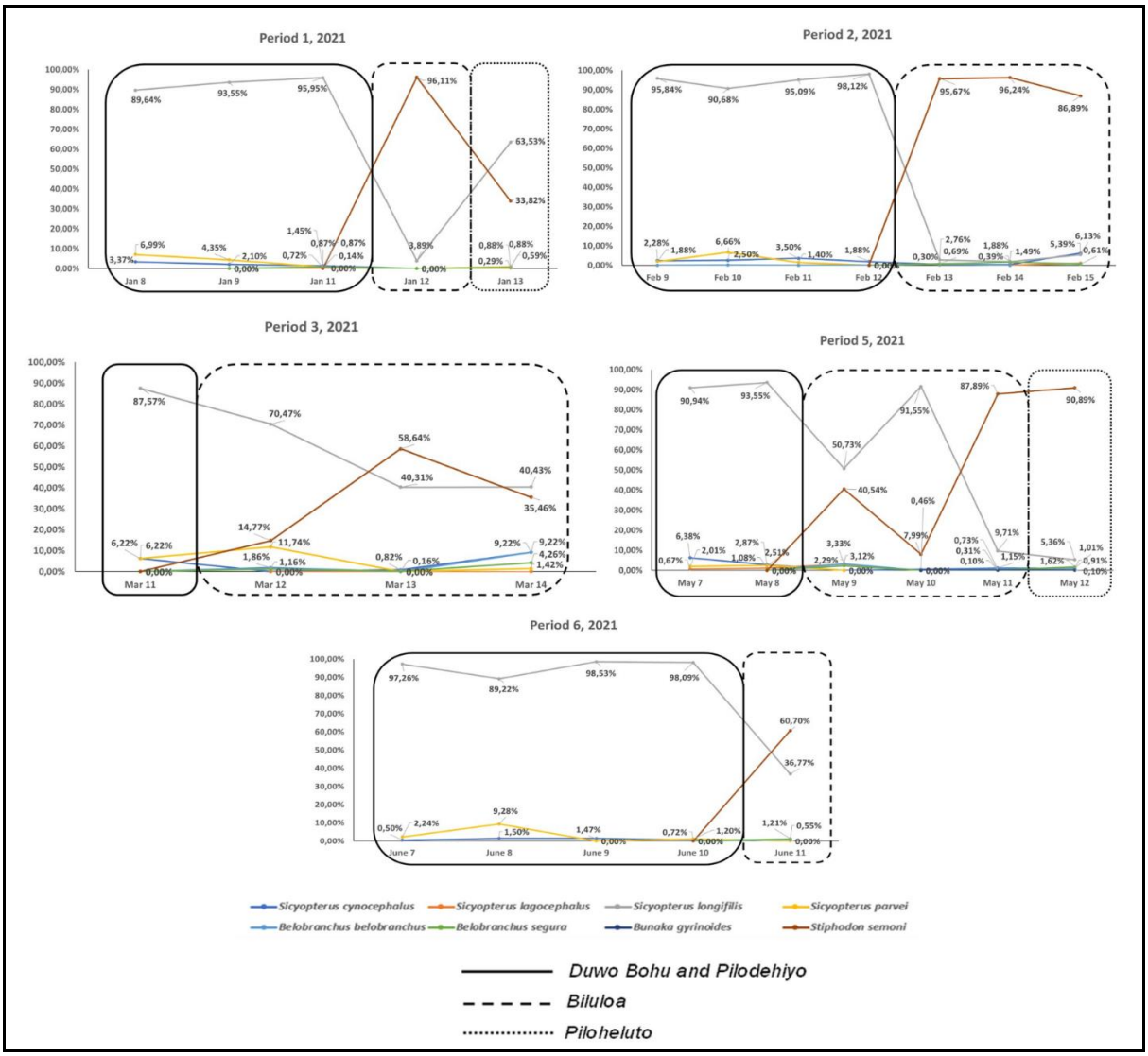

Figure 3. Nike fish schooling composition in the six season periods of 2021.

Meanwhile, taimolo is the name of the Nike fish group already in the river. As an amphidromous species, Nike fish will spawn in fresh waters. Their eggs are laid on the substrate at the bottom of the water. After the eggs hatch, the larvae drift into the sea, and then the post-larvae and juveniles migrate back to the river where their parents came from (Yamasaki et al 2011). The taimolo group usually appears after the emergence period of the biluloa group. The results of data analysis showed that this group was dominated by *S. longifilis* at the end of seasons 1, 3, 4, and 5 in 2019, with a compositional value range of 51.18-98.00%. (Figure 2). According to Mantu (2022, personal communication), the term taimolo (submerged in feces) refers to a Nike fish group that has entered the river and mixed with human feces. Moreover, it was observed that the houses around the mouth of the Bone Bolango River do not have latrines and this makes the people dispose of their feces directly into the river. Lamusu (2022, personal communication) also added that the taimolo group was prohibited from being arrested in the past because their mixture with human feces can be a source of diseases, but the fishermen are currently ignoring the restriction. The regulation was made to suppress human greed and indirectly provide a chance for the Nike fish to return to the river to complete their life cycle. The findings from this research showed that scientific

processes associated with the experience can be utilized to develop theories to explain life occurrences and predict future events (Fussell 1996). This implies that local and scientific knowledge can be used to determine the generalized natural phenomena from certain observations (Berkes et al 1995).

The local knowledge expressed orally showed that Nike fish originates from rivers as indicated by the experience and direct observation of the people in the field. This is in line with the previous findings that pre-literate societies often have rich cultural traditions generally passed on orally and may require specialized cognitive skills, which differ from scientific knowledge (Reyes-García et al 2016). It is also important to note that knowledge derived from experience and observations is usually interpreted as a myth by some people due to the limitations of scientific knowledge. This myth was observed in this research to have proven the life cycle of the Nike fish as an amphidromous group and this was further clarified by the reported discovery of the adult phase of the Nike fish school species, which include *S*. *longifilis, S. lagocephalus, B. belobranchus, B. segura*, and *S. semoni* in the Bone-Bolango River (Sahami & Habibie 2020) and *B. belobranchus* in the Bone River, Gorontalo (Pasisingi et al 2020). Moreover, it is also possible to explain the knowledge of the local people perceiving that Nike fish started as red clots like blood from a scientific perspective. It simply indicates that the pre-larva phase of the fish that have just hatched in the river drifted into sea waters by the river currents. Ellien et al (2016) also showed that the eggs of amphidromous fish usually turn into pre-larvae after hatching, while Maeda & Tachihara (2010) and Teichert et al (2016) showed that the larvae that have just hatched in fresh waters normally drift into sea waters passively with immediate effect. Furthermore, the shape of the clumps is associated with the living behavior of these fish as groups to provide self-defense against predators while searching for food (Sahami et al 2020). The red color that looks like blood is believed to be the color of the head, gills, and belly of this fish in the pre-larvae phase, thereby making the school of fish look like blood clots at a first glance.

Knowledge transformation as a sustainable Nike fish management effort. 'Sustainability' is conceptualized based on three intersecting main pillars, which include the social, economic, and environmental aspects (Virtanen et al 2020). Meanwhile, local knowledge is currently considered the foundation for effective knowledge development (Cardinale et al 2012) and it is mainly attributed to community experiences, which are often controlled and managed by local communities through formal and informal institutions (Agrawal 2002). The increasing focus on local knowledge resources implies that communities are likely to be of paramount importance in ensuring sustainable management and maintaining relevance to ecology (Nyumba et al 2018). This implies that they can be used for community survival in the context of environmental risks, vulnerabilities, and uncertainties through informal education processes in local contexts (Shava et al 2009). There is recently an increase in the interest to discuss the role of local communities and institutions in the management of natural resources and ecosystems (Colding et al 2003). The importance of local knowledge is associated with the fact that residents and users of local resources have the ability to observe natural phenomena early (Bart 2006). It is, however, important to note that local knowledge is very diverse based on region and observed to be growing continuously due to the interaction between experience, innovation, and different types of knowledge including the written, oral, visual, tacit, gender, practical, and scientific knowledge (Hill et al 2020). This further contributes to the scientific perspective of enriching national development policies (Nugroho et al 2018).

Nike fish has long been used by local people, but there has not been much government effort to ensure its sustainability. It was discovered that the efforts made by the Gorontalo Provincial Government are limited to the designation of Nike fish as Communal Intellectual Property Rights (HKI) from Gorontalo Province with the Inventory Number SDG.01.2020.000001. Meanwhile, this research found that the Gorontalo people are familiar with the taxonomy of the fish and have been making conservation efforts for a long time as indicated by the ban on catching Nike fish in the river (taimolo) (Lamusu 2022, personal communication). It is also important to state that the appearance of Nike

biluloa as the last group in the current season can be used as the basis to set a time limit for the catches. This knowledge can be transformed into policies to manage and sustain these fishes. Moreover, there is also the need for local-level decisions, as the custodians of the resources, to maintain a sustainable and resilient socio-ecological system (Asmamaw et al 2020).

Social learning can be used by communities to develop the capacity-building needed to deal with future changes (Shava et al 2009), while the recovery and utilization of local knowledge can be applied as the main instrument to empower local communities (Cardinale et al 2012). Several national and international programs have incorporated the values of local knowledge and, in some cases, were used to develop binding legal rules (Berkes 2012). It was discovered that a literature review was conducted on local knowledge systems in ecosystem assessment and related contexts in order to strengthen the combined theoretical and practical understanding, and to provide empirical guidance for their application (Tengö et al 2014). However, the current transformation of local knowledge is often neglected in scientific discourse (Lam et al 2020), despite the need to embed sustainable resource management in a social context through the combination of local and scientific knowledge in order to accelerate the adaptive management process (Colding et al 2003). This is important because local knowledge generated in local communities is increasingly perceived to be relevant for sustainable management (IPBES 2019). For example, the countries adhering to the Convention on Biological Diversity (CBD) have agreed to protect and promote the use of living resources in accordance with local cultural practices that satisfy the requirements for conservation or sustainability (Tengö et al 2017).

Conclusions. The local people of Gorontalo generally know that the Nike fish does not have a brood and is a gift from divinity as observed from their myths. The local knowledge shows that the fish originates from a lump that drifts from the river, becoming a larva after reaching the sea, and finally, turns into a Nike fish. This is related to the characteristics of amphidromous fish as presented from a scientific perspective that Nike fish in the waters of Tomini Bay, Gorontalo City normally school post-larvae and juvenile amphidromous gobies from Gobiidae and Eleotridae families. Moreover, the local people also know the taxonomy of Nike fish as indicated by the different group names provided for the species such as duwo bohu, pilodehiyo, biluloa, piloheluto, and taimolo. These groups were observed not to be present in every period of emergence, appearing unpredictably between 3 to 8 days. The duwo bohu and pilodehiyo groups are composed of the same fish with different sizes and times of birth. This scientifically means they have the same constituent species, which are from the genus *Sicyopterus* (*S. longifilis, S. cynocephalus, S. parvei,* and *S. lagocephalus*) and dominated by *S. longifilis*. Meanwhile, the biluloa group has a whiter color, is smaller in size than pilodehiyo, and contains species *S. semoni* (Gobiidae), *B. belobranchus* and *B. segura* (Eleotridae), with *S. semoni* discovered to be the dominant species. The piloheluto group was mixed with glass eels and usually appear at the end of the season, while the last group, taimolo, are those already in the river and dominated by *S*. *longifilis*. The community was observed to have applied local knowledge to maintain the sustainability of these species by prohibiting the catching of the taimolo group and the implementation of the dayango ritual. It is, however, important to note that not all local knowledge can be adopted, such as the dayango tradition, which was adjudged not to be relevant to religious teachings. It was also discovered that there are no laws governing the use of Nike fish in the waters of Tomini Bay, Gorontalo City. Therefore, this adaptive local knowledge can be transformed to formulate sustainable Nike fish management policies in terms of setting fishing limits for only the biluloa group and enforcing fishing bans for the piloheluto and taimolo groups.

Acknowledgements. This study was supported by the Directorate General of Higher Education, Ministry of Education, Culture, Research, and Technology through the Basic Research Scheme for Higher Education Excellence for Fiscal Year 2023 with Contract Number: 137/E5/PG.02.00.PL/2023. Deepest gratitude is also extended to all

respondents that sacrificed their time to share information as well as to those that contributed to the research.

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

References

Agrawal A., 2002 Indigenous knowledge and the politics of classification. International Social Science Journal 54(173):287-297.

Asmamaw M., Mereta S. T., Ambelu A., 2020 The role of local knowledge in enhancing the resilience of dinki watershed social-ecological system, central highlands of Ethiopia. PLoS ONE 15(9):e02238460.

Asrul A., Rindarjono M. G., Sarwono, 2017 [The existence of sasi in environmental management and community participation in Haruku State, Central Maluku Regency, Maluku Province in 2013]. GeoEco 3(1):69-81. [In Indonesian].

Ayaa D. D., Waswa F., 2016 Role of indigenous knowledge systems in the conservation of the bio-physical environment among the Teso community in Busia County-Kenya. African Journal Environmental Science and Technology 10(12):467-475.

Bart D., 2006 Integrating local ecological knowledge and manipulative experiments to find the causes of environmental change. Frontiers in Ecology and the Environment 4(10):541–546.

Berkes F., 2012 Sacred ecology. 3rd Edition. Taylor & Francis, Philadelphia, 209 p.

Berkes F., Folke C., Gadgil M., 1995 Traditional ecological knowledge, biodiversity, resilience and sustainability. In: Biodiversity conservation. Ecology, economy & environment. Vol. 4. Perrings C. A., Mäler K. G., Folke C., Holling C. S., Jansson B. O. (eds), Kluwer Academic Publishers, pp. 281-299.

Caceres-Escobar H., Kark S., Atkinson S. C., Possingham H. P., Davis K. J., 2019 Integrating local knowledge to prioritise invasive species management. People and Nature 1(2):220-233.

Cardinale B. J., Duffy J. E., Gonzalez A., Hooper D. U., Perrings C., Venail P., Narwani A., Mace G. M., Tilman D., Wardle D. A., Kinzig A. P., Daily G. C., Loreau M., Grace J. B., Larigauderie A., Srivastava D. S., Naeem S., 2012 Biodiversity loss and its impact on humanity. Nature 486(7401):59-67.

Chalmers N., Fabricius C., 2007 Expert and generalist local knowledge about land-cover change on South Africa's Wild Coast: Can local ecological knowledge add value to science? Ecology and Society 12(1):10.

Colding J., Folke C., Elmqvist T., 2003 Social institutions in ecosystem management and biodiversity conservation. Tropical Ecology 44(1):25-41.

Corburn J., 2003 Bringing local knowledge into environmental decision making: Improving urban planning for communities at risk. Journal of Planning Education and Research 22(4):420-433.

Díaz S., Demissew S., Carabias J., Joly C., Lonsdale M., Ash N., Larigauderie A., Adhikari J. R., Arico S., Báldi A., Bartuska A., Baste I. A., Bilgin A., Brondizio E., Chan K. M. A., Figueroa V. E., Duraiappah A. D., Fischer M., Hill R., Koetz T., Leadley P., Lyver P., Mace G. M., Martin-Lopez B., Okumura M., Pacheco D., Pascual U., Pérez E. S., Reyers B., Roth E., Saito O., Scholes R. J., Sharma N., Tallis H., Thaman R., Watson R., Yahara T., Hamid Z. A., Akosim C., Al-Hafedh Y., Allahverdiyev R., Amankwah E., Asah S. T., Asfaw Z., Bartus G., Brooks L. A., Caillaux J., Dalle G., Darnaedi D., Driver A., Erpul G., Escobar-Eyzaguirre P., Failler P., Fouda A. M. M., Fu B., Gundimeda H., Hashimoto S., Homer F., Lavorel S., Lichtenstein G., Mala W. A., Mandivenyi W., Matczak P., Mbizvo C., Mehrdadi M., Metzger J. P., Mikissa J. B., Moller H., Mooney H. A., Mumby P., Nagendra H., Nesshover C., Oteng-Yeboah A. A., Pataki G., Roué M., Rubis J., Schultz M., Smith P., Sumaila R., Takeuchi K., Thomas S., Verma M., Yeo-Chang Y., Zlatanova D., 2015 The IPBES conceptual framework - connecting nature and people. Current Opinion in Environmental Sustainability 14:1-16.

Díaz S., Pascual U., Stenseke M., Martín-López B., Watson R. T., Molnár Z., Hill R., Chan K. M. A., Baste I. A., Brauman K. A., Polasky S., Church A., Lonsdale M., Larigauderie A., Leadley P. W., van Oudenhoven A. P. E., van der Plaat F., Schröter M., Lavorel S., Aumeeruddy-Thomas Y., Bukvareva E., Davies K., Demissew S., Erpul G., Failler P., Guerra C. A., Hewitt C. L., Keune H., Lindley S., Shirayama Y., 2018 Assessing nature's contributions to people. Science 359(6373):270-272.

Ellien C., Werner U., Keith P., 2016 Morphological changes during the transition from freshwater to sea water in an amphidromous goby, *Sicyopterus lagocephalus* (Pallas 1770) (Teleostei). Ecology of Freshwater Fish 25(1):48-59.

Fussell W., 1996 The value of local knowledge and the importance of shifting beliefs in the process of social change. Community Development Journal 31(1):44-53.

Haryono, Tjakrawidjaja A. H., Riyanto A., 2002 [Ichthyofauna in the waters around Mount Kabela, Bogani Nani Wartabone National Park, Sulawesi Utara]. Jurnal Iktiologi Indonesia 2(2):31-40. [In Indonesian].

Hill R., Adem C., Alangui W. V., Molnár Z., Aumeeruddy-Thomas Y., Bridgewater P., Tengö M., Thaman R., Yao C. Y. A., Berkes F., Carino J., da Cunha M. C., Diaw M. C., Díaz S., Figueroa V. E., Fisher J., Hardison P., Ichikawa K., Kariuki P., Karki M., Lyver P. O. B., Malmer P., Masardule O., Yeboah A. A. O., Pacheco D., Pataridze T., Perez E., Roué M., Roba H., Rubis J., Saito O., Xue D., 2020 Working with indigenous, local and scientific knowledge in assessments of nature and nature's linkages with people. Current Opinion in Environmental Sustainability 43:8-20.

Keith P., Lord C., Busson F., Sauri S., Hubert N., Hadiaty R., 2015 A new species of *Sicyopterus* (Gobiidae) from Indonesia. Cybium 39(4):243-248.

Kohsaka R., Rogel M., 2021 Traditional and local knowledge for sustainable development: empowering the indigenous and local communities of the world. In: Partnerships for the goals. Filho W. L., Azul A. M., Brandli L., Salvia A. L., Wall T. (eds), Springer, pp. 1-13.

Laira M., 2016 [Mane'e ceremony in the Kakorotan community, Nanusa District, Talaud Islands Regency]. Holistik 9(18):1-18. [In Indonesian].

Lam D. P. M., Hinz E., Lang D. J., Tengö M., Wehrden H. V., Martín-López B., 2020 Indigenous and local knowledge in sustainability transformations research: A literature review. Ecology and Society 25(1):1-25.

Liu W. T., 2014 The application of resilience assessment—resilience of what, to what, with what? A case study based on Caledon, Ontario, Canada. Ecology and Society 19(4):21.

Maeda K., Tachihara K., 2010 Diel and seasonal occurrence patterns of drifting fish larvae in the Teima Stream, Okinawa Island. Pacific Science 64(2):161-176.

McCarter J., Gavin M. C., Baereleo S., Love M., 2014 The challenges of maintaining indigenous ecological knowledge. Ecology and Society 19(3):39.

Nugroho K., Carden F., Antlov H., 2018 Local knowledge matters: Power, context and policymaking in Indonesia. Policy Press, University of Bristol, Bristol, 174 p.

Nurjirana, Haris A., Sahami F. M., Keith P., Burhanuddin A. I., 2019 Preliminary note on the morphological characters of penja (amphidromous goby post larvae) in West Sulawesi and Gorontalo Bay. IOP Conference Series: Earth and Environmental Science 370:012007.

Nyumba T. O., Wilson K., Derrick C. J., Mukherjee N., 2018 The use of focus group discussion methodology: Insights from two decades of application in conservation. Methods in Ecology and Evolution 9(1):20-32.

Olii A. H., Sahami F. M., Hamzah S. N., Pasisingi N., 2019 Molecular approach to identify gobioid fishes, "Nike" and "Hundala" (local name), from Gorontalo Waters, Indonesia. Online Journal of Biological Sciences 19(1):51-56.

Pangemanan N. P., Kepel R. C., Bataragoa N. E., Tumbol R., Sahami F. M., 2020 Morphological and molecular identification of nike fish, *Ophioleotris aporos* in Tondano Lake, North Sulawesi, Indonesia. AACL Bioflux 13(3):1614-1621.

Pasisingi N., Habibie S. A., Olii A. H., 2020 Are *Awaous ocellaris* and *Belobranchus belobranchus* the two species of Nike fish schools? Aceh Journal of Animal Science 5(2):87-91.

Pateda M., 2001 [Gorontalo-Indonesian dictionary]. Pusat Bahasa Pendidikan Nasional, Balai Pustaka, Indonesia, 302 p. [In Indonesian].
Periago M. E., Tamburini D. M., Ojeda R. A., Cáceres D. M., Díaz S., 2017 Combining ecological aspects and local knowledge for the conservation of two native mammals in the Gran Chaco. Journal of Arid Environments 147:54-62.
Reyes-García V., Pyhälä A., Díaz-Reviriego I., Duda R., Fernández-Llamazares Á., Gallois S., Guèze M., Napitupulu L., 2016 Schooling, local knowledge and working memory: A study among three contemporary hunter-gatherer societies. PLoS ONE 11(1):e0145265.
Sahami F. M., Habibie S. A., 2020 Exploration of adult phase of Nike fish to maintain its sustainability in Gorontalo Bay waters, Indonesia. AACL Bioflux 13(5):2859-2867.
Sahami F. M., Habibie S. A., 2021 Diversity of species in making up Nike fish schools and a new record of *Eleotris melanosoma* in Tomini Paguyaman Bay, Gorontalo, Indonesia. Biodiversitas 22(12):5459-5467.
Sahami F. M., Kepel R. C., Olii A. H., Pratasik S. B., 2019a Determination of morphological alteration based on molecular analysis and melanophore pattern of the migrating Nike fish in Gorontalo Bay, Indonesia. AACL Bioflux 12(4):1358-1365.
Sahami F. M., Kepel R. C., Olii A. H., Pratasik S. B., 2019b What species make up the Nike fish assemblages at the macrotidal estuary in Gorontalo Bay, Indonesia? F1000Research 8:1654.
Sahami F. M., Kepel R. C., Olii A. H., Pratasik S. B., Lasabuda R., Wantasen A., Habibie S. A., 2020 Morphometric and genetic variations of species composers of nike fish assemblages in Gorontalo Bay waters, Indonesia. Biodiversitas 21(10):4571-4581.
Sánchez-Garcés G. C., 2017 A review of amphidromous freshwater fishes of the Chocó biogeographical region (Colombia and Ecuador): diversity, ecology, fisheries and conservation. Cybium 41(2):157-169.
Shava S., Zazu C., Tidball K., O'Donoghue R., 2009 Local knowledge as a source of community resilience. Indilinga-African Journal of Indigenous Knowledge Systems 8(2):218–229.
Susanto M. K., Bataragoa N. E., Moningkey R. D., 2017 [Size distribution and growth of young payangka fish, *Ophioleotris aporos* (Bleeker) from Lake Tondano]. Jurnal Ilmiah Platax 5(2):189-197. [In Indonesian].
Tamanampo J. F. W. S., Bataragoa N. E., 2017 [Potential and management of juvenile payangka fish *Ophioleotris aporos* in Lake Tondano]. Jurnal Ilmiah Platax 5(2):264-272. [In Indonesian].
Teichert N., Valade P., Grondin H., Trichet E., Sardenne F., Gaudin P., 2016 Pelagic larval traits of the amphidromous goby *Sicyopterus lagocephalus* display seasonal variations related to temperature in La Réunion Island. Ecology of Freshwater Fish 25(2):234-247.
Tengö M., Brondizio E. S., Elmqvist T., Malmer P., Spierenburg M., 2014 Connecting diverse knowledge systems for enhanced ecosystem governance: The multiple evidence base approach. Ambio 43(5):579-591.
Turner N. J., Ignace M. B., Ignace R., 2000 Traditional ecological knowledge and wisdom of aboriginal peoples in British Columbia. Ecological Applications 10(5):1275-1287.
Ulicsni V., Babai D., Vadász C., Vadász-Besnyői V., Báldi A., Molnár Z., 2019 Bridging conservation science and traditional knowledge of wild animals: The need for expert guidance and inclusion of local knowledge holders. Ambio 48(7):769-778.
Valbo-Jorgensen J., Poulsen F. A., 2000 Using local knowledge as a research tool in the study of river fish biology: Experiences from the Mekong. Environment, Development and Sustainability 2:253-376.
Virtanen P. K., Siragusa L., Guttorm H., 2020 Editorial overview: Indigenous conceptualizations of sustainability. Current Opinion in Environmental Sustainability 43:A1-A2.
Yamasaki N., Kondo M., Maeda K., Tachihara K., 2011 Reproductive biology of three amphidromous gobies, *Sicyopterus japonicus*, *Awaous melanocephalus*, and *Stenogobius* sp., on Okinawa Island. Cybium 35(4):345-359.

*** IPBES, 2019 Global assessment report of the intergovernmental science-policy platform on biodiversity and ecosystem services. Brondízio E. S., Settele J., Díaz S., Ngo H. T. (eds), IPBES Secretariat, Bonn, Germany, 1144 p.
*** Law of The Republic of Indonesia Number 32 of 2009 concerning environmental protection and management. [In Indonesian].
*** Ministry of Law and Human Rights, 2020 [Communal intellectual property right (HKI) for Gorontalo Province]. Inventory Number SDG.01.2020.000001. [In Indonesian].
*** Regulation of the Minister of Environment and Forestry of the Republic of Indonesia number P.34/MENLHK/SETJEN/KUM.1/5/2017 concerning recognition and protection of local wisdom in management natural resources and environment. [In Indonesian].
*** UNESCO, 2009 Learning and knowing in indigenous societies today. UNESCO, Paris, 128 p.

Received: 14 November 2023. Accepted: 03 December 2023. Published online: 24 February 2024.
Authors:
Femy Mahmud Sahami, Faculty of Marine and Fisheries Technology, Universitas Negeri Gorontalo, 6 Jenderal Sudirman St., Kota Tengah, Gorontalo City, 96128 Gorontalo, Indonesia, e-mail: femysahami@ung.ac.id
Sri Nuryatin Hamzah, Faculty of Marine and Fisheries Technology, Universitas Negeri Gorontalo, 6 Jenderal Sudirman St., Kota Tengah, Gorontalo City, 96128 Gorontalo, Indonesia, e-mail: sri.nuryatin@ung.ac.id
Sitty Ainsyah Habibie, Faculty of Marine and Fisheries Technology, Universitas Negeri Gorontalo, 6 Jenderal Sudirman St., Kota Tengah, Gorontalo City, 96128 Gorontalo, Indonesia, e-mail: ainsyahabibie@ung.ac.id
Abdul Hamid Tome, Faculty of Law, Universitas Negeri Gorontalo, 6 Jenderal Sudirman St., Kota Tengah, Gorontalo City, 96128 Gorontalo, Indonesia, e-mail: hamidtome@ung.ac.id
Mohamad Rusdiyanto Usman Puluhulawa, Faculty of Law, Universitas Negeri Gorontalo, 6 Jenderal Sudirman St., Kota Tengah, Gorontalo City, 96128 Gorontalo, Indonesia, e-mail: mohammad.puluhulawa@ung.ac.id

How to cite this article:
Sahami F. M., Hamzah S. N., Habibie S. A., Tome A. H., Puluhulawa M. R. U., 2024 Amphidromous Nike fish sustainability efforts: the local knowledge and scientific perspective approach. AACL Bioflux 17(1):394-406.