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Short communication: Amphidromous goby postlarvae (penja) migration seasons and fisheries in West Sulawesi, Indonesia, preliminary data

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Abstract. *Nurjirana, Burhanuddin AI, Keith P, Haris A, Afrisal M. 2021. Short communication: Amphidromous goby postlarvae (penja) migration seasons and fisheries in West Sulawesi, Indonesia. Biodiversitas 23: 375-380.* Several gobioid species have amphidromous migration patterns; adult gobies spawn in their freshwater habitat, embryos are carried by river currents to reach the sea where they undergo a planktonic phase lasting several months before migrating to estuarine and then freshwater (predominantly riverine) environments to grow and breed. Around the island of Sulawesi in Indonesia, these migrating postlarvae have various local names; in West Sulawesi they are collectively known as penja, a popular fisheries commodity, but data on their migration patterns are limited. This study aimed to determine penja migration seasons and document some aspects of the penja fisheries in West Sulawesi. The research was conducted in the lower reaches of five rivers: the Mapilli, Mandar, Teppo, Palipi, and Lariang rivers. Penja samples were collected from fishermen's catches using several types of fishing gear such as *seser* (scoop nets), *dariq* or *bunde* (push nets), *panesser* (casting net) and other traditional or artisanal fishing equipment. Samples were also collected from traditional markets. The postlarvae were measured and grouped based on morphological characters. The results showed temporal differences in migration patterns between the five study sites, while external morphology indicated the presence of several species in migrating penja schools. During the rainy season, populations with a more diverse morphology were found than during the dry season.

Keywords: Amphidromy, larval fisheries, metamorphosis, migration patterns

INTRODUCTION

The Gobiiformes (gobies) are a widespread and speciose order of bony fishes with various life histories, including amphidromy (Keith 2003; Keith and Lord 2012). Adult amphidromous gobies spawn in freshwater habitat, embryos are carried by river currents and hatch before reaching the sea where they undergo a planktonic phase lasting several months before migrating to estuarine and then freshwater (predominantly riverine) environments to grow and breed (McDowall 2007; Keith et al. 2008; Lord et al. 2010). According to McDowall (2007), the driving force behind amphidromous migrations is to ensure access to sufficient food as their needs evolve during each life stage, in particular where suitable food for larval and early juvenile stages may be limited or lacking in adult and spawning habitat.

Gobies with an obligate or facultative amphidromous migration pattern are common across the Indo-Pacific, including Indonesia (Keith and Lord 2012; Mennesson et al. 2021). Schools of migrating goby post-larvae are a popular fisheries commodity in many regions of Indonesia and are particularly common around the major island of Sulawesi in Indonesia with local names including *nike*, *duwo* and *duwonge* in Central Sulawesi, *owiku* in Southeast Sulawesi, *nike* in North Sulawesi, *payangka, nike* or *duwo* in Gorontalo, and *penja, peja, epun* and *duang* in West Sulawesi (Ambo-Rappe and Moore 2018; Nurjirana et al. 2019b; Nurjirana et al. 2020; Sahami et al. 2020; Nurjirana et al. 2021). In Flores and Bengkulu they are called *ipun-ipun*, and a common Javanese name is *impun* (Said 2011; Devi 2012).

In West Sulawesi the most commonly used name for this gobioid post-larvae is *ikan penja* or penja. Local people are aware that large schools of penja appear in many rivers or estuarine areas at fairly regular intervals throughout the year, generally around the new moon, a pattern that remains a mystery to most local people. Few are aware that penja are migrating and many consider that they are a single small species of fish (Nurjirana et al. 2019b). Mostly consumed locally, penja form the basis of several popular local dishes. Anecdotal data indicate that penja are heavily fished; in this context, it is important to remedy the lack of data on penja fisheries and seasonal migration patterns in West Sulawesi to improve their management.

MATERIALS AND METHODS

Study area

This research took place in West Sulawesi, Indonesia, from January to December 2018 in the lower reaches, estuaries, and surrounding coastal waters of five rivers: the Mapilli, Mandar, Teppo, Palipi, and Lariang rivers (Figure 1). Observations of migration time are carried out every month throughout 2018.

Sample collection

The determination of the migration time of penja fish is carried out in the traditional way, namely by observing the moon phase by local fishermen and examining the digestive organs of the fish caught by fishermen. When entering the new moon phase, the local fishermen start to inspect the waters around the coast and river estuaries (Nurjirana et al. 2021). In addition, some fishermen always check the intestines of the fish they catch, if penja fish are found in their intestines, they will prepare boats to immediately conduct sweeping around sea waters and river estuaries, prepare penja fishing gear such as *seser* (scoop nets), *dariq* or *bunde* (push nets), *panesser* (casting net) and other traditional or artisanal fishing equipment. The fishermen in a group then cast their nets along the river to catch the penja, other fishermen use large push or scoop nets in the shallow waters along the shore. The fishermen catch penja during the day and night in the sea waters and river estuaries. The fishing process is generally carried out for several days, depending on the presence of a group of penja fish in the surrounding waters. Penja samples were collected as much as one container containing about 750-7000 individuals for each location. Samples were obtained randomly from the catches of the local fishermen and from traditional markets along the coast of West Sulawesi. The postlarvae samples were divided into groups based on differences in morphology (morphotype) and were preserved in labeled sample bottles filled with 96% ethanol.

RESULTS AND DISCUSSION

The results show that the samples from schools of penja included specimens that differed in several morphological traits such as head shape, body shape, coloration, and size. The data indicate that several species of goby tend to migrate together, with different species dominating during each migration period (Figure 4).

Migration patterns

The penja migration seasons varied between the five research sites in West Sulawesi in terms of timing and duration (Table 1). There was a spatial movement pattern, with penja first gathering to form schools near to the coast, then migrating to estuaries and entering the rivers. Depending on the species, penja will then start migrating upstream to reach their respective habitats, with most species tending to settle in areas with rapids or waterfalls (Miller 1984; Nishimoto and Kuamo'o 1997; Tate 1997; Keith 2003). However, even during the new moon and when the moon entered the new moon phase, it was not necessarily possible to find schools of migrating penja. The data indicate that penja only recruits occasionally (or possibly not at all) to some rivers. In other words, not all rivers become migration routes for amphidromous gobies as here Teppo and Palipi.

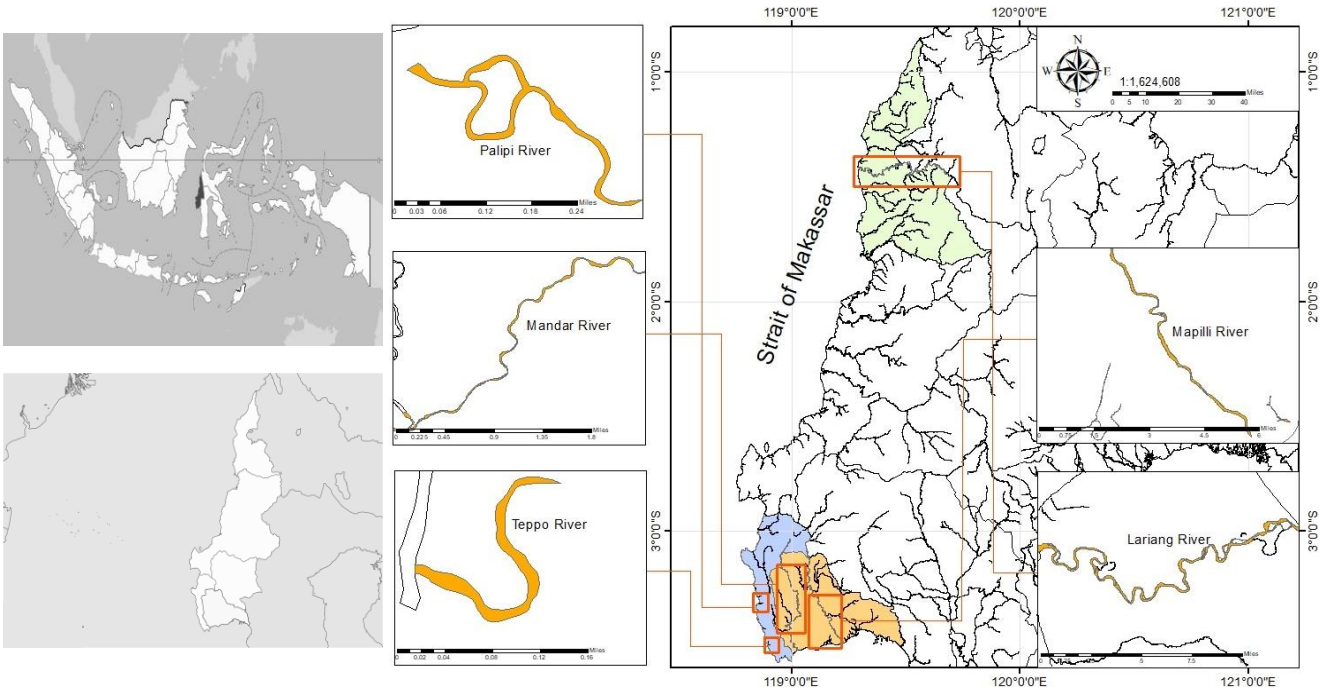

Figure 1. The five research sites in West Sulawesi, Indonesia

Table 1. Occurrence and duration of penja migration at five sites in West Sulawesi, Indonesia

Month (2018)	Research site				
	Mapilli river	**Mandar river**	**Teppo river**	**Palipi river**	**Lariang river**
January	Day 17-19	Day 17-18	-	-	Day 17-19
February	Day 16-19	Day 16-20	-	-	Day 16-18
March	Day 17-18	Day 17-19	-	-	Day 17-19
April	Day 16-20	Day 16-18	-	-	-
May	Day 15-17	Day 15-16	Day 15-17	-	Day 15-18
June	Day 14-18	Day 14-18	-	-	Day 14-18
July	Day 13-15	Day 13-17	-	-	-
August	Day 11-12	Day 11-15	-	-	Day 11-15
September	Day 10-14	Day 10-13	-	Day 10-14	Day 10-14
October	Day 9-11	Day 9-11	-	-	Day 9-11
November	Day 8-10	Day 8-10	-	-	Day 8-11
December	Day 7-9	Day 7-8	-	-	Day 7-10

In larger rivers with a fairly swift flow year-round, penja migration was observed every month, although sometimes the schools were very small, or only a few fish were encountered. In smaller rivers with less regular flow patterns, the penja had an unpredictable migration pattern; sometimes, migration only took place once during the year-long study period. One factor that could have impeded the migration of penja into several rivers, such as Teppo River and Palipi River, was the presence of obstructions caused by silting up the river estuary. Another factor that could make it difficult for penja to gain access to some rivers is that during the dry season, several rivers, especially smaller streams, often become extremely shallow, especially in the lower reaches and the estuary. This means that schools of penja approaching the coast during the new moon phase might be unable to enter these rivers as migration routes and therefore unable to gain the upper reaches, even if these might be suitable for growth to the adult phase.

Research sites such as the Mapilli River, Lariang River, and Mandar River become migration routes for schools of penja almost every month. Sometimes these postlarvae enter the rivers together with or followed by schools of glass eels (*Anguilla* spp.). The data from direct observations of migrating penja and personal interviews support the local belief that penja appears (i.e. migration often takes place) when entering the new moon phase. Furthermore, when this moon phase is accompanied by heavy rains, it is a sign for the local community that the penja schools will come. A similar case is reported from La Reunion, where migration of amphidromous goby post-larvae of the species *Sicyopterus lagocephalus* is often associated with relatively heavy rainfall and the flow of freshwater seems to trigger migration and occasional migration can occur after heavy or prolonged rain even in rivers whose flow may be interrupted during dry periods (Delacroix 1987; Delacroix and Champeau 1992).

After the pelagic larva phase, post Larvae return to the river gather in large numbers at the mouths of the rivers, as they need to find river systems to fulfill their life cycle (Keith 2003). Settlement in freshwaters occurs by successive waves, hydrological conditions and function of the lunar cycle (Ellien 2016). A second transformation takes place there, under the control of thyroid hormones, allowing them to adapt again to a freshwater environment after several months spent at sea (Ellien 2016).

At sites such as the Mapilli River and the Mandar River, many fishermen search for penja when the lunar cycle enters the new moon phase. Some fishermen go to the sea in groups of small boats and search the area in the morning, evening, or night. They observe the color of the seawater, as the presence of penja schools is usually marked by a change in color, with large irregular dark patches. The fishermen then cast their nets to catch the penja in the river (Figure 2A). Other fishermen use large push or scoop nets in the shallow waters along the shore (Figure 2B).

One practical method used by people living around the Lariang River to predict the appearance of penja is to examine the digestive tract of several (mostly pelagic) fish commonly caught by the fishermen (e.g., skipjack tuna and yellowfin tuna). If penja are found in the guts of these fish, they can be sure that one or more schools of penja will soon enter the river. The local community calls this phenomenon a penja broadcast, a sign that the penja fish will migrate to the location and a warning to fishermen that they need to be ready and prepare their penja fishing gear such as *bunde* (scoop nets), *seser* (push nets), and other traditional or artisanal fishing equipment. In Sampaga District, local fishermen also examine the digestive tracts of skipjack tuna and several demersal fishes, looking for the "penja broadcast". Their observation methods pay attention to the condition of the penja in the digestive tract. If the penja are in a broken down and partially digested state, this indicates the schools are still far from the coast. If, however, the penja in the guts of these predators are still fresh, this means that the schools are approaching the coast, and the fishermen will swiftly prepare their fishing gear either alone or in groups, as described by Busra (2020).

Figure 2. Fishing for penja along the coast and in the Mandar River estuary using two traditional fishing gears. A. A casting net called Dariq; B. A push or scoop net called Panesser (Photographs by M.R. Alimuddin)

Changes in body-color

The penja caught by fishermen in seawater still have black strips along with their bodies which will gradually disappear after the penja enter the river (Figure 3). This color change is thought to be due to processes triggered by environmental change, in particular the shift from high to low salinity. This means that penja has to undergo several adaptations, especially with respect to changes in osmotic pressure (Keith et al. 2006; Keith et al. 2008).

Amphidromous gobies also have to change their food habits as they migrate from marine to brackish and freshwater environments (Keith et al. 2006; Keith et al. 2008). The marine phase is planktonic and largely planktivorous, with decapod larvae as their main food source. After migrating to the river as postlarvae and during the transition to juvenile and the adult phase, they adopt a benthic herbivorous lifestyle and feed mostly on algae. Changes in body form related to this shift in behavior include a change in the position of the mouth from terminal to subterminal, changes in the shape of the tail, changes in body color (chromatophores), all of which can be considered as a form of morphological adaptation to environmental change.

This metamorphosis in body shape from the postlarval to juvenile phase is gradual, resulting in a wide variation between individuals, as reflected in Figure 4. Keith et al. (2008) also found that changes during the metamorphosis process were reflected in the otolith, an organ which is commonly used to determine age in fish; there is a hallmark noticeably thicker ring which is only found in individuals that have migrated to a riverine environment and is widely recognized as a metamorphosis checkmark. Lord et al. (2010) stated that the metamorphosis checkmark on the otolith is responsible for reflecting the adaptation process during the metamorphosis process and in determining the daily increments of fish (Ellien 2011). Sicydiinae have a tolerance to changes in salinity because they need to change environments twice in their life cycle and when they change a postlarval to juvenile phase, will be described in the otolith circle (Shen and Tzeng 2002; Ellen 2011; Teichert et al. 2016). During the process of changing food habits, there will be a significant reorganization of the cranium and special dental arrangements, as much as possible to monopolize all possible calcium absorbed from the body, thereby inhibiting growth during the adaptation process (Shen and Tzeng 2002).

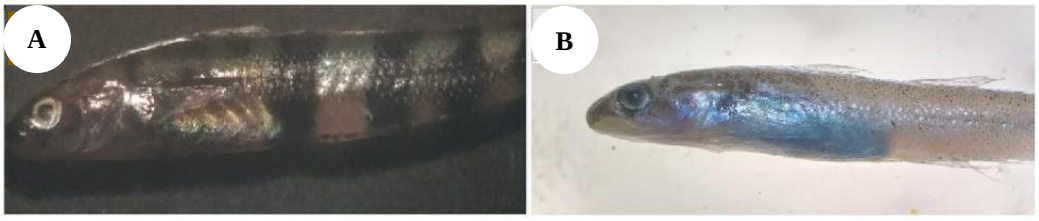

Figure 3. Changes in the body colour of amphidromous goby postlarvae (penja). A. while still in the sea; B. after entering the river

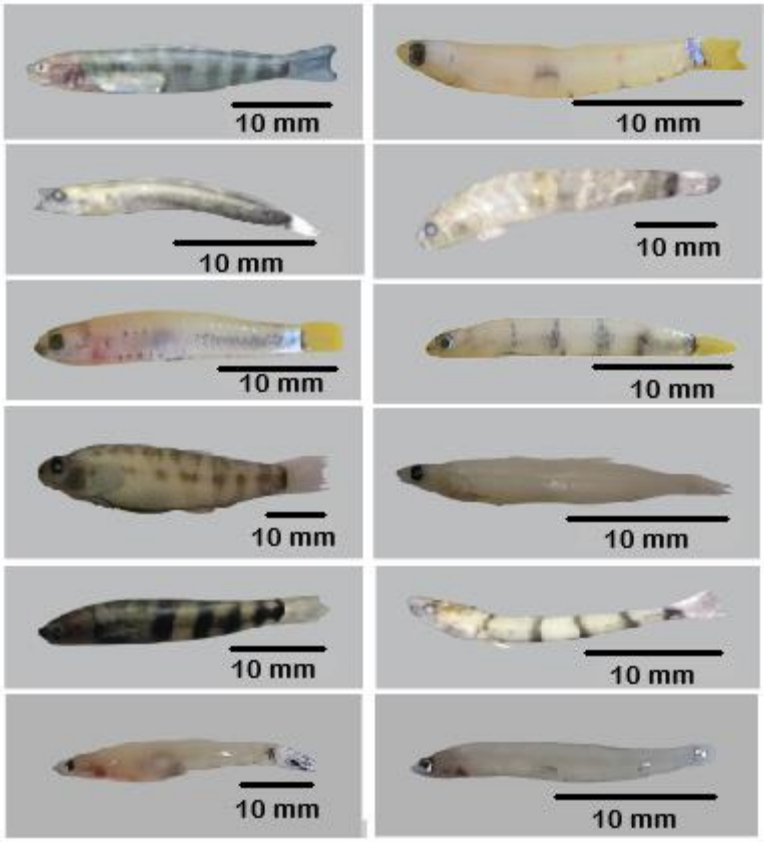

Figure 4. Samples of amphidromous goby postlarvae (penja) from West Sulawesi, Indonesia

To date, it is still very difficult to identify penja to the species level based on their morphology because there is no specific reference for the identification of gobioid postlarvae, even if we can distinguish the different genus altogether, mainly by the size and body shape. One reason for this is that several amphidromous goby species undergo metamorphosis during their early life stages so that morphological identification can only be done with confidence in the adult phase. Keith et al. (2006) made observations in vivo of several amphidromous gobies from French Polynesia and New Caledonia, rearing them from the postlarval to the adult stage. The species identified included *Awaous ocellaris*, *Awaous guamensis*, *Lentipes rubrofasciatus* Maugé, *Sicyopterus marquesensis*, *S. lagocephalus*, *Stenogobius yateiensis*, *Stenogobius genvittatus*, and *Eleotris fusca*. These observations showed significant ontogenetic changes in body shape and color, especially in the genus *Sicyopterus*. Recent research on penja and adult gobies from several rivers in West Sulawesi has identified species from several genera, including *Sicyopterus lagocephalus*, *Sicyopterus longifilis*, *Sicyopterus cynocephalus*, *Stiphodon atropurpureus*, *Stiphodon semoni*, *Stiphodon pelewensis*, *Sicyopus zosterophorus*, *Smilosicyopus leprurus*, *Butis* sp., *Glossogobius celebius*, *Schismatogobius saurii*, *Amphiprion ocellaris*, *Awaous grammepomus*, *Stenogobius genvittatus*, *Giuris margaritacea*, *Ophiocara porocephala*, *Belobranchus belobranchus*, *Eleotris fusca*, and *Eleotris melanosoma* (Nurjirana et al. 2019a; Nurjirana et al. 2019b; Nurjirana et al. 2020). This diversity highlights the urgent need for further exploration of penja schools, in particular, to determine whether there are any species endemic to specific areas of Sulawesi such as West Sulawesi, as well as to contribute to the inventory of the Sulawesian freshwater and diadromous ichthyofauna and to improve management of the fisheries.

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REFERENCES

Ambo-Rappe R, Abigail MM. 2018. Sulawesi seas, Indonesia. In: Sheppard C (eds). World Seas: An Environmental Evaluation, Volume II: The Indian Ocean to the Pacific. Elsevier Academic Press, London, United Kingdom.

Busra B. 2020. Paqduang: Mistisme dan Eksotisme Penangkapan Ikan Seribu di Antara Sejarah Peradaban Masyarakat Nelayan Pesisir Sampaga Kabupaten Mamuju Sulawesi Barat.

Delacroix P, Champeau A. 1992. Ponte en eau douce de *Sicyopterus Lagocephalus* (Pallas) poisson gobiidae amphibionte des revieres de la reunion. Hydroécol Appl 1: 49-63.

Delacroix P. 1987. Etude Des Bichiques, Juveniles de *Sicyopterus Lagocephalus* (Pallas), Poisson Gobiidae, Migrateur Des Rivieres de La Reunion (Ocean Indien): Exploitation, Repartition, Biologie de La Reproduction et de La Croissance. [Thesis]. University of La Reunion, Réunion. [French]

Devi LI. 2012. Identifikasi Postlarva Famili Gobiidae dari Muara Sungai Kedurang, Bengkulu melalui DNA Barcode. [Thesis]. Institut Pertanian Bogor, Bogor. [Indonesian]

Ellien C, Valade P, Bosmans J, Taillebois L, Teichert N, Keith P. 2011. Influence of salinity on larval development of *Sicyopterus lagocephalus* (Pallas, 1770) (Gobioidei). Cybium 35: 381-390. DOI: 10.26028/cybium/2011-354-011.

Ellien C, Werner U, Keith P. 2016. Morphological changes during the transition from freshwater to sea water in an amphidromous goby, *Sicyopterus lagocephalu*s (Pallas 1770) (Teleostei). Ecol Freshw Fish 25: 48-59. DOI: 10.1111/eff.12190.

Keith P, Lord C, Vigneux E. 2006. In vivo observations on postlarval development of freshwater Gobies and Eleotrids from French Polynesia and New Caledonia. Ichthyol Explor Freshw 17 (2): 187-191.

Keith P. 2003. Biology and ecology of amphidromous Gobiidae of the Indo-Pacific and the Caribbean Regions. J Fish Biol 63 (4): 831-847. DOI: 10.1046/j.1095-8649.2003.00197x.

Keith P, Hoareau TB, Lord C, Ah-Yane O, Gimonneau G, Robinet T, Valade P. 2008. Characterisation of post-larval to juvenile stages, metamorphosis and recruitment of an amphidromous goby, *Sicyopterus lagocephalus* (Pallas) (Teleostei: Gobiidae: Sicydiinae). Mar Freshw Res 59 (10): 876-889. DOI: 10.1071/MF08116.

Keith P, Clara L. 2012. Tropical freshwater gobies: Amphidromy as a life cycle. In: Patzner RA, van Tassell L, Kovačić JM, Kapoor BG (eds). The Biology of Gobies. CRC Press, Boca Raton.

Lord C, Brun C, Hautecœur M, Keith P. 2010. Insights on endemism: Comparison of the duration of the marine larval phase estimated by otolith microstructural analysis of three amphidromous *Sicyopterus* species (Gobioidei: Sicydiinae) from Vanuatu and New Caledonia. Ecol Freshw Fish 19 (1): 26-38. DOI: 10.1111/j.1600-0633.2009.00386.x.

McDowall RM. 2007. On amphidromy, a distinct form of diadromy in aquatic organisms. Fish Fish 8 (1): 1-13. DOI: 10.1111/j.1467-2979.2007.00232x.

Mennesson MI, Keith P, Sauri S, Busson F, Delrieu-Trottin E, Limmon G, Sukmono T, Nurjirana, Risdawati R, Dahruddin H, Hubert N. 2021. *Eleotris* (Teleostei: Eleotridae) from Indonesia with description of three new species within the 'melanosoma' neuromast pattern group. Pac Sci 75 (4): 469-496. DOI: 10.2984/75.4.2.

Miller PJ. 1984. The tokology of gobioid fishes. In: Potts GW, Wootton RJ (eds). Fishes Reproduction: Strategies and Tactics. Academic Press, London.

Nishimoto RT, Kuamo'o DG. 1997. Recruitment of goby postlarvae into Hakalau Stream, Hawai'i Island. Micronesia Agana 30 (1): 41-49.

Nurjirana, Afrisal M, Sufardin, Haris A, Burhanuddin AI. 2020. Diversity and distribution freshwater ichthyofaunal of West Sulawesi. IOP Conf Ser: Earth Environ Sci 486 (1): 012079. DOI: 10.1088/1755-1315/486/1/012079.

Nurjirana, Burhanuddin AI, Haris A. 2019a. Diversity of penja fish (amphidromous goby) in Leppangan River, West Sulawesi, Indonesia. AACL Bioflux 12 (1): 246-249.

Nurjirana, Haris A, Sahami FM, Keith P, Burhanuddin AI. 2019b. Preliminary note on the morphological characters of penja (amphidromous goby postlarvae) in West Sulawesi and Gorontalo Bay. IOP Conf Ser: Earth Environ Sci 370: 012007. DOI: 10.1088/1755-1315/370/1/012007.

Nurjirana, Keith P, Burhanuddin AI, Haris A, Afrisal M. 2021. DNA barcoding of two amphidromous goby postlarvae ('penja') morphotypes from Mandar River, West Sulawesi, Indonesia. Cybium 45 (3): 243-249. DOI: 10.26028/cybium/2021-453-009.

Sahami FM, Kepel RC, Olii AH, Pratasik SB, Lasabuda R, Wantasen A, Habibie SA. 2020. Morphometric and genetic variations of species composers of nikefish assemblages in Gorontalo Bay Waters, Indonesia. Biodiversitas 21 (10): 571-4581. DOI 10.13057/biodiv/d211015.

Said PM. 2011. Ekologi Ekonomi Sumberdaya Larva dan Juvenil Ikan di Teluk Pelabuhanratu, Kabupaten Sukabumi, Provinsi Jawa Barat. [Thesis]. Institut Pertanian Bogor, Bogor. [Indonesian]

Shen KN, Tzeng WN. 2002. Formation of a metamorphosis check in otoliths of the amphidromous goby *Sicyopterus japonicus*. Mar Ecol Prog Ser 228 (3): 205-211. DOI: 10.3354/meps228205.

Tate DC. 1997. The role of behavioral interactions of immature Hawaiian stream fishes (Pisces: Gobiodei) in population dispersal and distribution. Micronesica 30 (1): 51-70.

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. Ecol Freshw Fish 25 (2): 234-247. DOI: 10.1111/eff.12205.