

**The Gobiid Fishes (Teleostei: Gobioidae: Sicydiinae)
of the Headwater Streams of Pohnpei, Eastern Caroline Islands,
Federated States of Micronesia**

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Abstract—Four hundred and twenty-seven gobies of five species (three endemic) were collected in headwater streams of Pohnpei, Federated States of Micronesia (FSM) during February–November 1999. *Sicyopterus lagocephalus* and the genus *Lentipes* represented by an undescribed species are reported in the FSM for the first time. *Stiphodon caeruleus* is the most abundant goby species in Pohnpei rivers, at least in mid to upper reaches; gobies previously reported as *Stiphodon* cf. *elegans* are an undescribed species. Sexual dimorphism in coloration and pattern was detected in all species, but a statistically significant difference in body size based on standard length was demonstrated only in *Stiphodon caeruleus*. Locality data provide evidence of habitat partitioning or segregation along a stream gradient in some species, but further study is needed to clarify these relationships.

Introduction

Gobies are a prominent part of riverine fish communities throughout the tropical Pacific (Ryan 1991), but information on the distribution, ecology, and taxonomy of many species, especially throughout Micronesia, is incomplete or lacking (Nelson et al. 1997). The incomplete nature of this information can be directly attributed to the uncertain systematic and nomenclatural status of most genera, and the relatively few surveys of insular streams. In the first comprehensive survey of stream macrofauna in the Caroline Islands, Maciolek & Ford (1987) recorded seven species of gobies on Pohnpei, including *Glossogobius celebius*, *Redigobius bikolanus*, and five Sicydiinae unidentified as to species. From among

these five “unknowns,” Parenti & Maciolek (1993) described *Sicyopus nigriradiatus*, *Sicyopterus lividus*, *S. eudentatus*, and *Stiphodon caeruleus* (all endemic to Pohnpei), and they identified “*Stiphodon* species 2” of Maciolek & Ford (1987) as *Stiphodon* cf. *elegans*. All their samples were from the Nanpil-Kiepw and Lehn Mesi rivers and several smaller streams also in the northern and western parts of the island, and at elevations below about 200 m. The same seven species (and no others) were recorded also by Nelson et al. (1996, 1997) who surveyed the Nanpil-Kiepw and Lehn Mesi rivers at similar elevations twice in early 1996. The present study contributes two additional species to the list of gobies recorded from Pohnpei and presents new locality records for three others along with additional information on morphological variation. It is based largely on our collections and observations at 33 stations (mainly above 200 m) among six different rivers from throughout the island during February–November 1999.

Study Area and Methods

Pohnpei is a ruggedly mountainous tropical Pacific island (355 km² in area) located 766 km north of the equator in the Eastern Caroline Islands, Federated States of Micronesia (Fig. 1). Maximum elevations in the central highlands are just under 800 m with at least 11 peaks exceeding 600 m (U.S. Army Corps of Engineers 1986). Densely forested ridges and valleys radiate outward and downward to coastal lowlands and surrounding mangroves. The 1994 national census recorded 31,540 people living on Pohnpei (Office of Planning and Statistics 1996) mainly in coastal areas. The central highlands remain uninhabited and no roads traverse the island. An abundance of lush, verdant vegetation notwithstanding, Trustrum (1996), based on aerial photo analysis, reported a decline in mature native upland forest from about 42% of the vegetation cover in 1975 to about 15% in 1995. He attributed the loss largely to the clearcutting of numerous small plots for cultivating sakau (= kava in Fiji), *Piper methysticum*.

The average annual temperature on Pohnpei is 27 C and the average monthly temperature does not vary from the annual average by more than 1 C (Laird 1982). Mean annual rainfall in Kolonia, the main settlement (on the northern coast) is approximately 485 cm, with estimates for the mountains being as high as 1,015 cm (Merlin et al. 1992). The abundant rainfall feeds numerous streams. Those we surveyed averaged about 2–4 m wide and 0.5–1.0 m deep with some pools below the larger waterfalls reaching depths of about 3 m. The substrate in the stream beds consisted largely of boulders and cobbles along with some exposed bedrock and small deposits of gravel. Gradients were not measured, but rapids, runs, and cascades were prevalent. Numerous waterfalls 5–50 m high were encountered along nearly all courses. Water temperatures were 23–27 C, and elevations at study sites were 146–550 m.

Thirty three stations distributed among six rivers were surveyed for both freshwater shrimps and gobiid fishes during February–November 1999 (Fig. 1).

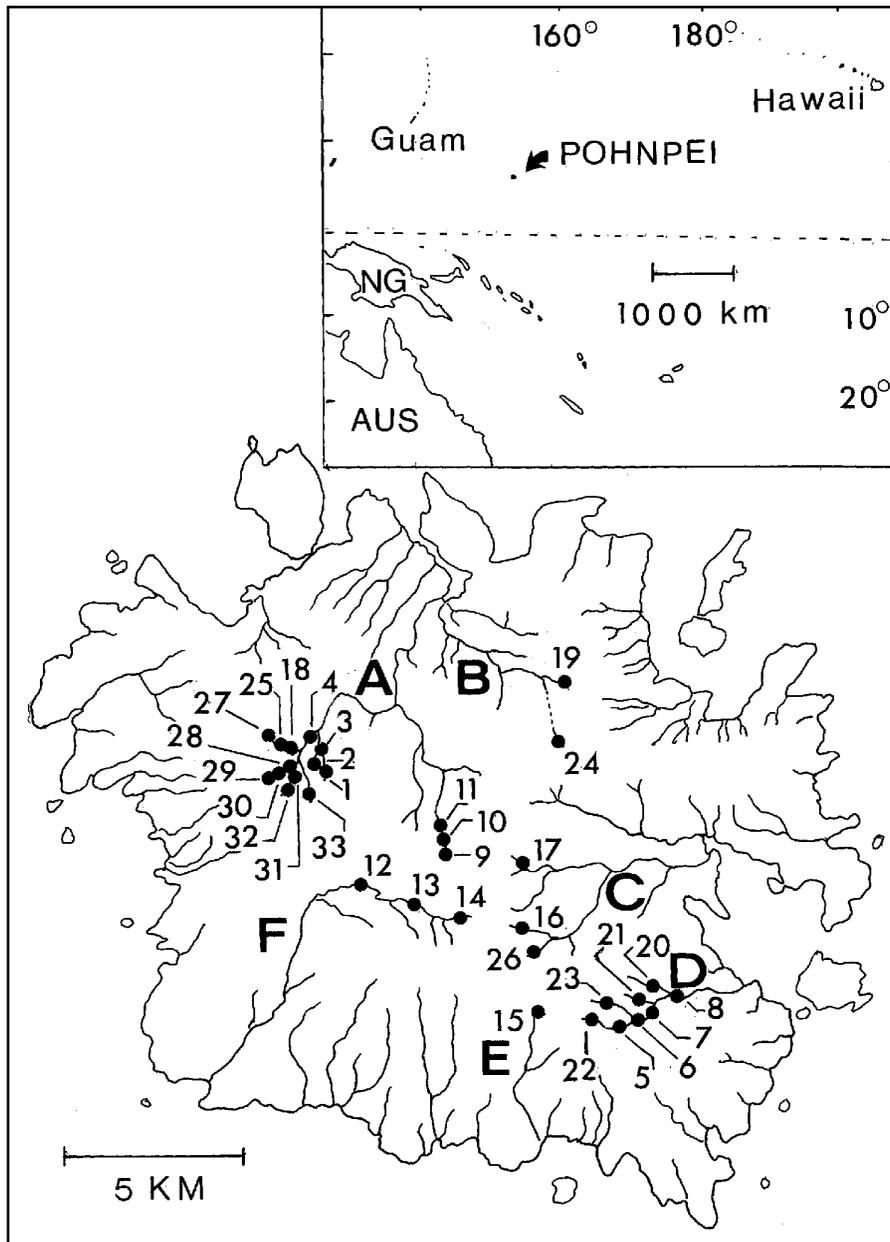


Figure 1.—Location Map for Pohnpei and collecting stations for 1999 headwaters survey. A = Nanpil-Kiepw River, B = Meitik River, C = Senipehn River, D = Mahnd River, E = Neh River, F = Lehn Mesi River, Aus = Australia, NG = New Guinea; broken line = equator.

Twenty six (79%) were above 200 m and accounted for 50 hours (= 91%) of the search effort, loosely defined to include streamside processing of specimens (including shrimp), note-taking, and time spent walking along stream banks within station areas. Inasmuch as "search effort" included several disparate components, we did not calculate a capture rate index for the gobies. The stations averaged about 25–50 m long with some limited to small pools only a meter or two in diameter and others covering as much as 100–150 m of the stream. Areas above and below major waterfalls (> 8 m high) were treated as separate stations. Elevations were measured with a Barigo altimeter scaled in 20-foot increments.

The nomenclature of Pohnpei place names is complex with many orthographic variations; the name of a river may change several times along its course depending on which community it is passing through. We used what we believe are among the most frequently applied and most readily recognizable names adopted from the literature cited and from a 1:25, 000 scale topographic map (U.S. Geological Survey 1983). When referring to the western branches of the Nanpil-Kiepw River, we frequently use the simplified name Nanpil.

Specimens were collected with hand-held nets and miniaturized spears of coat hanger wire, welding rods, and elasticized bands. They were fixed in 10% formalin, washed, transferred to 35% isopropanol, and cataloged as series GB. Standard length (SL) was measured in millimeters by using dial calipers and the measurements were submitted to a Student's t-test for significance. Sex was determined from external morphology. The 427 specimens were donated to the B. P. Bishop Museum (Honolulu), California Academy of Sciences (San Francisco), Florida Museum of Natural History, University of Florida (Gainesville), Museum of Comparative Zoology, Harvard University (Cambridge, Mass.), College of Micronesia (Pohnpei), National Museum of Natural History, Smithsonian Institution (Washington, D.C.), and Royal Ontario Museum (Toronto).

Results

We collected and cataloged 427 gobies of five species from 25 of 33 stations distributed among six rivers throughout the island (Fig. 1). The eight stations that did not yield specimens were the uppermost reaches of narrow, shallow tributaries (probably with interrupted flow during extended periods of low rainfall) and areas with relatively sluggish flow and accumulation of organic debris on high elevation plateaus. Four were above 300 m (9, 24, 27, 29) and four were below (1, 2, 3, 19), and all were the terminal stations on their respective tributaries. Stations 19 and 24 were our only sites on the Meitik River, and we consider our lack of specimens from this river an artifact of sampling because some of the species we encountered in other streams probably inhabit the main channel at more moderate elevations on the Meitik.

Species Accounts

Sicyopus nigriradiatus.—This species was as widespread as *Stiphodon caeruleus* (the most common species) but much less numerous, and it was the one we found most closely associated with the uppermost reaches of the rivers. Of the 33 gobies we collected above 400 m (accounting for 10% of the search effort), nine (27.3%) were *S. nigriradiatus* representing 18% of the *S. nigriradiatus* specimens from all elevations; the 22 *Stiphodon caeruleus* collected at this elevation represented only 7.2% of the species sample (Table 1). Males of *Sicyopus nigriradiatus* tend to be unicolor light brown or tan, occasionally washed with yellow, and often with 6–7 indistinct darker (brown) saddle bars between head and tail. Specimen GB 162 had a single dark brown band encircling the otherwise unmarked body between the first and second dorsal fins. Many females (and some males) are more boldly patterned (in tones of brown and tan) frequently with a broad, pale, irregular lateral stripe extending from head to tail in a field of darker pigmentation, which occasionally encroaches within the pale area at intervals forming a series of irregular cells or blotches. GB 283 had six well-defined pairs of darkly colored, inverted C-shaped marks on the sides. The black rays of the median and paired fins in both sexes are diagnostic.

Lentipes sp.—Eleven males and 17 females of an undescribed species of *Lentipes* were collected at stations 18, 25, 28, 30, 32, and 33, all on the Nanpil River at elevations between 201–323 m during 28 August–20 November 1999. Males tend to have a grayish blue ground color, whereas females are shades of brown, tan, or gray. Individuals of both sexes often show 2–9 nearly obsolete pairs of pale orange, beige, or tan spots on the dorsum. The darkly colored fine to coarse stipples or spots on the posterior part of the body, mainly below the midline, readily distinguish this species from all the others we encountered. Members of this species also were frequently observed free-swimming in the water column,

Table 1. Distribution of goby specimens (M = male, F = female) collected in Pohnpei headwater streams during February–November 1999.

Species	Frequency ^a	River ^b				
		N-K	Sen	Man	Neh	LMe
<i>Sicyopus nigriradiatus</i>	13 (39%)	3M/5F	6M	20M/7F	3M/2F	2M/2F
<i>Lentipes sp.</i>	6 (18%)	11M/17F				
<i>Sicyopterus lagocephalus</i>	2 (6%)			1F	3M/12F	
<i>Sicyopterus lividus</i>	11 (33%)	2M/1F	9M/4F	8M/5F		
<i>Stiphodon caeruleus</i>	19 (58%)	18M/30F	21M/51F	43M/38F	9M/8F	33M/49F

^a The number of stations where the species was collected, with the percent of the total number of stations in parentheses.

^b N-K = Nanpil-Kiepw, Sen = Senipehn, Man = Mahnd, Neh = Neh, LMe = Lehn Mesi; the Meitik River is omitted here as no gobies were collected at its two stations.

whereas individuals of other species typically were attached to a firm substrate. This account is the first report of the genus *Lentipes* from Micronesia, and a description of the new species is in preparation (Watson ms). In addition to the specimens obtained during this [1999] study, one was collected in the Lehn Mesi River at an elevation of 80 m on 9 July 1986 by J. A. Maciolek and J. I. Ford, another in the Nanpil River in January 1980, and another in a stream on Kosrae, about 560 km ESE of Pohnpei, in 1996 (Watson, ms).

Sicyopterus lagocephalus.—This species has been recorded previously at many disparate island localities in the Indian Ocean and western Pacific, and under many different names (Watson, unpublished notes). The 15 we collected in the Lehn Mesi River and another in the Mahnd River are the first reported for Pohnpei and Micronesia. This was the largest goby species we encountered (maximum SL 106.2 mm), averaging nearly twice the size of the next largest species, *Sicyopterus lividus* (Table 2). All were collected at 238–244 m in elevation, usually in the deeper pools or runs along the main river channels. The dorsolateral ground color is tan, gray, or olive, often with 7–10 darker colored saddle bars. The venter is usually white bordered by light brown or gold merging with the darker pigmentation on the sides. Males tend to have bluish or greenish hues on the sides, with the caudal fin being orange and narrowly edged with blue. Pectoral fins in males are silvery gray in contrast to the duller, grayish brown or tan fins of females. A black horseshoe-shaped mark (inverted C) on the tail of both sexes is diagnostic. In GB 309, a male, the ground color turned dark blue, the pectoral fins turned from silver to black, and the caudal fin became more vibrant orange, all within seconds of immersion in formalin. A dark gray or brown oblique bar extended from the posterior border of the eye to the angle of the jaw in most specimens.

Sicyopterus lividus.—We encountered this species regularly in the Senipehn, Mahnd, and Lehn Mesi rivers but did not see it in the Nanpil-Kiepw, where Maciolek & Ford (1987) recorded it ("*Sicyopterus* sp. 1") at six different sites, nor did we encounter it on the Meitik and Neh rivers. Males are often vivid blue usually with 6–8 dark (brown or black) saddle bars between head and tail and with an orange caudal fin. The brilliant and contrasting colors were not always evident in situ, but they rapidly developed following immersion in formalin and replaced the more subdued light brown ground color with copper or gold highlights and often nearly obsolete saddle bars. The more vividly colored males often have a pale blue venter with ventral edges of the pectoral fins yellow, and with the dorsal fin rays yellow tipped with blue. Females lack the bright colors being light brown with the venter cream-colored. *Sicyopterus lividus* was especially numerous in the Senipehn River below our survey sites at an elevation of about 92 m, where density was estimated at about 1.0/m², and where many brilliant blue presumed males were observed chasing away others in apparent territorial display on 11 September 1999.

Stiphodon caeruleus.—These fish were by far the most abundant species throughout the island and accounted for 304 (71.2%) of our specimens, even as efforts to collect them were curtailed at most stations to focus on other species. High goby densities exceeding 50/m² reported by Nelson et al. (1996, 1997) were attributed largely to this species. We found it common in all rivers excluding the Meitik (Table 1). Males characteristically were vivid blue or green, and we noted that coloration in those recently captured and placed in water-filled tubes varied from blue to green to almost dull gray depending on the angle of light and possibly the physiological state of the specimen. Females lacked bright colors and their ground color was consistently light brown, gray, or tan.

Discussion

Three (60%) of the five goby species we encountered in Pohnpei headwaters (*Sicyopus nigriradiatus*, *Sicyopterus lividus*, *Stiphodon caeruleus*) are so far as known endemic to the island. The number would be four of six (67%) had we collected *Sicyopterus eudentatus*, which may occur in small numbers; Maciolek and Ford (*vide* Parenti & Maciolek 1993) collected 17 in the Nanpil River at elevations between about 100–200 m. Of the two indigenous but nonendemic gobies collected in this study, *Sicyopterus lagocephalus* is widespread in the western Pacific and Indian Ocean islands but recorded in Micronesia here for the first time, and *Lentipes* sp. occurs also on Kosrae, where one collected in 1996 was examined by REW. Two additional species, *Glosogobius celebius* and *Redigobius bikolanus* were recorded in the lower reaches of Pohnpei rivers by Nelson et al. (1996, 1997), but not encountered in our survey. The species referred to as *Stiphodon* cf. *elegans* by Parenti & Maciolek (1993) (= “*Stiphodon* sp. 2” in Maciolek & Ford, 1987) is an undescribed species apparently restricted to the lower stream reaches on Pohnpei. *Stiphodon elegans* (*sensu stricto*) currently is known only from the Society and Tubuai Islands, French Polynesia, and the Samoa Islands (Watson 1995).

The only other fish species we observed in the headwaters was the eel, *Anguilla marmorata*, which was common throughout and ranged in size from about 0.2–2.0 m. The largest typically occupied the deeper pools at the foot of waterfalls, whereas smaller size-classes were more widely dispersed, occurring even in shallow seepage areas and on rain-sodden areas of the forest floor. Eels were especially numerous in the Mahnd River, where we counted 14 in shallows along approximately 3.0 km of stream bed during one visit.

All the surveys indicate the most abundant species of goby in Pohnpei rivers is *Stiphodon caeruleus* (Maciolek & Ford 1987; Nelson et al. 1996, 1997; this study—304 specimens comprising 71% of our sample collection). *Sicyopterus lividus* was reported also as “common” by Nelson et al. (1996, 1997), and we observed it frequently as well, recording it in 11 (33%) of the stations surveyed (Table 1). However, we found *Sicyopus nigriradiatus* more numerous than

Sicyopterus lividus (Table 1), whereas Nelson et al. (1996, 1997) considered *S. nigriradiatus* “uncommon” and Parenti & Maciolek (1993) recorded only 19 compared with 109 *Sicyopterus lividus*. Our findings suggest that *Sicyopterus nigriradiatus* is more characteristically an inhabitant of the upper reaches of the streams than of low to moderate elevations, where previous surveys were done. Whether this distribution is preferential or an example of ecological displacement is unknown. Competitive exclusion based on feeding ecology is unlikely as *Sicyopterus nigriradiatus* is the only carnivore or omnivore among at least 4–5 herbivorous sicydiines (Nelson et al. 1996, 1997); the feeding habits of *Lentipes* sp. are unknown.

Sicyopterus eudentatus is among the least common if not the rarest of the gobies in Pohnpei rivers. In the original description, Parenti & Maciolek (1993) recorded 17 specimens, all collected in the Nanpil-Kiepw River in April 1982. We collected none in our study area and only one incidentally on the Senipehn River well below our survey sites at about 92 m on 11 September 1999. But how many of the large gobies we saw but did not collect were this species and not the seemingly more abundant *S. lagocephalus* is unknown. Whether *S. eudentatus* and *S. lagocephalus* (morphologically very similar, large-bodied herbivores) replace each other along a stream gradient is undetermined.

The undescribed species of *Lentipes* is locally common in some sections of the Nanpil River, with as many as 10–15 seen together in a shallow pool at the

Table 2. Standard length measurements (mm) of gobies collected in Pohnpei headwater streams during February–November 1999, given in the sequence range, (N), mean \pm 1 SD.

Species	Males	Females	t-test ^a
<i>Sicyopterus nigriradiatus</i>	23.9–64.6 (35)	24.1–67.3 (15)	
	45.2 \pm 9.3	44.4 \pm 12.5	ns
<i>Lentipes</i> sp.	38.6–51.3 (11)	29.8–50.8 (17)	
	43.9 \pm 3.6	44.6 \pm 4.8	ns
<i>Sicyopterus lagocephalus</i>	79.5–105.4 (3)	83.4–106.2 (13)	
	95.8 \pm 14.2	97.7 \pm 8.0	ns
<i>Sicyopterus lividus</i>	44.3–69.0 (19)	39.1–74.1 (10)	
	56.8 \pm 7.3	60.4 \pm 11.3	ns
<i>Stiphodon caeruleus</i>	16.8–43.2 (128)	16.2–37.2 (176)	
	26.3 \pm 5.7	24.9 \pm 4.5	*

^a * = $P < 0.05$, ns = no significant difference, $P > 0.05$.

foot of a waterfall at station 28. Its apparent absence at most of our other sites may be artifactual and additional investigations should focus on locating other populations as it is known elsewhere from one specimen collected in the Lehn Mesi and another from a stream on Kosrae.

The gobies of Pohnpei headwater streams appear to have few natural predators. The eel, *Anguilla marmorata*, a ubiquitous and aggressive carnivore with catholic tastes, almost certainly feeds on them as does the Pacific Reef-Heron, which occasionally forages along streamsides away from its more typical coastal habitats. There is no direct exploitation of river gobies by humans; however, the increasing encroachment of local agriculture (cultivation of sakau) into the highlands is a potential threat. The clearcutting of 1–2 hectare plots on montane slopes adjacent to headwater streams for example, will likely alter stream ecology (light, temperature, turbidity, volume fluctuations, etc.) and negatively affect stream species (see Kido 1996). The preservation of native upland forest is a priority project for the Pohnpei branch of The Nature Conservancy. Bill Raynor, Director, has achieved some measure of success in convincing traditional community leaders to persuade local residents to “plant [sakau] low.” But resistance is high as the crop grows best on the high, steep, wet montane slopes.

Acknowledgments

We thank G. Burgess, K. Hartel, T. Iwamoto, L. Parenti, K. Rhodes, and R. Winterbottom for responding to our numerous queries concerning Pohnpei gobies, G. Burgess for relaying specimens in transit, and D. Kesler and K. Rhodes for their very much appreciated assistance during several collecting trips. We also thank J. M. Fitzsimons and an anonymous reviewer for their helpful comments on the manuscript.

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