

Distribution of *Sicydium Valenciennes* 1837 (Pisces: Gobiidae) in Mexico and Central America

Distribución de *Sicydium Valenciennes* 1837 (Pisces: Gobiidae) en México y Centro América

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ABSTRACT

Gobies of the genus *Sicydium* Valenciennes are widespread in Mexico and Central America, but have a different distribution pattern on the Atlantic and Pacific slopes of the region. On the Pacific slope, where mountain ranges are found near the coast and the coastal plain is narrow, *Sicydium* is continuously distributed in rivers from Mazatlán, Sinaloa, Mexico, to central Panama. On the Atlantic slope, *Sicydium* is known from three disjunct areas where coastal mountain ranges are present, central Mexico, northern Honduras, and northeastern Costa Rica and northern Panama, and has not been recorded from intervening areas with broad coastal plains. The amphidromous life history of *Sicydium* gobies may prevent them from occupying rivers flowing through broad coastal plains. *Sicydium* gobies spawn in rocky mountainous river reaches and their larvae drift downstream to the ocean where they begin feeding. In rivers crossing broad coastal plains the distance to the ocean is relatively long, and I hypothesize that newly hatched larvae might starve before they reached their marine feeding habitat or that post-larvae might starve on their return migration up river to adult habitat.

Key words: Goby, Life history, Amphidromy, Diadromy, Larval drift.

RESUMEN

Los gobios del género *Sicydium* Valenciennes se distribuyen ampliamente en México y Centro América, pero presentan diferentes patrones de distribución en las vertientes del Atlántico y Pacífico. En esta última, donde las zonas montañosas se localizan cerca de la costa y la planicie costera es estrecha, *Sicydium* tiene una distribución uniforme desde Mazatlán, Sinaloa, México, hasta la parte central de Panamá. En la vertiente del Atlántico *Sicydium* se limita a tres áreas separadas donde existen regiones montañosas cercanas a la costa, aunque no se encuentra en zonas que tienen planicies costeras extensas. En esta vertiente su distribución incluye la porción central de México, norte de Honduras, noreste de Costa Rica y norte de Panamá. Su ciclo de vida, del tipo anfídromo, parece impedirles habitar en los ríos que recorren planicies costeras extensas. *Sicydium* lleva a cabo su reproducción en áreas rocosas de ríos de montaña y las larvas son transportadas por la corriente hasta el mar, donde inician su alimentación. En ríos que atraviesan planicies costeras la distancia al océano es larga, por lo que propongo la hipótesis de que las larvas recién eclosionadas mueren por falta de alimento antes de llegar a un hábitat marino propicio para su alimentación, o bien, los estadios postlarvarios mueren por la misma causa antes de regresar a su hábitat de vida adulta.

Palabras clave: Gobio, Ciclo de vida, Anfídromía, Diadromía, Migración de larvas.

INTRODUCTION

Gobies of the genus *Sicydium* inhabit rivers of tropical west Africa, Caribbean islands, both the Atlantic and Pacific slopes of Mexico, Central America, and northern South America, and eastern Pacific islands (Eigenmann, 1922; Erdman, 1961, Miller, 1966; Bussing, 1987; Harrison, 1994; Miller *et al.*, 2005). In many rivers they are abundant and a key part of the food web (Lyons & Schneider, 1990; Penzcak, 1992). *Sicydium* gobies are sensitive to environmental degradation and are good indicators of environmental quality (Lyons *et al.*, 1995). The taxonomy of *Sicydium* is uncertain and currently under revision (F. Pezold, pers. comm.). There are over 20 nominal taxa described from the Western Hemisphere, of which recent authors recognize from 6 to 12 species (Erdman, 1961, Brockmann, 1965; Bussing, 1987, 1996; Watson, 2000).

In Mexico and Central America, the distribution pattern of *Sicydium* gobies differs between the Pacific and Atlantic slopes. On the Pacific slope *Sicydium* gobies have an essentially continuous distribution from northern Mexico through central Panama (Figure 1). However, on the Atlantic slope they are reported only from three disjunct areas, in central Mexico, northern Honduras, and Costa Rica and Panama. My objective in this paper is to propose a hypothesis based on the life history of *Sicydium* to explain their distribution pattern in Mexico and Central America.

MATERIAL AND METHODS

I determined the distribution of *Sicydium* in Mexico and Central America based on published accounts, primarily Hildebrand, 1925; Loftin, 1965; Miller, 1966, 1986; Martin, 1972; Villa, 1982; Bussing, 1987, 1996; Greenfield & Thomerson, 1997; Castro-Aguirre *et al.* 1999; Miller *et al.*, 2005, unpublished records from 23 museums in North America, and my own field observations. Localities were plotted on 1:1,000,000 topographic maps. From a randomly chosen set of 25 rivers containing *Sicydium* and another set of 25 from which *Sicydium* was absent, I measured the total length of the river and the distance, following the river channel, from the ocean to the 200-m elevation contour. Total length was an index of river size, and I assumed that river flow was directly proportional to river length. I considered the 200-m contour to define the inland edge of the coastal plain. For rivers lacking records of *Sicydium*, I only included those that had been sampled at two or more localities in reaches of appropriate habitat in order to reduce the possibility that *Sicydium* was actually present in these rivers but had been missed during surveys. I compared the log-transformed total and coastal-plain lengths of rivers with and without *Sicydium* with *t*-tests and linear regression (SAS, 1990).

RESULTS

On the Pacific slope of Mexico and Central America, *Sicydium* gobies occur from rivers north of the city of Mazatlán, Sinaloa, Mexico (24° N; 107° W) to central Panama (9° N; 79° W). Within this zone *Sicydium* is found in most river systems that have been sampled adequately (Figure 1). There are few records from southern Mexico, Guatemala, and El Salvador, and none from eastern Panama, but rivers in these regions have seen few fish collections. Gobies from Mexico, Guatemala, El Salvador, and Honduras are currently referred to as *S. multipunctatum* Regan 1906, whereas those from Nicaragua, Costa Rica, and Panama are referred to as *S. salvini* Ogilvie-Grant 1884. The entire Pacific slope of Mexico and Central America has mountains near the coast, and rivers flow through the coastal plain for less than 60 km before reaching the ocean except in eastern Panama, where rivers typically flow 75 km or more.

On the Atlantic slope of Mexico and Central America, *Sicydium* gobies are known from three disjunct areas (Figure 1). The northernmost area extends from near the city of Tuxpan (21° N; 97° W) to near the city of San Andrés Tuxtla (19° N; 95° W) in the state of Veracruz in central Mexico. The species occurring here is *S. gymnogaster* Ogilvie-Grant 1884. Within this area, *Sicydium* is reported only from rivers located in coastal mountain ranges, and rivers flowing more than 75 km through the coastal plain (e.g., Río Papaloapan) lack records of *Sicydium*.

Sicydium has not been found along the Atlantic slope of Mexico to the east of San Andrés Tuxtla, which includes the northern side of the Isthmus of Tehuantepec, the large Río Grijalva/Usumacinta basin, and the Yucatán Peninsula, and from all of Belize and the Atlantic slope of Guatemala. Throughout most of this area rivers either flow more than 100 km through a coastal plain (Isthmus of Tehuantepec, Grijalva/Usumacinta basin, northern Belize and Guatemala) or are largely absent (Yucatan Peninsula). However, coastal mountain ranges occur in southern Belize and Guatemala and the rivers draining these mountains flow only 30 to 60 km through the coastal plain. *Sicydium* gobies have not been found in these rivers, although sampling has been limited and the genus may occur in remote areas not yet surveyed.

The central area of the Atlantic slope with *Sicydium* is located in northern Honduras between the city of Puerto Cortés (16° N; 88° W) and the Río Plátano (16° N; 84.5° W). Here coastal mountain ranges occur and rivers flow 5 to 50 km through the coastal plain. Only a few records of *Sicydium*, all referred to *S. gymnogaster*, are known, but most rivers have not been adequately sampled.

The Mosquitia region of extreme eastern Honduras and all of eastern Nicaragua has no records of *Sicydium*. However, the

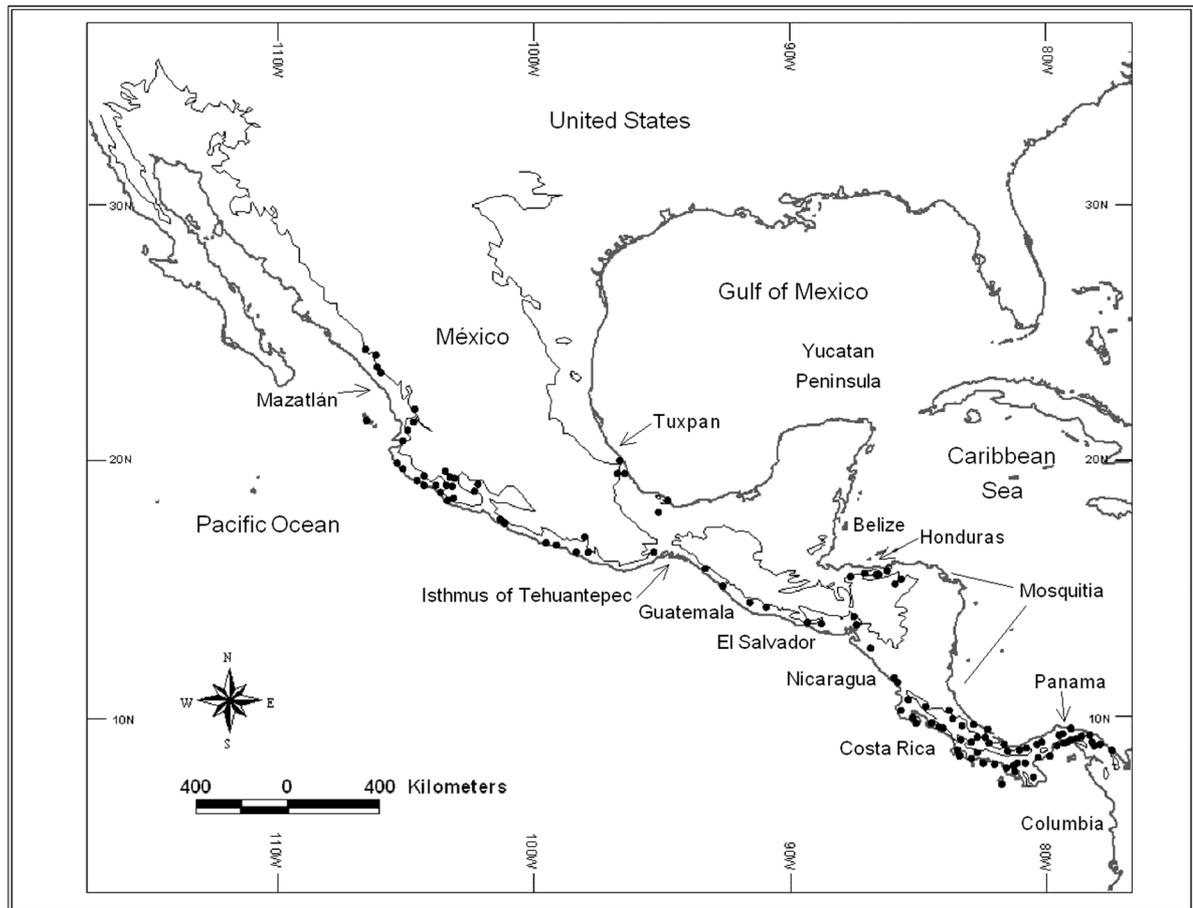


Figure 1. Known distribution of *Sicydium* gobies in Mexico and Central America and adjacent areas. See the text for the sources of data. The 200-m elevation contour is indicated by a fine line, delineating the extent of the coastal plain.

region has seen only limited sampling. No coastal mountains occur in Mosquitia, and the rivers there flow 100 to 200 km or more through a broad coastal plain.

The southernmost of the three areas of the Atlantic slope with *Sicydium* includes all of northeastern Costa Rica (10.5° N; 84° W) and northern Panama to the border with Colombia (9° N; 77.5° W), extending into northern Colombia. Here mountains range close to the coast and rivers flow 25 to 90 km through the coastal plain. At least four species of *Sicydium* occur in this area: *S. adelum* Bussing 1996, *S. altum* Meek 1908, *S. plumieri* (Bloch 1786), and *S. punctatum* Perugia 1896. *Sicydium altum* is found throughout the area, but *S. adelum* is limited to a small area of southeastern Costa Rica near the border with Panama and *S. plumieri* and *S. punctatum* to extreme eastern Panama near the border with Colombia.

Overall, within their range in Mexico and Central America, *Sicydium* gobies have not been found in rivers that begin in inland mountain ranges and flow through a broad coastal plain. Conversely, they are present in many rivers, southern Belize and Guatemala perhaps excepted, that originate in coastal moun-

tains and flow through a narrow coastal plain. On the Pacific slope, coastal mountain ranges occur throughout the range of *Sicydium*, and the genus is continuously distributed. On the Atlantic slope, coastal mountain ranges occur in only a few areas, and these are the only areas where *Sicydium* has been found. Rivers with *Sicydium* are significantly shorter in total length than rivers without *Sicydium* (mean 151 km, range 5 to 930 km vs. mean 274 km, range 60 to 950 km; $t = 3.87$; $p = 0.0004$). They also flow a significantly shorter distance through the coastal plain before they reach the ocean (mean 31 km, range 4 to 90 km vs. 120 km, range 32 to 300 km; $t = 7.03$; $P < 0.0001$). For those rivers that contain *Sicydium*, the length of the river is significantly positively related to the distance it flows through the coastal plain ($F = 177.7$; $p < 0.0001$; $r^2 = 0.88$).

DISCUSSION

The pattern of distribution of *Sicydium* in Mexico and Central America is clearly related to the presence of coastal mountain ranges and the width of the coastal plain. What might cause the presence of *Sicydium* in rivers draining

coastal mountain ranges and their apparent absence from rivers that originate from inland mountains and flow through a broad coastal plain to reach the ocean? I hypothesize that the answer may be found in the life history of the members of the genus *Sicydium* and related genera of gobies, termed sicydiines, are amphidromous, a modification of diadromy (McDowall, 1988). As such, they spawn in freshwater streams and rivers. Newly hatched larvae drift downstream to the ocean where they spend weeks or months in a pelagic phase feeding on plankton (Bell and Brown, 1995; Keith, 2003). They eventually move to the mouths of rivers where they settle to the bottom, transform from larvae to juveniles, and migrate upstream (Silva-Melo & Acero-P., 1990; Bell *et al.*, 1995). During their transformation they switch from feeding on plankton to grazing algae and aufwuchs from rocks (Winemiller, 1983; Penczak, 1992; Keith, 2003). As juveniles and adults, *Sicydium* gobies live in pools and riffles in relatively high gradient mountainous reaches of rivers where rocks are common (Lyons and Schneider, 1990; Silva-Melo & Acero-P. 1990). Breeding males defend a territory under or near rocks and guard the adhesive eggs that the females lay there (Keith, 2003). When the eggs hatch, the larvae immediately begin drifting downstream to the ocean, starting the life cycle anew.

The period during which larvae are drifting downstream to the ocean is critical in determining survival (Iguchi & Mizuno, 1999). Larvae do not feed during this period and gain nutrition from yolk (Bell & Brown, 1995; Keith, 2003). They must reach the ocean and begin feeding there before the yolk is used up or they will starve. Studies on amphidromous *Rhinogobius* gobies in Japan indicate that starvation during larval drift occurs and is a major factor in limiting their distribution within and among rivers (Moriyama *et al.*, 1998; Iguchi & Mizuno, 1999; Maruyama *et al.*, 2003). No studies have specifically examined starvation in drifting sicydiine larvae, but it seems likely to be a risk in certain settings. Compared to other gobies and many other fish species, sicydiine gobies have relatively small eggs and larvae and little yolk (Miller, 1984), and the larvae can survive for only a short period, probably only a matter of days under normal conditions, without feeding.

Building upon the ideas of Iguchi and Mizuno (1999), I hypothesize that the likelihood of larval starvation during downstream drift prevents *Sicydium* gobies from persisting in rivers traversing broad coastal plains in Mexico and Central America. Such rivers have a flat slope in their lower reaches and, relative to comparably sized but steeper rivers flowing from coastal mountain ranges, would likely have finer alluvial substrates, few rocks, and slower currents (Leopold *et al.*, 1964; Gordon *et al.*, 1992). The only habitat with rocks suitable

for feeding and spawning by adults would be in the mountains upstream of the coastal plain. Any larvae produced would thus have to drift a relatively long distance on relatively slow currents until they reached the ocean and could begin to feed. Therefore, larval starvation would seem to be much more likely in a river flowing through a broad coastal plain than in a river flowing from a coastal mountain range, where spawning could take place closer to the ocean and stronger currents would deliver the larvae to the ocean more quickly. Rivers flowing across a broad coastal plain would also be more challenging than rivers draining coastal mountain ranges for juveniles moving upstream to adult habitat, as rivers with a broad coastal plain would require longer migrations and would have few rocks in their lower reaches to allow for feeding. Thus juveniles might also be vulnerable to starvation as they migrated upstream to suitable feeding habitat.

In conclusion, I hypothesize that *Sicydium* gobies are unable to complete their amphidromous life cycle in, and are thus precluded from, rivers in Mexico and Central America that flow across broad coastal plains. This hypothesis could be tested by a study that estimated times to starvation in larval and juvenile *Sicydium* gobies and compared these times with estimated downstream drift times and upstream migration times in rivers flowing different distances and at different velocities through the coastal plain.

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