

# THE EFFECTS OF BARRIERS ON THE CLIMBING ABILITY OF TWO AMPHIDROMOUS GOBIIDS (*SICYOPTERUS SPP.* AND *STIPHODON ELEGANS*) ON MOOREA, FRENCH POLYNESIA

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**Abstract.** Amphidromy is a distinct life history, in which organisms live and spawn in fresh water, their larvae float downstream to salt water where they remain for some time, and juveniles migrate back upstream to complete their feeding and growing in fresh water. On oceanic islands, this life history serves as a strategy for settlement of new islands, recolonization of freshwater habitats after major disturbances, and downstream predator evasion. Many members of the family gobiidae exhibit amphidromous life histories on tropical islands, and have evolved the ability to climb waterfalls in order to reach upstream habitats. Though the importance of climbing ability in juvenile gobies has been well established, climbing ability in adults is often overlooked. Retaining climbing ability could be advantageous for adult gobiids, as they are subjected to many of the same risks as juveniles. On the island of Moorea in French Polynesia, amphidromous gobiids make up a large part of the freshwater vertebrate fauna. I hypothesized that the climbing ability of these fishes would be negatively impacted by increases in geophysical pressures such as flowrate and gradient, as well as the presence of man-made stream barriers. In this study, *Sicyopterus spp.* and *Stiphodon elegans* adults were challenged to climb under simulated waterfall conditions, in order to define the effects of gradient and flow rate on their climbing ability. The two species were also included in a survey with relation to man-made barriers on the island. While increases in waterfall angle negatively affected the climbing success of *Stiphodon elegans*, *Sicyopterus spp.* exhibited an increase in completion time, but showed no decrease in climbing success. When subjected to multiple flow rates, *Stiphodon elegans* was more successful and slower at lower flow rates. Surveys suggested that the construction of barriers plays a key roll in migration success among *Sicyopterus* species. Understanding limits to the climbing ability of amphidromous gobiids is important to both the life history and conservation of fishes on Moorea, as well as faunas of oceanic islands across the globe.

*Key words:* amphidromy; climbing; *Sicyopterus*; *Stiphodon*; Moorea, French Polynesia;

## INTRODUCTION

Diadromy, as defined by Myers, refers to animals that truly migrate between salt and fresh water (1949). Amphidromy is a specific diadromous life history, characterized by organisms who live and spawn in freshwater, whose larvae float downstream to salt water where they remain for some time, and whose juveniles migrate back upstream to complete most of their feeding and growing in fresh water (Myers 1949, McDowall 1992, 2007). Many examples of amphidromy are found on oceanic islands, where it serves as a strategy for colonization of new islands as they emerge from 'hot spots' along plate boundaries (McDowall 2007). Furthermore, having larvae at sea enables recolonization of freshwater habitats after major perturbation, caused by volcanic eruptions or by rapid changes in the flow of small streams (McDowall 2007). A

broad range of taxa display amphidromous life histories, including diverse families of fishes, decapod crustaceans, and gastropod molluscs (McDowall 2007, Resh *et al.* 1992, Resh 2005).

Many gobiid fishes are characterized by amphidromous life histories, in which they breed upstream in freshwater pools, offspring are swept to sea and develop in oceanic waters, followed by the upstream migration of juveniles. Amphidromous gobiid fishes have penetrated the freshwater streams of volcanic islands around the world (McDowall 2001), where steep gradients, turbid waters, and waterfalls often characterize the landscape. Thus, fish are presented with a set of challenging barriers for upriver-migrating juveniles. In order to overcome such barriers, the ability to climb waterfalls has evolved in many goby species (Keith 2003, Thacker 2003). The continued survival of amphidromous

gobiid species depends on juvenile fish (which range only 10 to 25 mm in length) being able to successfully scale rushing waterfalls as much as 35,000 times the length of their bodies (e.g. Schoenfuss and Blob 2003). Studies of Hawaiian gobiid fishes by Schoenfuss and Blob (2003) have suggested that juvenile gobies show considerable diversity in locomotor mechanisms, despite the constraining demands of an environment as extreme as waterfalls, making gobies an ideal subject for the study of amphidromous organisms.

Although the importance of climbing ability has been well established for amphidromous gobiid juveniles, the climbing ability of adult gobiids is often overlooked. The retention of climbing ability could be advantageous for adult fish as well as juveniles (Blob *et al.* 2007). Adult fish in upstream tropical habitats face many of the same risks as juveniles, including displacement by catastrophic disturbances (Fitzsimons & Nishimoto 1995). Retaining climbing ability may also serve as a strategy to evade predators in downstream pools (Schoenfuss and Blob 2007, Blob *et al.* 2010). Climbing success might be expected to decrease in adult gobiids, however, after upstream habitats are reached and selective pressures associated with barrier-crossing are lifted. Furthermore, from a kinematic standpoint, as fish grow, morphological climbing structures struggle to support adult body mass (Blob *et al.* 2007).

One species of adult Hawaiian gobiid—*Sicyopterus stimpsoni*—has demonstrated exceptional retention of juvenile climbing ability. As a juvenile, *S. stimpsoni* undergoes a metamorphosis that allows for its mouth to be used as a secondary climbing organ (Schoenfuss and Blob 2003, Blob *et al.* 2007). This additional locomotor organ allows the fish to 'inch' up vertical surfaces by alternately attaching oral and pelvic suction disks to substratum and is thought to be less energetically costly than techniques used by other climbers (Schoenfuss and Blob 2003). The unique climbing behavior observed in *S. stimpsoni* appears to be especially well conserved in adult climbing technique (Blob *et al.* 2007). While size greatly limits the power production of powerbursting adult gobiids, adult *S. stimpsoni* still used oral and pelvic suckers to inch up surfaces at similar speeds to juveniles (Blob *et al.* 2006, 2007).

Five species of amphidromous gobies live in the stream systems of Moorea, French

Polynesia (Askay 2000, Moorea Biocode Project 2013). Research by Askay (2000) on their distribution and microhabitat suggested that three species (*Stiphodon elegans*, *Awaous ocellaris*, and *Stenogobius genivittatus*) were all restricted to lower elevation. On the other hand, *Sicyopterus lagocephalus* and *Sicyopterus pugnans* were universally distributed, despite barriers encountered at higher elevations (Askay 2000, Moorea Biocode Project 2013). In addition to large waterfalls that characterize the landscape on Moorea, road-crossings have been built over several streams that also impede the upstream migration of amphidromous organisms (Resh 2005). While the environmental and geographic factors of goby distribution on Moorea have been well documented, the locomotor challenges associated with migration upstream have not been studied. The high-elevation distribution of *Sicyopterus* species on Moorea suggests that like their Hawaiian relative *S. stimpsoni*, *S. lagocephalus* and *S. pugnans* also climb waterfalls as juveniles as part of their life cycle. The downstream-distributed species, however, may lack the same climbing skills observed by their sicydiine relatives.

This study challenged adults of the genus *Sicyopterus* and the species *Stiphodon elegans* to climb in simulated waterfall conditions, to define the threshold for their climbing ability. Furthermore, it serves as an initial survey of goby distribution above and below man-made barriers. The extent to which climbing ability is conserved in adult fish can provide insight into their ability to repopulate habitats after extreme disturbances. I hypothesized that increases in waterfall flow and gradient will lead to decreases in overall climbing success among all gobiids. In addition, I hypothesized that there will be an inverse relationship between fish body size and climbing success. If this is true, smaller individuals may be better suited for repopulating disturbed habitats after displacement, and more successful at escaping habitats of high predator abundance. By illustrating how pressures such as gradient, flow and mass affect climbing ability, a better understanding of adult migration is gained. From a conservational standpoint, understanding adult climbing ability can help dictate the construction style of man-made barriers such as road crossings to better allow for upstream migration. This, in turn, can illustrate major ecological benefits for amphidromous fishes when applied in the context of recolonizing disturbed habitats and evading predators.

## METHODS

All fish collection, experimental trials, and surveys occurred on the island of Moorea, French Polynesia. Five freshwater species within the family Gobiidae occur on this island: *Awaous ocellaris*, *Stiphodon elegans*, *Stenogobius genivittatus*, *Sicyopterus pugnans*, and *Sicyopterus lagocephalus* (Askay 2000, Moorea Biocode Project 2013). This study focused on both gobies from the genus *Sicyopterus* and the species *Stiphodon elegans*. *S. lagocephalus* and *S. pugnans* exist in a variety of similar colormorphs that lead to difficulty distinguishing between species, and therefore were combined into a single test group and referred to as *Stiphodon spp.* for the purpose of this study. The genus was selected for its reputation as a champion climber, and its widespread distribution on the island of Moorea (Askay 2000, Blob *et al.* 2006, 2007, Schoenfuss and Blob 2003). *Stiphodon elegans* is the closest relative to *Sicyopterus spp.* on the island of Moorea, but its distribution on the island is limited to low elevation stream sites, making it an interesting group for comparison.

### *Climbing Trials*

**Fish Collection:** Fish collection took place from October 3<sup>rd</sup> to November 5<sup>th</sup>, 2013. During several collection events, adult gobies of the genera *Sicyopterus* and *Stiphodon* were captured in freshwater streams of the Opunahu (17°31'S 149°50'W), Pao Pao (17°30'S 149°49'W), and Afareaitu (17°32'S 149°47'W) watersheds. Collection sites were chosen so that the streams were shallow enough to wade in and had limited plant detritus for fish to burrow under. *Sicyopterus spp.* and *Stiphodonon elegans* were both identified using a dichotomous key field key based off an identification Key by Askay (2000, *see Appendix A*). Fish were captured using mesh fishing nets (*see Appendix A for details on capture methods*). Animals were immediately transferred in aerated stream water to the UC Berkeley Gump Research Station, where they were stored in aerated stream water tanks for no more than four days to use in the fish climbing experiment (see below). After data collection, fish were returned to their corresponding collection sites. All work was conducted within the

guidelines of University of California, Berkeley, Animal Use Protocol T042-0814.



guidelines of University of California, Berkeley, Animal Use Protocol T042-0814.

**Experimental Set-up:** To compare climbing technique under controlled conditions, an artificial waterfall was be constructed to mimic barriers gobies may face in nature following the methods of Blob *et al.* (2007). The waterfall was constructed using a 70 cm long rain gutter that connected two basins at differing elevations. The lower basin was 18 cm long x 25 cm wide x 15 cm deep and was filled halfway with Z-SPAR A-788 Splash Zone Epoxy to secure the ramp in place. The chute extended from the basin at one of two treatment angles (15° or 45° from the horizontal), and fine-grained sand was sifted and glued to the ramp to provide substrate. To generate flow over the apparatus, water was circulated using an aquarium pump attached to the two basins. Flow rate was alternated between high (0.37 L/s) and low (0.23 L/s) flows using a secondary siphon to divert water from the top basin.

**Data Collection:** Each trial begun by introducing a fish into the lower basin with water flowing down the ramp. To avoid extensive stress on any individual,



FIG. 2. A photo of the climbing arena. A 70cm chute connected the upper basin to the 18x25x15cm lower basin. Water was circulated using an internal aquarium pump. Fish were introduced into the bottom basin and allowed 20 minutes to complete climbing challenges on a simulated waterfall.

observations were made at a distance, and fish were removed and replaced with new individuals if climbing did not commence within 20 minutes. During climbing, live observations were made, and trials were filmed using a GoPro HERO3 Silver Edition at a resolution of 960p and 30 frames per second. Each fish was used only once per treatment. For each trial, the following data were recorded: whether the individual succeeded (1=successful, 0=unsuccessful), attempted, or failed to climb; and the time for individuals to complete the challenge. Morphological data taken included: body length, mouth width, and pelvic sucker

diameter. To avoid any stress on the animals before climbing, morphological data was collected after the fish was exercised. Furthermore, all measurements were collected using a photography chamber and photo analysis using the program ImageJ to avoid over-handling (Rasband 1997-2012).

*Statistical Analysis:* Statistical analysis was performed using R (R Development Core Team, version 3.0.1, 2013). The mean time to complete the climb was calculated for each species. Differences in performance variables between species and treatments were evaluated using Analysis of Variance (ANOVA) tests and T-tests. Linear regressions were made for each of the six treatments to compare climbing success to morphological data (e.g., weight, length, sucker diameter).

#### *Opunahu Stream Barrier Survey*

In order to relate laboratory results to the distribution of *Sicyopterus spp.* and *Stiphodon elegans* in streams of Moorea, I performed a survey of the two groups in relation to two man-made barriers found in the Opunahu watershed.

*Survey Sites:* The first barrier was a concrete road crossing and was categorized as a low-challenge barrier (17°31'32.63" S, 149°50'10.55" W). A single concrete pillar supported the bridge with openings allowed for free-flowing stream water to pass through on either side. The openings measured 142 cm and 148 cm wide, and the stream elevation



FIG 3. Photographs looking upstream at the open bridge (left) and the culverted bridge (right). The bridges serve as potential barriers to amphidromous organisms such as *Sicyopterus pugnans*, *Sicyopterus lagocephalus*, and *Stiphodon elegans*. The open bridge was identified as an easy barrier, while the culverted bridge was considered difficult to cross.

increased by no more than 12 cm. The second barrier (17°31'33.50" S, 149°49'59.29" W), was a culverted stream crossing, and consisted of a concrete wall with two pipes, 118 cm in diameter, that allowed water to drain downstream. The pipes were elevated 45 cm above the downstream surface of the water. This barrier was identified as a challenging barrier to cross.

*Survey Procedure:* Counting absolute numbers of fish was difficult, because a single fish could swim past several times during observation, and many seek shelter where they are out of sight. Therefore, I focused on the presence or absence of each species in any given pool. As approaching objects easily frighten gobies, I carefully entered target pools and remained still in one location, where I observed fish for ten minutes. This procedure was repeated in three adjacent pools above and below each barrier.

## RESULTS

### *The effect of ramp angle on climbing ability*

28 trials were conducted with *Sicyopterus spp.* and 37 were conducted with *Stiphodon elegans*, totaling 65 climbing trials throughout the duration of this study. During the angle manipulation trials, differences in success rate and completion time were observed with respect to ramp angle and species (Fig.1).

The proportion of successful individuals for *Sicyopterus spp.* remained relatively constant during both high and low angle challenges, at 0.67 and 0.69, respectively. There was no significant difference between the success proportions under these conditions. However, the mean time required to complete the challenge more than doubled for *Sicyopterus spp.* from 58.5 seconds on the low-angle ramp to 125.8 seconds on the steeper ramp. An independent samples t-test was conducted to compare mean completion times for *Sicyopterus spp.* at low and high angles. There was a significant difference in the mean completion times for low (M=58.5, SD=95.44) and high (M=125.8, SD=85.20) angles (T.test,  $t_{11,27}=3.12$ ,  $p<0.01$ ).

During the low-angle trial, the success rate of *Stiphodon elegans* was comparable to that of *Sicyopterus spp.* at 0.58. However, when the ramp angle was raised to 45 degrees, success was nonexistent for the species, where zero of the nine challenged individuals were able to complete the climb. A two-way between

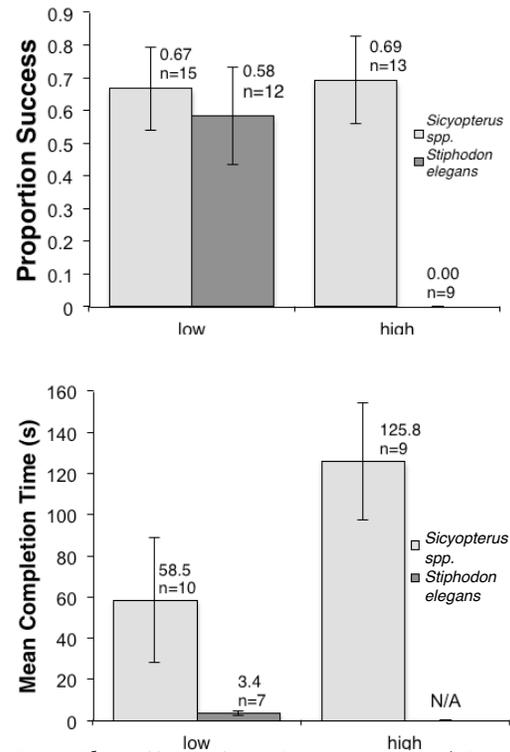


FIG 4. The effect of angle on success (above) and mean completion time (below) for *Sicyopterus spp.* and *Stiphodon elegans*. There was a significant effect of species on the proportion of successful individuals (ANOVA,  $F_{1,45}=7.48$ ,  $p<0.01$ ) that was dependent on the interaction of ramp angle (ANOVA,  $F_{1,45}=5.47$ ,  $p=0.02$ ). There was a significant difference in the mean completion times for low (M=58.5, SD=95.44) and high (M=125.8, SD=85.20) angles (T.test,  $t_{11,27}=3.12$ ,  $p<0.01$ ). There was a significant difference in the mean completion times for *Sicyopterus spp.* (M=58.5, SD=95.44) and *Stiphodon elegans* (M=3.4, SD=2.15) at the low ramp angle (T.test,  $t_{19,80}=3.58$ ,  $p<0.01$ ). Comparisons of mean completion time for *Stiphodon elegans* and high ramp angle were omitted, as there were no successful individuals.

subjects ANOVA was conducted to compare species-specific differences for success rate at high and low angle conditions. There was a significant effect of species on the proportion of successful individuals (ANOVA,  $F_{1,45}=7.48$ ,  $p<0.01$ ) that was dependent on the interaction of ramp angle (ANOVA,  $F_{1,45}=5.47$ ,  $p=0.02$ ).

Because there were no successful *Stiphodon elegans* trials at the high angle condition, species-specific comparisons for mean completion time were omitted. However, at the low ramp angle, the mean time to reach the upper basin was significantly faster in *Stiphodon elegans* individuals that in *Sicyopterus spp.*, with mean completion times of 3.4 seconds and 58.5 seconds, respectively.

Another independent samples t-test was conducted to compare mean completion times for *Sicyopterus spp.* and *Stiphodon elegans* at the lower ramp angle. There was a significant difference in the mean completion times for *Sicyopterus spp.* (M=58.5, SD=95.44) and *Stiphodon elegans* (M=3.4, SD=2.15) at the low ramp angle (T.test,  $t_{19,80}=3.58$ ,  $p<0.01$ ).

*The effect of flow on climbing ability in Stiphodon elegans*

Because *Stiphodon elegans* failed the steep-angle climbing challenge, I subjected the species to a third treatment, reducing the flow rate of the waterfall while maintaining the 15-degree ramp angle. The reduced flow rate yielded shifts in both success rate and completion time (Fig.1). The low flow rate generated a success proportion of 0.82, while a reduced success proportion of 0.58 was observed at the high flow rate. An independent samples t-test was used to compare success proportions for *Stiphodon elegans* under low and high flow conditions.

While the number of successful individuals decreased at the higher flow rate, the individuals that successfully completed the high flow challenge did so in a much shorter amount of time. When flow rate increased, the mean completion time for *Stiphodon elegans* decreased from 16.3 seconds to 3.4 seconds. A second independent samples t-test showed that there was a significant difference between mean completion times at low (M=16.3, SD=25.04) and high (M=3.4, SD=0.81) flow treatments (T.test,  $t_{32,41}=2.61$ ,  $p=0.01$ ).

*The effect of body length on climbing ability*

For both *Sicyopterus spp.* and *Stiphodon elegans* there was no significant correlation between body length and climbing success, nor body length and mean completion time. Rather, both responses were randomly distributed among fish body lengths.

*Stream Barrier Field Survey*

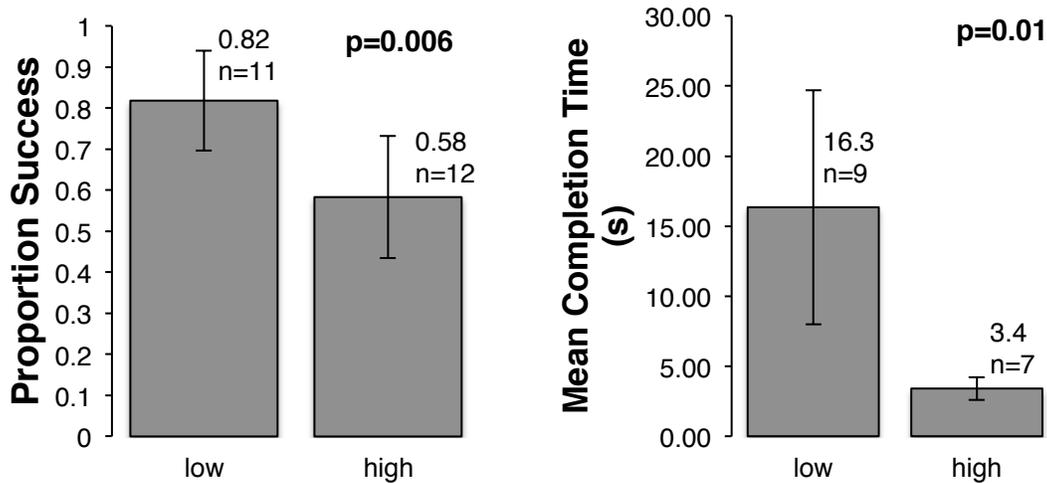


FIG 5. The effect of flow rate on success rate (left) and mean completion time (right) for *Stiphodon Elegans*. An independent samples t-test showed that there was a significant difference between success rates at low (M=0.82, SD=0.40) and high (M=0.58, SD=0.51) flow treatments (T.test,  $t_{17,74}=-2.03$ ,  $p<0.01$ ). A second independent samples t-test showed that there was a significant difference between mean completion times at low (M=16.3, SD=25.04) and high (M=3.4, SD=0.81) flow treatments (T.test,  $t_{32,41}=2.61$ ,  $p=0.01$ ).

The difference between success rates at low (M=0.82, SD=0.40) and high (M=0.58, SD=0.51) flow treatments was significantly different (T.test,  $t_{17,74}=-2.03$ ,  $p<0.01$ ).

A total of 12 pools were surveyed, three above and three below each of the two barriers. Although *Stiphodon elegans* was absent from all of the sample locations,

*Sicyopterus spp.* exhibited a clear pattern in terms of distribution with relation to the open and culvert barriers. At the open bridge site, *Sicyopterus spp.* was found in every sampled pool above and below the bridge. However, *Sicyopterus spp.* was only found downstream from the culverted barrier. There were no gobies present in the sample pools upstream from the culverted barrier.

## DISCUSSION

### *Effect of treatment variables on climbing ability*

The patterns observed in *Sicyopterus spp.* climbing trials demonstrate that this genus is an excellent climber, and is able to retain its climbing ability even as an adult. This was demonstrated when increases in angle had no effect on the success rate of the group, though they did lead to an increase in mean completion time. This pattern suggests that adult *Sicyopterus* gobiids are capable of climbing challenging barriers, with the only repercussion being an increase in climbing time during more difficult challenges. The lack of correlation between body size and success rate also suggests that this species is capable of climbing at a similar level of success, despite increases in body mass as the fish mature. These patterns remain in concurrence with previous research on adult *Sicyopterus* gobiids conducted by Blob (2007), where he suggests that the locomotor mechanisms employed by *Sicyopterus stimpsonii* are particularly suited to prevent the loss of climbing ability in adults.

Unlike *Sicyopterus spp.*, the *Stiphodon elegans* trials demonstrated that there was a true limit to their ability to cross barriers. The increase in ramp angle hindered the climbing success of this species to the point that no individuals were able to successfully reach the top basin. During these trials, I observed that in order for *Stiphodon elegans* to succeed, it seemed necessary for the ramp to be lowered to the point that individuals could essentially swim up the ramp in a single bout, rather than climb like their Sicydiine relatives. This would support my findings that *Stiphodon elegans* completed the low angle challenge significantly faster than *Sicyopterus spp.*, which was capable of alternating between climbing and resting while scaling the arena. The hypothesis that *Stiphodon elegans* is less capable of resting while climbing also connects to findings that increased flow led to fewer successful individuals, but those who

complete the challenge did so significantly faster. In this scenario, *Stiphodon elegans* was impeded overall by the heavier flowing challenge. However, successful individuals may have swam quicker as their ability to rest was even further hindered at the higher flow rate. Nevertheless, these suggestions are preliminary, and leave much room for future study of the species and their climbing ability. It is necessary to further evaluate the *Stiphodon elegans* climbing trials from a kinematic standpoint, with a focus on time spent in motion and at rest, to better explain their speed advantage over *Sicyopterus spp.*, despite their inferior success rate.

Comparison of *Sicyopterus spp.* and *Stiphodon elegans* trials illustrate that *Sicyopterus spp.* possesses a true advantage for crossing barriers. Although the mean time to complete climb was shorter for *Stiphodon elegans*, *Sicyopterus spp.* showed enduring capabilities even at higher angles, and better retention of climbing ability overall. Although *Sicyopterus spp.* was not subjected to the reduced-flow treatment, we can assume that their success would remain constant and superior in less challenging conditions. By increasing the sample size and treatment variables provided in this study, we can gain a more specific understanding of the climbing limits of these two species.

### *Opunahu field survey and applications to barrier crossing*

The stream crossing survey confirms distribution data suggested by previous studies, and offers insight into how barriers affect amphidromous organisms throughout their life cycle. The absence of *Stiphodon elegans* from the entire survey is likely a result of its limited distribution in lower stream reaches, confirming observations made by Askay (2000). *Stiphodon elegans* is limited to low elevation reaches and is most likely unable to pass smaller downstream barriers that are climbed by *Sicyopterus spp.* The distribution of *Sicyopterus spp.* in relation to the Opunahu stream crossings serves as an indicator for conservation efforts on Moorea. Man-made barriers can significantly impact the migration patterns and distribution of amphidromous fauna on Moorea. While this has been demonstrated for amphidromous macroinvertebrates previously (Resh 2005), this survey serves as the first indicator of its detrimental effects on amphidromous fishes such as gobies. The open-bottom barrier was

penetrable by *Sicyopterus spp.*, which was present both above and below the bridge. However, the absence of *Sicyopterus spp.* upstream from the culverted bridge indicates that it functions as an unsurpassable barrier, and blocks organisms like *Sicyopterus spp.* from reaching long stretches of otherwise suitable habitats. Thus, the ability for amphidromous fishes to cross barriers such as bridges and dams is highly dependent in the design of the barrier, and can be facilitated with proper remodeling and construction of future stream crossings.

#### *Barrier crossing in an amphidromous life cycle*

The ability to cross barriers is of profound importance to the life history and conservation of amphidromous fishes on Moorea, as it is for faunas of oceanic islands across the tropics. Understanding limits to the climbing ability of amphidromous gobiids provides better insight into the structuring of conservation efforts on the island, such as the design and maintenance of stream crossings and barriers. If streams are obstructed, barriers impede migration, as well as make organisms more vulnerable to downstream predators. It is paramount that amphidromous organisms be able to penetrate upstream habitats during their life cycle to grow and breed. The presence of amphidromy in all organisms is a fundamental part of the ecology of tropical islands, as it facilitates the recolonization of disturbed habitats after major disturbances, downstream predator evasion, migration between islands and ultimately the colonization of new niches worldwide.

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## APPENDIX A



FIG 6. Species used in study. *Sicyopterus* spp. (left) and *Stiphodon elegans* (right).

## DICHOTOMOUS GOBIE KEY AND FIELD TIPS FOR MOOREA FRENCH POLYNESIA

The following field guide was developed to aid students of the *Biogeography and Geomorphology of Tropical Islands* class at UC Berkeley. It contains basic information for identification in the field, as well as tips for capture. It was created in reference to a detailed goby identification key created by Sean Askay (2000), with some additional information from my personal observations and experience.

Katie Kobayashi  
Moorea Class of 2013

**Is there a polka dot on the dorsal fin?**

**YES: *Awaous ocellaris***

Also note the huge gill structures on this species, reminiscent of chipmunk cheeks. This species moves quickly and constantly, unlike other species who rest on various substrate when at undisturbed.

**NO: Is there a teardrop marking beneath the eye?**

**NO: *Stiphodon elegans***

Also note that the eyes do not protrude from the head in this species. *Stiphodon* males often show iridescent colors. Both males and females have a dark stripe on the side of their body that stretches from nose to tail.

Capture: This species is remarkably easy to capture. Medium or large aquarium nets will suffice. The fish is most easily caught by slowly corralling the fish between two nets on either side of the fish. Then, scoop towards yourself with one hand while spooking the fish into the net with the other.

**YES: *Stenogobius genivittatus***

The teardrop marking on this species is very obvious, and the rest of the fish is bland and light in color, making the marking stand out even more.

This species can be caught using a similar method to *Stiphodon elegans*, however, because the fish is larger, fishing nets with larger diameters and longer poles will make capture much easier.

**YES: Does the teardrop marking angle posteriorly?**

**NO: *Sicyopterus pugnans* and *Sicyopterus lagocephalus* (formerly known as *Sicyopterus taeniurus*)**

There has been controversy over whether or not these species are actually just color morphs of *Sicyopterus lagocephalus*, and are difficult to identify to the species level in the field. Always check current literature for species revisions. There are several color morphs for this genus, ranging from bright orange, to brown, to blue. The species often has seven dark, saddle-shaped bands on its body; and they become darker when provoked. This is the only species on Moorea that uses its mouth as a secondary climbing organ, which is visible when handling the organism or when it is swimming in a transparent tank.

Capture: *Sicyopterus spp.* is undoubtedly the most difficult goby to catch on Moorea. They are extremely skittish and flee from approaching objects even at a great distance. Proper fishing nets are paramount. They should have long handles and wide diameter openings (around 30 cm), and the mesh should be fine enough to capture fish, but large enough to see through and filter out sand and rocks. With a net in each hand, move your primary net over the surface of the water, mimicking a floating leaf, and allow it to sink over a resting goby very slowly. Use the second net to spook the fish up into the water watercolumn and swipe with primary net by scooping towards yourself. In higher flow settings, use a similar method to that explained for *Stiphodon elegans*. Expect to move extremely slowly and act with patience. Alternately, I have had success using one or two buddies each equipped with aquarium nets. Surround the fish on all sides, making sure you are flush with the substrate and blocking all escape routes. Then, wait and or spook the fish into one of the nets.