

## Research Article

# Observations of Agonistic Behavior between Two Male Gobies *Acentrogobius virgatulus* (Jordan & Snyder, 1901), in Maizuru Bay, Kyoto Prefecture, Japan

Hunter Harter Godfrey  and Yumi Henmi 

Maizuru Fisheries Research Station, Field Science Education and Research Center, Kyoto University, Nagahama, Maizuru, Kyoto 625-0086, Japan

Correspondence should be addressed to Hunter Harter Godfrey; [hunter.godfrey.46x@st.kyoto-u.ac.jp](mailto:hunter.godfrey.46x@st.kyoto-u.ac.jp)

Received 13 December 2022; Revised 15 February 2023; Accepted 28 March 2023; Published 24 April 2023

Academic Editor: Horst Kaiser

Copyright © 2023 Hunter Harter Godfrey and Yumi Henmi. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

*Acentrogobius virgatulus* (Jordan & Snyder, 1901) is a small coastal species of goby found along the Western Pacific. It is commonly found in Maizuru bay along the muddy sediment between the intertidal zone and depths of 10 m. In June and July of 2022, two independent agonistic interactions between male *A. virgatulus* were observed and recorded during its spawning season. One interaction, lasting over 4 minutes, included certain aggressive behaviors such as jaw locking, mouth gaping, fin extensions, rapid color changes, and fast strikes to the head and body. Another interaction exhibited similar mouth gaping, fin extension, and rapid color changes but did not lead to further escalation. These behaviors coincide with those found in similar species and provides in situ evidence of these uncommon interactions. This is the first record of agonistic behavior by an *Acentrogobius* species. Accumulating findings such as these can contextualize intraspecific interactions, reveal differences across multiple species, and guide future experiments.

## 1. Introduction

Goby agonistic behavior between conspecifics is substantially examined in both captive and in situ observations and behaviors vary greatly among different species [1, 2]. There are many circumstances associated with fish agonism [3]. A common association is with territorial or sexual competition during spawning seasons, which is particularly present in sand and mud dwelling gobies such as *Amblyeleotris japonica*, *Gobiussculus flavescens*, *Lepidogobius lepidus*, and *Eucyclogobius newberryi* [4–7]. In most cases, size is a deciding factor of success and deters most agonistic interactions between competitors [2, 5, 7–9]. It is when conspecifics are of similar size that aggressive interactions escalate and different mechanisms for competition can be observed and documented [7]. These kinds of interactions are rare and not easily replicated in tank environments [10]. While there are many commonalities in behaviors among

families, ethograms of specific species can be unique. Documenting more species behaviors and the environments they are observed in could underscore their differences and similarities. In situ observations and experiments also avoid the unwanted habituation of focal fish in captivity which may perverse natural behaviors [11]. Furthermore, in situ experiments are seen as having higher ecological validity and can provide more valuable insights, as they can be easily compared to previously documented research [4, 9, 12]. Here, we examine an interaction captured in the natural environment of a species of *Acentrogobius* goby that has not been documented in peer-reviewed literature.

*Acentrogobius virgatulus* [13] is a small goby reaching 8 cm total length [14]. It ranges from Hokkaido down to the southern Kyushu Islands of Japan, including the east coast of the Korean Peninsula and Eastern China Sea [14, 15]. This species of *Acentrogobius* prefers high salinity, muddy to coarse sand environments, and inhabits the intertidal zone

to depths of 10 m, spatially between its closely related species [15–18]; *Acentrogobius* sp. 2 [14] and *Acentrogobius pflaumii* [19]. According to a 2010 survey conducted in Maizuru Bay [20], the spawning season for *A. virgatus* lasts about two and a half months, from early June to late August, while the water temperature is between 14.7 and 30.1°C. *Acentrogobius virgatus* typically spawn under substrate such as brick or roofing tiles [21] and have a facilitative relationship with *Alpheus* shrimp burrows [16, 18]. This study reports for the first time the agonistic behavior of *A. virgatus* observed during routine underwater visual censuses in Maizuru Bay, in the Sea of Japan.

## 2. Materials and Methods

Routine underwater visual censuses are conducted twice a month while diving on SCUBA along the coast of Maizuru Fisheries Research Station, Kyoto University, Maizuru Bay (35°29'21.5"N 135°22'02.7"E) between depths of 1–12 m [22]. Censuses follow the coastline and survey the various environments and structural (natural and artificial) outcroppings in the area. Water visibility ranges from 1 to 10 meters. The seabed consists of a shallow oyster shell shelf that quickly drops off into a muddy substrate at about 5 meters. This muddy substrate is typically bare but contains scatterings of oyster shell clusters, artificial reefs, and other anthropogenic debris. *Alpheus* shrimp burrows are common along the substrate and are commonly cohabitated by *Acentrogobius* species and *Cryptocentrus filifer* [23]. Video cameras (Olympus Tough TG5; Japan) in underwater housings are used to document irregularities or unknown species for later identification. Videos are taken of any unusual behaviors on each dive in order to reference in later reports as a secondary objective. Oceanographic data is collected daily from the same location [24].

## 3. Results

The first author observed and recorded on video an agonistic interaction between two male *A. virgatus* living in the silty substrate along the east side of Maizuru Fisheries Research Station (35°29'22.6"N 135°22'07.2"E). Two cases of agonistic interaction of *A. virgatus* totaling 330 secs were observed from April to September 2022.

The first recording was taken around 11:00 on 23 June 2022 at a depth of 5 m, 21.5°C, and a salinity of 34.0 PSU. Several *Acentrogobius* spp. were observed while SCUBA diving along the benthos. In contrast, two larger males of approximately 7 cm each were engaged in a jaw lock upon recording (ESM Video S1; Figure 1(a)). Other, smaller *A. virgatus* were in the area during the encounter. In this instance, the fish on the viewer's left attempts to break the lock while the fish on the viewer's right attempts to maintain the lock (Figure 1(b)). This is the only jaw locking behavior the fish display during the encounter. After 75 secs, the lock is broken, and the fish on the right that had attempted to maintain the lock flees to a patch of algae. The fish on the left attempts to chase the fleeing fish until it escapes momentarily (Figure 1(c)). After 90 secs, the escaped fish returns,

and the two begin a series of repetitious lateral displays, mouth gaping, encircling, fin extension (Figure 1(d)), and finally strikes to the head and body using the individual's mouth (Figure 1(e)). It is through these quick rapid strikes that distinction between each fish is deemed unfeasible. During this encounter, the two individuals undergo distinct color changes from their normal coloration, notably lighter body colors (Figures 2(a) and 2(b)). After 93 secs of agonistic behavior and 12 distinct strikes, one of the specimens swims away from the area and back into the patch of algae nearby, ending the interaction. The total interaction, from the first observation, lasted 258 seconds.

A second recording was taken at approximately 10:30 on 25 July 2022 at a depth of 5 m, 26.4°C, and salinity 33.3 PSU. In this second recording, similar lateral displays, mouth gaping, and rapid color changes lasting 72 sec were observed between two male *A. virgatus* but did not further escalate to jaw locking or strikes to the head and body (Figure 1(f), ESM Video S2).

## 4. Discussion

Each of the subject *A. virgatus* observed was identified as males through the distinct dark margins on the anal, pelvic, and lower caudal fins, which are colorless in females [25]. While this behavior has not previously been reported in this species, similarly related taxa in the family Gobiidae are known to exhibit territorial aggression in similar fashion. Many of these behaviors have been examined in both laboratory settings (lab-based) and field observations (in situ). One example being *Eviota storthynx* (lab-based), exhibiting male on male aggression similar to the actions seen in *A. virgatus* in the form of mouth gaping, lateral displays, fin extension, rapid color change, and intentional strikes to the head and body [26]. These behaviors are associated with many species of goby in regard to male-male competition during spawning seasons, as with *Rhinogobiops nicholsii* (in situ), *Amblyeleotris japonica* (in situ), *Pomatoschistus minutus* (lab-based), and *Bathygobius soporator* (lab-based), and it is noted that larger sized males typically see success in these interactions [7, 8, 27, 28].

However, these behaviors are not uniform among all gobies. Behaviors such as butting and head-beating have been documented in *Paragobiodon* sp. (in situ) as well as gape pushing and parallel swimming in *Microgobius gulosus* (in situ) [29, 30]. In *Gymnogobius heptacanthus* (in situ), *Gobiusculus flavescens* (in situ) (lab-based), and *Eucyclogobius newberryi* (lab-based), the females sometimes maintain territory and exhibit agonistic behavior towards conspecifics [4, 6, 9, 31]. These studies show similarities in behavior types but exhibit unique differences. The difference between the two recordings of *A. virgatus* can likely be attributed to the success and failure of deterrence signaling, which did or did not lead to the escalated aggression of striking and jaw locking. In many species, the encircling lateral display and mouth gaping allow them to primarily present size and deter aggression from smaller conspecifics [32] as seen in lab-based [10] and in situ observations [7]. It should be acknowledged that the signaling behaviors of

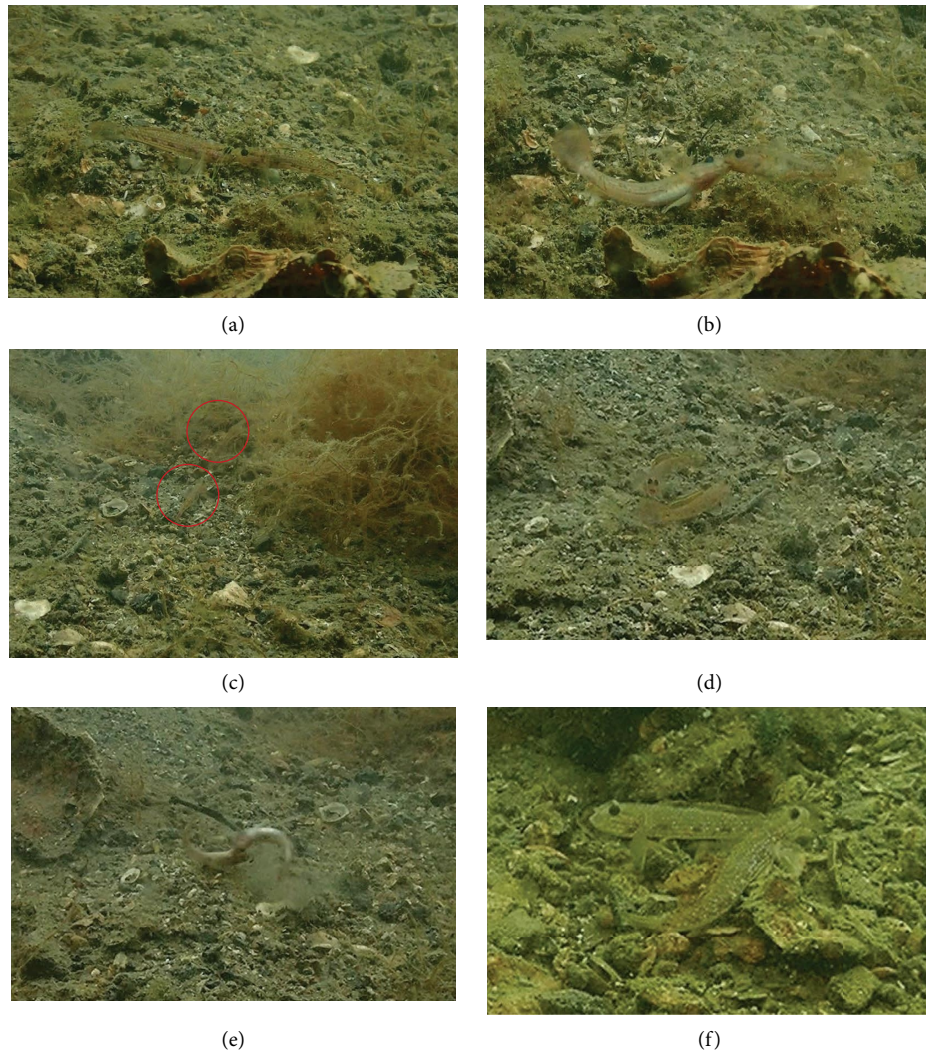


FIGURE 1: Agonistic interaction between two *Acentrogobius virgatus*, in Maizuru Bay, Kyoto prefecture, Japan, (a–e) recorded on 23 June 2022, (f) recorded 25 July 2022. (a) Initial jaw lock upon observation. (b) Struggles to break/maintain jaw lock. (c) Escape and chase. (d) Lateral displays, mouth gaping, encircling, and fin extension. (e) Strikes and bites to the head and body. (f) Second recording of lateral displays and mouth gaping.

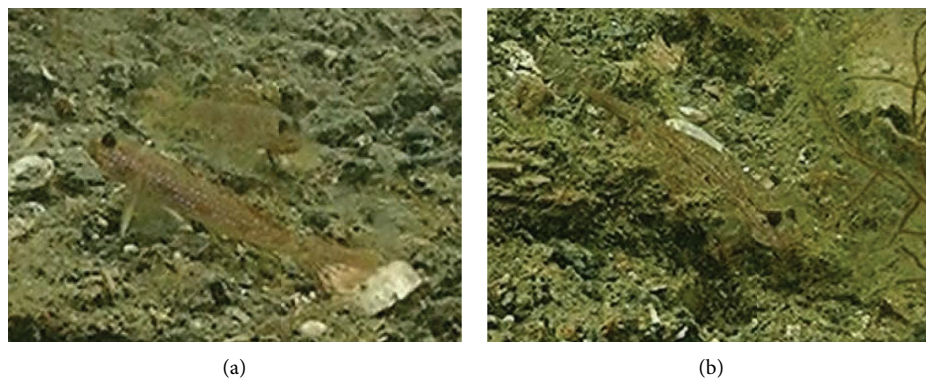


FIGURE 2: Coloration of *Acentrogobius virgatus*, in Maizuru Bay, Kyoto prefecture, Japan, recorded on 23 June 2022. (a) Coloration during the encounter. (b) Coloration change after the encounter ended.

*A. virgatus* are more conspicuous and not as easily identified as jaw locking and striking during the SCUBA surveys.

Of these studies, the key difference in experimental testing comes down to laboratory-based and in situ observational experiments. Several species of sand dwelling gobies have been studied in both contexts. Wacker et al. [9] examined *Gobiusculus flavescens* aggressive behaviors through laboratory experiments in the context of what was described by field observational experiments conducted by Forsgren et al. [4], building on previous in situ experiments examining its agonistic behaviors in western Europe. Similarly, the aggressive behavior of the sand goby *Pomatoschistus minutus* has been extensively studied in aquaria which was aided by earlier agonistic behaviors examined in situ [8, 33, 34]. Swenson [6] primarily studied behaviors of *Eucyclogobius newberryi* in captive conditions and also made opportunistic observations of aggressive behaviors while in the field, citing similar field observations made by Swift et al. [35]. Field studies are likely limited to species that are more easily accessible and could be further limited by environmental conditions. However, it is argued as being the more ecologically valid method when there is a currently overwhelming reliance on lab-based research in fish cognition [12]. While *A. virgatus* belongs to the *Gobiopsis* lineage [36], no studies have documented the behavior or territoriality in the species belonging to this lineage. These present observations could also advise subsequent tank experiments for similar gobies in the western Pacific.

Further research could identify the factors resulting in this agonistic behavior and the reasons for such aggression. Such events of agonism between conspecifics are rare and not easily documented in marine environments due to the absence of draws such as baited underwater cameras [37] (in situ). It is argued that in situ studies are the best way to understand reproductive and social dynamics, albeit difficult to conduct in the marine environment and can be data limited [38] (in situ). Field observations such as this one give baselines for further experiments examining these behaviors. By further identifying factors and habitat association of these behaviors, future behavioral experiments can tailor data collection methods such as remote cameras to specific environments. Observational field studies can contextualize these social dynamics, highlight differences across multiple species, and guide future experiments.

## Data Availability

All the available data are provided within the supporting figures and Electronic Supplementary Data. Oceanographic information can be provided upon request from the corresponding authors.

## Conflicts of Interest

The authors declare that there are no conflicts of interest.

## Acknowledgments

We would like to thank Reiji Masuda (Kyoto University) for being a safe dive partner, Keita W. Suzuki (Kyoto University) for oceanic conditions, and Shoko Matsui (Osaka Museum of Natural History) for species identification. The authors thank Dr. Horst Kaiser (Rhodes University) and an anonymous reviewer for their constructive comments on an earlier draft. We would also like to thank all those involved at Maizuru Fisheries Research Station for their support. There was no funding allocated for this study but was conducted as part of the authors employment at Maizuru Fisheries Research Station, Field Science Education and Research Center, Kyoto University.

## Supplementary Materials

ESM Video S1: Agonistic interaction between two *Acentrogobius virgatus* (Gobiidae), in Maizuru Bay, Kyoto Prefecture, Japan recorded on 23 June 2022. ESM Video S2: Agonistic threat displays between two *Acentrogobius virgatus* (Gobiidae), in Maizuru Bay, Kyoto Prefecture, Japan recorded 25 July 2022. (*Supplementary Materials*)

## References

- [1] G. S. Helfman, B. B. Collette, D. E. Facey, and B. W. Bowen, *The Diversity of Fishes: Biology, Evolution, and Ecology*, John Wiley & Sons, London, UK, 2009.
- [2] P. Keith and C. Lord, *The Biology of Gobies*, R. A. Patzner and B. G. Kapoor, Eds., Science Publishers, Hauppauge, NY, USA, 2011.
- [3] M. M. F. Lutnesky and J. P. Szypper, "The influence of spatial food distribution on agonistic behavior in juvenile mahimahi, *Coryphaena hippurus*," *Journal of Applied Ichthyology*, vol. 7, no. 4, pp. 253–256, 1991.
- [4] E. Forsgren, T. Amundsen, Å. A. Borg, and J. Bjelvenmark, "Unusually dynamic sex roles in a fish," *Nature*, vol. 429, no. 6991, pp. 551–554, 2004.
- [5] G. D. Grossman, "Food, fights, and burrows: the adaptive significance of intraspecific aggression in the bay goby (Pisces: Gobiidae)," *Oecologia*, vol. 45, no. 2, pp. 261–266, 1980.
- [6] R. O. Swenson, "Sex-role reversal in the tidewater goby, *eucyclogobius newberryi*," *Environmental Biology of Fishes*, vol. 50, no. 1, pp. 27–40, 1997.
- [7] Y. Yanagisawa, "Social behaviour and mating system of the gobiid fish *amblyeleotris japonica*," *Japanese Journal of Ichthyology*, vol. 28, pp. 401–422, 1982.
- [8] K. Lindström and C. Pampoulie, "Effects of resource holding potential and resource value on tenure at nest sites in sand gobies," *Behavioral Ecology*, vol. 16, no. 1, pp. 70–74, 2005.
- [9] S. Wacker, K. de Jong, E. Forsgren, and T. Amundsen, "Large males fight and court more across a range of social environments: an experiment on the two spotted goby *gobiusculus flavescens*," *Journal of Fish Biology*, vol. 81, no. 1, pp. 21–34, 2012.
- [10] G. Caroline Mendes, L. Samuel Ricioli, and R. Guillermo-Ferreira, "Behavioral repertoire of biparental care in *apistogramma trifasciata* (Pisces: cichlidae)," *Journal of Applied Ichthyology*, vol. 37, no. 6, pp. 957–962, 2021.

- [11] H. Peeke and M. J. Herz, *Habituation: Behavioral Studies*, Elsevier, Amsterdam, Netherlands, 2012.
- [12] M. G. Salena, A. J. Turko, A. Singh et al., "Understanding fish cognition: a review and appraisal of current practices," *Animal Cognition*, vol. 24, no. 3, pp. 395–406, 2021.
- [13] D. Jordan and J. Snyder, *Proceedings of the United States National Museum*, Smithsonian Institution Press, Washington, DC, USA, 1901.
- [14] Akihito, K. Sakamoto, Y. Ikeda, and M. Aizawa, "Gobioidei," in *Fishes of Japan with Pictorial Keys to the Species*, T. Nakabo, Ed., p. 1471, 3rd edition, Tokai University Press, Hadano, Japan, 2013.
- [15] S. Matsui, R. Inui, and Y. Yamashita, "Distribution and habitat use of three *Acentrogobius* (Perciformes: Gobiidae) species in the coastal waters of Japan," *Ichthyological Research*, vol. 59, no. 4, pp. 373–377, 2012.
- [16] M. Horinouchi, "Distribution patterns of benthic juvenile gobies in and around seagrass habitats: effectiveness of seagrass shelter against predators," *Estuarine, Coastal and Shelf Science*, vol. 72, no. 4, pp. 657–664, 2007.
- [17] S. Matsui, K. Nakayama, Y. Kai, and Y. Yamashita, "Genetic divergence among three morphs of *acentrogobius pflaumi* (Gobiidae) around Japan and their identification using multiplex haplotype-specific PCR of mitochondrial DNA," *Ichthyological Research*, vol. 59, no. 3, pp. 216–222, 2012.
- [18] T. Suzuki, K. Shibukawa, K. Yano, and H. Senou, *A Photograph Guide to the Gobioid Fishes of Japan*, Heibonsha, Tokyo, Japan, 2021.
- [19] P. Bleeker, "Nalezingen op de ichthyologie van Japan," *Verhandelingen van het Bataviaasch Genootschap van Kunsten en Wetenschappen*, vol. 25, pp. 1–56, 1853.
- [20] S. Matsui, M. Ueno, and Y. Yamashita, "Growth characteristics and reproductive biology of three sympatric *acentrogobius* (perciformes: Gobiidae) species in Maizuru bay, kyoto prefecture," *Bulletin of the Japanese Society of Fisheries Oceanography*, vol. 78, pp. 75–85, 2014.
- [21] R. Inui, Y. Shinada, and T. Ohata, "Differences in the spawning habitats of 2 *acentrogobius* species (teleostei: Gobiidae) in kyushu, japan," *Biogeography*, vol. 13, pp. 35–39, 2011.
- [22] R. Masuda, "Seasonal and interannual variation of subtidal fish assemblages in wakasa bay with reference to the warming trend in the sea of japan," *Environmental Biology of Fishes*, vol. 82, no. 4, pp. 387–399, 2008.
- [23] A. G. Valenciennes and L. Cuvier, *Histoire Naturelle des Poissons*, Paris: Levrault, vol. 12, 1837
- [24] Maizuru Fisheries Research Station, "Oceanographic and meteorological data," 2022, <https://www.maizuru.marine.kais.kyoto-u.ac.jp/data/kaikyo.html>.
- [25] H. Yoshigou, "Three first record fishes from the hiroshima prefecture, and notes on three species including in *acentrogobius pflaumi*," *Hibakagaku*, vol. 201, pp. 1–13, 2001.
- [26] A. Shinomiya, *Reproductive Behavior of the Goby Eviota Storthynx (Rofen)*, Memoirs of Faculty of Fisheries Kagoshima University, Kagoshima, Japan, 1981.
- [27] W. N. Tavolga, "Reproductive behavior in the gobiid fish *bathygobius soporator*," *Bulletin of the American Museum of Natural History*, vol. 104, pp. 427–460, 1954.
- [28] J. W. Wiley, "Western north american goby. *coryphopterus nicholsii* (bean)," *Transactions of the San Diego Society of Natural History*, vol. 17, pp. 187–208, 1973.
- [29] B. Lassig, "Field observations on the reproductive behaviour of *paragobiodon* spp. (Osteichthyes: gobiidae) at heron island great barrier reef," *Marine Behavior & Physiology*, vol. 3, no. 4, pp. 283–293, 1976.
- [30] A. Gaisiner, "Parental care and reproductive behavior of the clown goby, *microgobius gulosus*, with observations on predator interactions," *Environmental Biology of Fishes*, vol. 73, no. 4, pp. 341–356, 2005.
- [31] A. I. Markevich, "Courtship role reversal in sevenspine goby, *gymnogobius heptacanthus* (gobiidae)," *Journal of Ichthyology*, vol. 60, no. 4, pp. 653–659, 2020.
- [32] M. Enquist and O. Leimar, "Evolution of fighting behaviour: decision rules and assessment of relative strength," *Journal of Theoretical Biology*, vol. 102, no. 3, pp. 387–410, 1983.
- [33] H. Flink and P. A. Svensson, "Nest size preferences and aggression in sand gobies (*Pomatoschistus minutus*)," *Behavioral Ecology and Sociobiology*, vol. 69, no. 9, pp. 1519–1525, 2015.
- [34] K. Lindström and K. Lindstrom, "Male-male competition for nest sites in the sand goby, *pomatoschistus minutus*," *Oikos*, vol. 53, no. 1, pp. 67–73, 1988.
- [35] C. C. Swift, J. L. Nelson, C. Maslow, and T. Stein, "Biology and distribution of the tidewater goby, *eucyclogobius newberryi* (Pisces: Gobiidae) of california," *Contributions In Science*, vol. 404, pp. 1–19, 1989.
- [36] W. T. McCraney, C. E. Thacker, and M. E. Alfaro, "Supermatrix phylogeny resolves goby lineages and reveals unstable root of Gobiaria," *Molecular Phylogenetics and Evolution*, vol. 151, Article ID 106862, 2020.
- [37] C. Yau, M. Collins, and I. Everson, "Commensalism between a liparid fish (*Careproctus* sp.) and stone crabs (Lithodidae) photographed in situ using a baited camera," *Journal of the Marine Biological Association of the United Kingdom*, vol. 80, no. 2, pp. 379–380, 2000.
- [38] J. K. Hellmann, K. A. Stiver, S. Marsh-Rollo, and S. H. Alonzo, "Defense against outside competition is linked to cooperation in male-male partnerships," *Behavioral Ecology*, vol. 31, no. 2, pp. 432–439, 2020.