

Sounds produced by spawning fishes

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Received 12.9.1990

Accepted 23.1.1991

Key words: *Hypoplectrus*, *Scarus*, Serranidae, Scaridae Fish spawning, Underwater acoustics

Synopsis

Low frequency sounds are shown to be associated with the spawning of two Caribbean coral reef fishes: the hamlet, *Hypoplectrus unicolor* (Serranidae) and the striped parrotfish, *Scarus iserti* (Scaridae). Both fishes produce distinctive sounds while broadcasting gametes in midwater. *H. unicolor* produces sounds via muscle stimulation of the swimbladder. Fin movements among group spawning *S. iserti* produce hydrodynamic noise. Although reproductive behaviors of these two species have been previously studied in detail, the association of sounds with mating is new. The mating sounds cannot be easily detected by human hearing underwater but are recordable using a hydrophone. The sounds are distinct and recognizable enough to allow counting and acoustic mapping of mating events in these species.

Introduction

Sounds play an important role in species identification, mate selection, and the timing of insemination in many other animals and insects (Sebeok 1977). Sound production has been reported for a variety of fishes, but specific sound patterns have been correlated with specific behaviors in only a few cases. Well-known examples involve sounds produced during the agonistic and courtship behavior of a few territorial species which lay demersal eggs in nests (Fine et al. 1977, Myrberg 1981, Hawkins & Myrberg 1983, Ladich 1990). Courtship-related sounds have also been identified in gadoid fishes that broadcast gametes in the water column (Hawkins & Rasmussen 1978). However, sounds directly associated with the actual mating act have not been reported for any fish species. This behavioral attribute has, so far, gone largely unnoticed in fishes because most fish sounds cannot be heard directly by the human ear underwater or through the glass of an aquarium. Furthermore, if sound

production occurs primarily or most frequently during mating, this would not have been readily documented because such behavior is rarely witnessed.

The purpose of this paper is to describe the sounds produced by two coral reef fishes during mating. The hamlet, *Hypoplectrus unicolor*, spawns in monogamous pairs (Barlow 1975, Fischer 1980a). The striped parrotfish, *Scarus iserti*, spawns in groups of 5 to 30 individuals (Colin 1978, *S. iserti* = *S. croicensis* Randall 1963, Randall & Nelson 1979). Both species are broadcast spawners with planktonic zygotes, embryos and larvae. The reproductive habits of these two species are among the most well-known of all coral reef fishes, but the direct association of sounds with mating has not been previously reported.

Methods

Study locations

The majority of recordings were made on the reefs offshore from the Discovery Bay Marine Laboratory, Jamaica. Recordings of *H. unicolor* were made during February 1988, November 1988, February-March 1989, July 1989 and March 1990 ($n > 100$). Additional recordings of *H. unicolor* were made on reefs in Salt-River canyon, St. Croix, USVI at the NOAA-NURC Aquarius Habitat station during October 1988. Depths ranged from 15 to 30 m. Recordings of *Scarus iserti* ($n = 17$) were also made at the DBML location and the fishes studied in July 1989 and March 1990 occurred at the same location described by Colin (1978) at a depth of about 25 to 30 m.

Acoustic recording and analysis

Synchronous audio-video recordings were made with an omnidirectional hydrophone coupled to an underwater video camera operated while using SCUBA. Hydrophone sensitivity was -162 dB Newton m^{-2} re $1 \mu Pa$ (micro Pascal or 0.000001 Newton m^{-2}), and was linear from 10 to 3000 Hz. The camera unit was a Sony handycam model CCD-V9 inside a waterproof casing. The hydrophone components were modified from U.S. Navy sonobuoy technology. Acoustic analysis was conducted using a Kay DSP Sona-graph Workstation (Model 5500) and a computer sound analysis package developed at W.H.O.I. by Martin et al. (1990).

Results

Sounds produced by Hypoplectrus unicolor

Hypoplectrus unicolor is a simultaneous hermaphrodite and each individual of a pair alternates sex roles during a series of matings. Two sound patterns were associated with reproductive behavior in this species. Each type of sound accompanied a particular sexual role.

A courtship call produced by one of the pair preceded mating. The calling individual assumed the wrap-around position in the mating embrace (Fig. 1) and spawned as the male. This courtship call consisted of a series of sound pulses with an overall duration of 0.2 to 1.5 sec (Fig. 2) and a dominant frequency of about 500 Hz. The number of pulses in a call was variable among the different color forms of *H. unicolor* although the extent of individual variation has yet to be determined. I refer to hamlets in general as *H. unicolor* and, in the figures, refer to specific color variants by their prior species names, e.g. see Randall (1968), Graves & Rosenblatt (1980).

The individual in the head-down position (Fig. 1) mated as the 'female' and produced a sound with every mating event recorded ($n > 100$). This sound occurred at the same time as the release of eggs. While making this sound, the 'female' vigorously fluttered her pectoral fins and rapidly contracted the abdominal musculature. The behavior and sound lasted about 1.5 sec, after which the pair abruptly separated and moved rapidly downward to the reef. They repeated this sequence again after a few minutes. The mating sound consisted of two distinct parts (Fig. 3). First, there was a short duration (ca. 0.15 sec) frequency modulated (FM), downward (600 Hz to 200 Hz) tonal sweep. This preceded the second part by about 0.25 seconds. The second part of the mating sound was of relatively longer duration (ca. 1.25 sec) and consisted of broadband noise (350 Hz to 1650 Hz).

Sounds produced by Scarus iserti

One type of sound was associated with the group mating of the parrotfish. *Scarus iserti* (Fig. 4): a broadband noise pattern covering 30 Hz to 1200 Hz (Fig. 5). Repeated matings produced similar sounds but no two mating sounds were exactly alike, either in duration or spectrographic pattern based on examination of 17 events. Fish gather into a tight group of about 5 to 30 individuals just before mating and then rush upward a few meters above bottom to actually mate. This behavior is commonly called a spawning rush and takes less than one

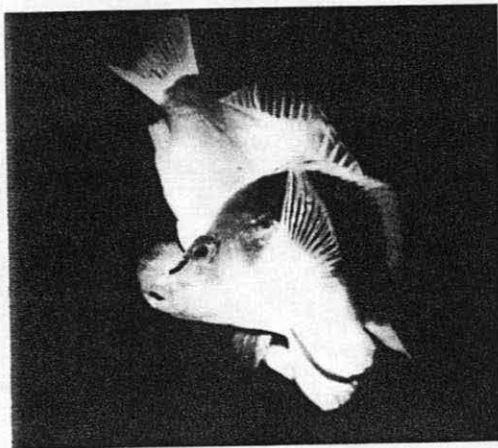
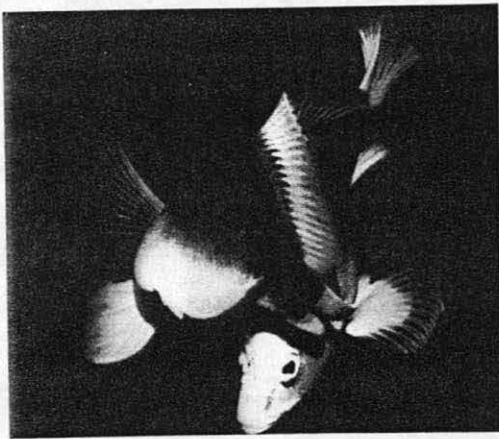
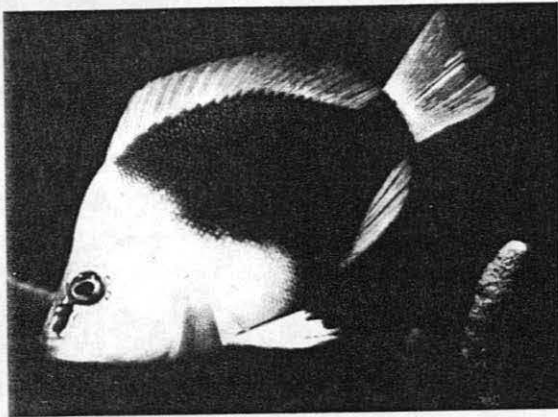


Fig. 1. Spawning postures of *Hypoplectrus unicolor* variety *guttavarius*. The mating sound is made by the fish in the head-down posture which is the female role (middle). The fish which is wrapped U-shaped around the female is the male and it made the courtship call prior to spawning (bottom). The fish are approximately 10 cm in length.

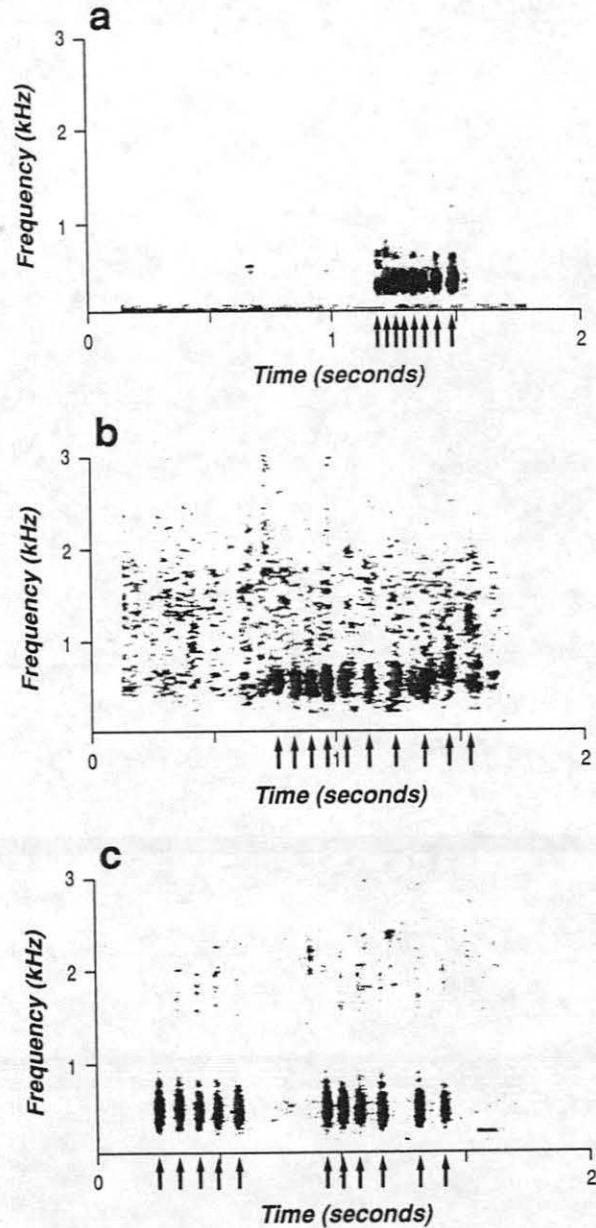


Fig. 2. Spectrographs of the mating calls from three varieties of *Hypoplectrus unicolor*. The arrows mark each of the pulses in a call, a - *guttavarius*, b - *nigricans*, c - *unicolor*.

second to complete. The fish broadcast gametes at the apex of the rush and then rapidly swim back to the reef. The time for the upward rush has been calculated from movie footage (Colin 1978) to vary between 0.21 and 0.40 sec and the return from 0.20 to 0.40 sec. The spawning sound was audible

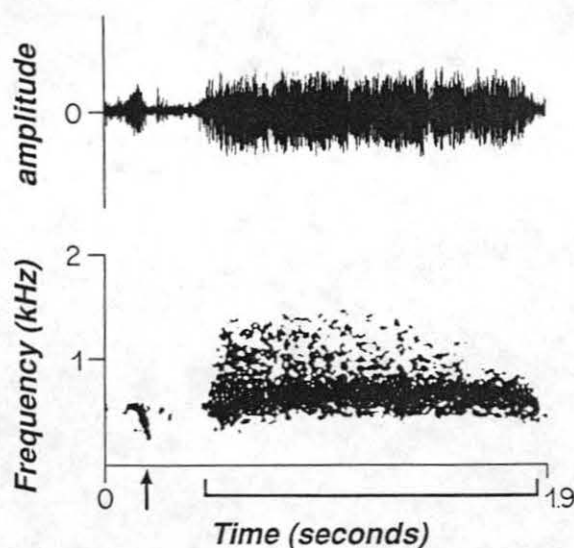


Fig. 3. Spectrogram and oscillogram example of the spawning sound from *Hypoplectrus unicolor* variety *nigricans*. Fish were about 10 cm from the hydrophone. The arrow marks the FM sweep and the bracket encompasses the broadband part of the spawning sound. The duration of the FM sweep preceding the broadband spawning sound was 0.1 sec, the duration of the broadband spawning sound was 1.43 sec, overall duration was 1.79 sec. The FM sweep sound peaked at 600 Hz and its minimum was 220 Hz. The broadband sound ranged from 350 to 1380 Hz. The major energy of the FM sound was about 520 Hz and for the broadband spawning sound it was about 620 Hz.

throughout the time that the group was swimming, not only at the instant of gamete release.

Discussion

Due largely to past limitations in underwater acoustic and camera technology, the mating associated sounds produced by hamlet and striped parrotfish have been missed despite several studies of spawning behavior in these species. The mating sounds are barely perceptible by human hearing underwater, as they are faint and usually difficult to distinguish in the presence of background noise. A single hydrophone was capable of recording the mating sounds up to a maximum of a few meters distance away.

The reproductive behavior of *Hypoplectrus unicolor* is complex and involves particular courtship

and spawning behaviors and the use of a specific mating site (Barlow 1975, Fischer 1980a, b, 1981, Lobel & Neudecker 1985). The hamlet is a simultaneous hermaphrodite and usually maintains a pair-bond with a single partner of the same color pattern. A pair typically mates from several to a few dozen times an evening. The daily spawning period is restricted to the evening crepuscular period, i.e. about 45 minutes before and during sunset-twilight. Sounds have not been previously detected from *H. unicolor* although other related serranids are well known sound producers (Fish & Mowbray 1970). In addition to the sounds associated with reproduction, *H. unicolor* also produces a series of quick acoustic pulses during some aggressive encounters (personal observation).

The courtship call precedes mating by several seconds and may be an important cue for mate identification and as a signal for mating readiness. The gross characteristics of this sound pattern appears similar to that typically described for other fishes (e.g. Fish & Mowbray 1970). Courtship calls among pomacentrids and centrarchids have been shown to be species specific and important in mate selection (Gerald 1971, Myrberg et al. 1978, 1986, Myrberg & Spires 1972, 1980). In combination with color pattern, the courtship call could help the various sympatric *H. unicolor* variants maintain assortative mating. Preliminary data suggests that the different color morphs of *H. unicolor* may produce call patterns which vary in the number of pulses per call duration. Research is underway to rigorously test this hypothesis.

The mating sound by *H. unicolor* was produced simultaneously with egg release and occurred with every mating event recorded ($n > 100$). It is acoustically distinct from all other fish sounds so far reported in the literature. The first part of this mating sound possibly signals the 'male' of the immediately impending release of eggs. The second part may have originated partly as a by-product of the mechanics of egg extrusion, by which abdominal muscles contract to force out eggs also cause vibrations against the swimbladder. The mechanism of sound production by *H. unicolor* probably involves the movement of the head and pectoral girdle musculature and the sonic swim-

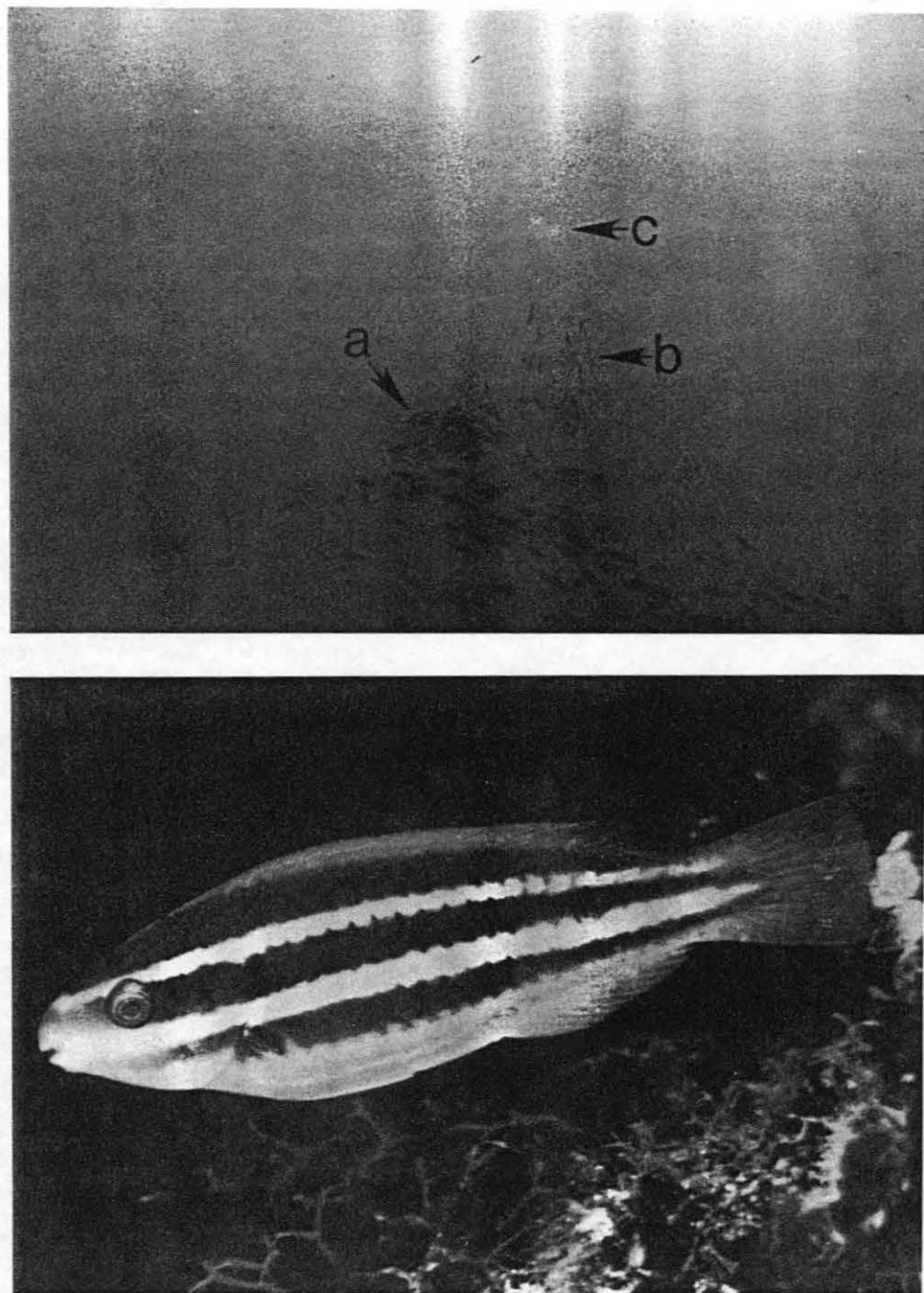


Fig. 4. Top: Spawning behavior of *Scarus iserti*. a – A group in tight formation posed and ready to begin a spawning rush, b – fish swimming downward after spawning, c – the point at which the fish just spawned. Bottom: The striped parrotfish, *Scarus iserti*, initial color phase (adult about 15 cm TL).

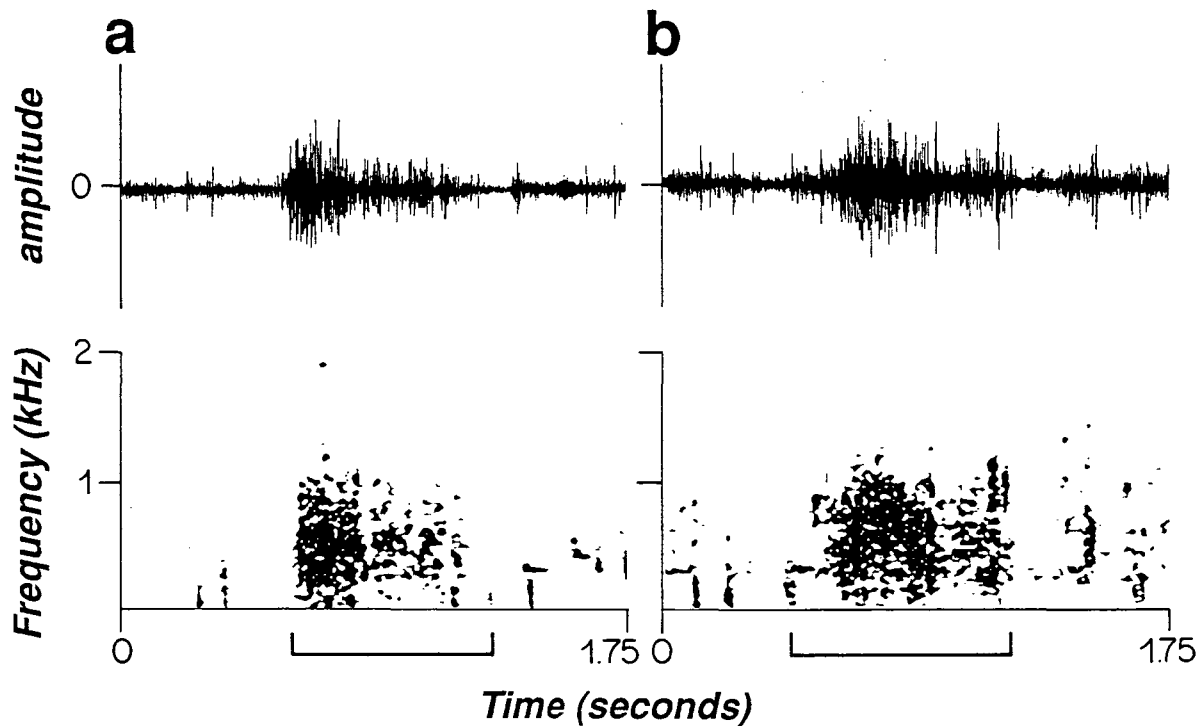


Fig. 5. Spectrographs and oscillographs examples of *Scarus iserti* mating sound. The bracket encompasses the spawning sound: a - Sound made by a group of about 12 fish about 50 cm from the hydrophone. Duration: 0.75 sec, frequency: 30 to 1160 Hz, major energy about 710 Hz. b - Sound made by about 20 fish about 50 cm from hydrophone. 0.64 sec, frequency: 60 to 1160 Hz: major energy is about 570 Hz.

bladder muscles against the swimbladder. Movement of the pectoral girdle musculature was clearly evident from the rapid fluttering of the pectoral fins. The spawning sound may help the spawning partner to coordinate simultaneous gamete release, thus maximizing insemination of eggs. The mixing of eggs and sperm may also be enhanced by turbulence created by the fluttering fins. Interestingly, the mating embrace position of the hamlet is such that the two partners have a line of vision in opposite directions. This position provides the greatest sphere of visual awareness for the pair but it also places the fish in a posture which separates the proximity of their genital vents. If the spawning pair were positioned so that their genital vents were closely aligned, it would result in both fish looking one way and leaving their backs vulnerable. Hamlet spawn at a time when large predatory fishes are particularly active and spawning fishes are sensitive

to the approach of a potential predator (Lobel & Neudecker 1985).

Scarus iserti is a common, widespread Caribbean species that has been the subject of research about its behavioral ecology and sexuality more than that of any other parrotfish (e.g., Colin 1978, Robertson & Warner 1978). The sounds normally associated with parrotfish activity result from the crushing of calcareous food by their pharyngeal jaw apparatus (Fish & Mowbray 1970). Some species also produce escape knocks (swimbladder sound) when handled in an aquarium (Fish & Mowbray 1970).

The mating-associated sound recorded for *Scarus iserti* appeared to be hydrodynamic noise resulting from the rapid movements of the fins from all the fishes of the group. The duration of spawning sound of *S. iserti* was longer than the time for the actual expulsion of eggs: it was approximately equal to the time of the entire rush upward and downward. The speed of the fish rushing upward

until turning at the point at which gametes are released was about 12 m s^{-1} (Colin 1978). Given this rapid acceleration over this short distance, and the duration of the sound which equalled the duration of the spawning rush it is most probable that the spawning associated sound of this parrotfish is hydrodynamic noise from the rapid swimming of the fish group. (If swimbladder-produced sounds are present, they were not detectable using the signal analysis methods available at this time). Hydrodynamically induced sounds from swimming fishes have been reported for several species, particularly carangids and clupeids, and these swimming sounds appear to be to a degree species-specific (Moulton 1960).

The two examples of mating sounds represent possible extremes for sound patterns from fishes. *H. unicolor* produces a biological sound with a repeated and complex spectrographic pattern. *Scarus iserti* produces mostly hydrodynamic noise associated with rapid swimming that results in a variable and less complex spectrogram. These two fishes are the first species that I have recorded and both produce distinctive sounds exclusively with spawning and/or mating. These results suggest that there is tremendous potential for finding other fishes producing sounds during mating.

Acknowledgements

This work was supported by the Island Foundation, The Kelley Foundation, Sippican Corp., The Smith Special Studies Fund of W.H.O.I., The NOAA Sea Grant program at W.H.O.I. (NA 86-AA-D-SG090 Project No. R/B-97-PD) and the NOAA National Undersea Research Program (NOAA/NURC-FDU 89-09-NA88A-H-URD20). Field logistics were sponsored in part by the Discovery Bay Marine Laboratory, Jamaica, and the East-West program, Northeastern University. I thank J. Catipovic, T. de Groot, K. Frstrup, J. Hannon, E. Kalko, A. Martin, J. Spiesberger, P. Tyack and W. Watkins for sharing their technical expertise in acoustics and P. Colin for showing me the location of the spawning *S. iserti*. I also thank two anonymous reviewers and the editor for very

helpful suggestions. This is Woods Hole Oceanographic Institution Contribution No. 7250.

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