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Dissertation

THE ROLE OF ACOUSTIC SIGNALS IN FISH COURTSHIP AND CHALLENGES IN BIOACOUSTIC FISH RESEARCH

by

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ABSTRACT

Sound production is a widespread phenomenon in fishes; however, the importance of acoustic signals and their potential to influence reproduction has not been determined. This dissertation examines fish acoustic courtship signals to investigate whether sound has a role in reproductive success. The pre-spawning sounds of several fishes were recorded and analyzed. The male advertisement call of two species of Belizean toadfish, *Sanopus astrifer* and *Batrachoides gilberti*, were found to significantly differ. These data, coupled with data in the literature suggest an influence of habitat characteristics on the calling behavior of toadfishes. Additionally, acoustic playback experiments were employed to investigate the role of male courtship sounds in the Malawi cichlid species, *Tramitichromis intermedius*. Playback results indicated that male sounds may initiate egg-laying behavior in females, but may not be behaviorally relevant

to conspecific males. A discussion of confounding factors in aquarium playback experiments is presented.

Technical aspects of fish sound recording, playback, and analysis were also examined to provide information for future fish bioacoustics studies. It was determined that digital cameras are a useful method of recording fish sounds to describe metric characteristics; however, temporal parameters are more accurately captured by hydrophones, which are optimal for use in scientific description of fish sounds. Underwater speakers commonly used in fish playback experiments were tested for fidelity when producing a low-frequency pulsed fish sound. The Electro-Voice UW30 speaker was found to perform the best playback at low sound pressure levels (<120 dB re 1 µPa) and at short distances (< 15 cm). The Clark Synthesis AQ339 speaker performed the best playback at higher sound pressure levels (>120 dB re 1 µPa) and at greater distances than the UW30. Many fish sounds have been described in the literature; however, there is no standardization of sample size used in species descriptions. A method is presented that can be used to estimate the level of inclusiveness of sound variability in sound descriptions, and to approximate sufficient sample sizes of recordings. The courtship calls of *Dascyllus albisella* and *Batrachoides gilberti* were examined to illustrate this method and to provide a benchmark for future sound descriptions.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AL	activity level
ANOVA	analysis of variance
B. gilberti	*Batrachoides gilberti*
B. trispinosus	*Batrachomoeus trispinosus*
C	central
C. conophorus	*Copadichromis conophorus*
CL	call length
cm	centimeter
Con	conspecific
CV	coefficient of variation
CV	correlation value
CV_w	coefficient of variation within individuals
CV_b	coefficient of variation between individuals
D. albisella	*Dascyllus albisella*
dB	decibels
e.g.	*exempli gratia*
et al.	*et alia*
ft	feet
H. didactylus	*Halobatrachus didactylus*
Hetero	heterospecific
Hz	hertz

i.e.	*id est*
kHz	kilohertz
L	left
L	liter(s)
m	meter(s)
min	minute(s)
mm	millimeter
ms	millisecond(s)
M. zebra	*Metriaclima zebra*
µPa	microPascal
N	note
O. beta	*Opsanus beta*
O. phobetron	*Opsanus phobetron*
O. tau	*Opsanus tau*
P	pulse, number of pulses
Pers. Comm.	personal communication
P. notatus	*Porichthys notatus*
ppt	parts per thousand
psi	pounds per square inch
R	right
re	reference
s	second(s)

S. astrifer	*Sanopus astrifer*
SD	standard deviation
sec	second(s)
SL	standard length
Spec	spectrogram
SPL	sound pressure level
spp.	species
T. intermedius	*Tramitichromis intermedius*
V	volt(s)
W	watt
Wave	waveform
WN	white noise

Introduction

Bioacoustics is the study of biological sounds, or the study of the perception, production, and association of behaviors with the acoustic signals of animals. An understanding of the acoustic behavior of animals allows for distinction between otherwise similar species, and the ability to investigate the role of sound in the processes of species divergence or the maintenance of species separation. The study of bioacoustics is one method that can be used to assess species diversity. Species diversity can be a stabilizing factor for ecosystems in the face of events such as global warming, over-harvesting, pollution, and habitat destruction – negative impacts that are currently experienced by much of the world's environments. Determining the differences in acoustic signals of animals allows examination of the processes that create and maintain species diversity, knowledge of which is critical to protecting this diversity.

Advances in the study of the acoustic signals of fish generally lags behind the study of terrestrial animal groups, mainly due to a bias of human observers studying subjects easily perceived and recorded in our native environment. In addition, many fish sounds are inaudible to the human ear without the aid of technical equipment. The accessibility of commercial technology such as underwater speakers, hydrophones, and rebreather diving systems, has increased greatly in the last 50-60 years (Rosenthal and

Lobel 2006). This has allowed scientists greater ability to listen, record, and playback fish sounds in order to examine the behavioral functions of fish sounds.

What fish bioacoustics has yet to determine, is how important acoustic signals are in the survival and successful reproduction of fishes. Therefore, the next big question in fish bioacoustics is: do acoustic signals play a role in fish reproduction? Reproduction is one of the most important life-history event in the lives of most animals, allowing for the transmission of genes to the next generation that, along with survival, is part of the definition of evolutionary fitness and success. Courtship is often the prelude to the act of reproduction, and many fish sounds are associated with courtship (Amorim 2006). Therefore, the aim of this dissertation was to investigate the role of fish sounds during courtship. The male courtship sounds in two groups of fishes, toadfish and cichlids, were examined to investigate whether these sounds may play a part in successful reproduction.

The boatwhistle courtship call of three species of toadfish, *Opsanus tau*, *Sanopus astrifer*, and *Batrachoides gilberti* were recorded in the field and then analyzed. The boatwhistle calls appeared to be species-specific (Chapter 1); however, recording equipment differed between species. To verify that the differences in call characteristics were not due to differences in equipment, an evaluation of digital camera and hydrophone recording technology was completed. Dissimilarities in temporal accuracy were found in digital camera recordings; however, significant differences in number of notes per call were accurately measured (Chapter 2). The results of this evaluation

indicated that the temporal parameters that were measured for *B. gilberti* could not be used for interspecific comparison; however, significant differences in the number of notes per call do exist between toadfish species.

Investigation into the role of male courtship calls of the Lake Malawi cichlid, *Tramitichromis intermedius*, began with determining the response of isolated reproductively mature females to the acoustic playback of male courtship sounds. Preliminary results of the acoustic playback experiments suggested that courtship sounds may instigate spawning behavior in females (Chapter 3). Thus, the male courtship sounds in this species may have a possible reproductive priming function, in addition to that of advertisement and attraction. Since field observations suggest *T. intermedius* males are also attentive to conspecific courtship calls, the preference for association with conspecific male courtship sounds was determined with a two-choice acoustic playback experiment. Results appeared to indicate that there was no male preference for association with conspecific courtship sounds at the species level (Chapter 4). However, acoustic quality of the fish sounds during experimental playback was hypothesized to be a factor in the unclear behavioral results. Therefore, an evaluation of comparable models of commercial underwater speakers used in recent fish playback experiments was completed to determine if playback quality could have influenced male response to the playback of acoustic signals. The Clark Synthesis AQ339 speaker was found to produce the most accurate playback of the *T. intermedius* courtship sound in higher amplitude, long distance, and high ambient noise situations, while the Electro-

Voice UW30 speaker produced the most accurate playback in low amplitude, short distance, and low ambient noise conditions (Chapter 5). The Clark Synthesis speakers utilized in the male *T. intermedius* playback experiments were the best choice for equipment; however, the accuracy in fish sound playback may still not have been sufficient to elicit a clear behavior response.

The final chapter of this dissertation attempted to address the question in fish bioacoustics of: what sample size is needed to describe a fish sound? The number of recorded sounds used to describe fish sounds in the literature varies widely, so a method was developed to characterize the variability of a sample, and to estimate the sample size required to describe the full-range of variability in the group of study (Chapter 6). The use of this method was demonstrated using sound analysis of the courtship sounds of *Batrachoides gilberti* and *Dascyllus albisella*. This characterization of variability could be included, in addition to reported mean sound parameters, in future fish sound descriptions.

The results of this dissertation research provided further evidence that the acoustic signals of fish do play an important role in fish reproduction. Additionally, it provided information that may help to address some of the challenges in fish bioacoustic research.

Chapter 1: Acoustic Signals of Two Toadfishes from Belize: *Sanopus astrifer* and *Batrachoides gilberti* (Batrachoididae)[1]

Abstract

The "boatwhistle" calls of *Sanopus astrifer* and *Batrachoides gilberti*, two toadfish species from Belize, are described for the first time. These descriptions add to the small number of toadfish species sounds known to date (6 out of 79 species). Both Belize toadfishes produced multiple notes per call, unlike most other toadfish species which produce a single-note call (with the exception of *Opsanus beta*). *S. astrifer* produced significantly more notes per call than *B. gilberti* ($p < .05$), and was recorded producing up to 7 notes, the highest number of notes per call of any toadfish species reported. Differences in the boatwhistle call between all species with available data are reviewed and it is hypothesized that phylogenetic relationships, morphology of the swimbladder, and evolutionary processes are factors that potentially influenced these differences.

[1] Previously published as Mosharo KK, Lobel PS (2012) Acoustic signals of two toadfishes from Belize: *Sanopus astrifer* and *Batrachoides gilberti* (Batrachoididae). Environmental Biology of Fishes 94: 623-638.