Chapter 81
Acoustic Communication in Fishes and Potential Effects of Noise

David A. Mann

Abstract Many soniferous fishes such as cods and groupers are commercially important. Sounds are produced during courtship and spawning, and there is the potential for aquatic noise to interfere with critical behaviors and affect populations. There are few data on the response of wild populations of sound-producing fishes to acoustic noise. New motion and sound exposure fish tags could be used to assess the behavioral responses of large numbers of fish to noise exposure. Many factors, such as fishing mortality and environmental variability in prey supply, could also affect populations and potentially interact with the behavioral responses to noise.

Keywords Toadfish • Sciaenidae • Grouper • Passive acoustics • Glider

1 Introduction

Although the importance of acoustic communication in marine mammals has long been appreciated, there has been a lag in the study of acoustic communication in fishes. This paper reviews acoustic communication with a focus on the aspects of communication as they relate to potential impacts from noise in three groups of fishes that are among the better studied soniferous fishes: toadfish (Batrachoididae), croakers and drums (Sciaenidae), and groupers (Epinephelidae). The paper closes with a call for a large-scale multi-investigator effort to catalog fish sounds and the development of technology to study the impacts of noise on communication and reproduction.

D.A. Mann (✉)
Loggerhead Instruments, 6776 Palmer Park Circle, Sarasota, FL 34238, USA
e-mail: dmann@loggerheadinstruments.com

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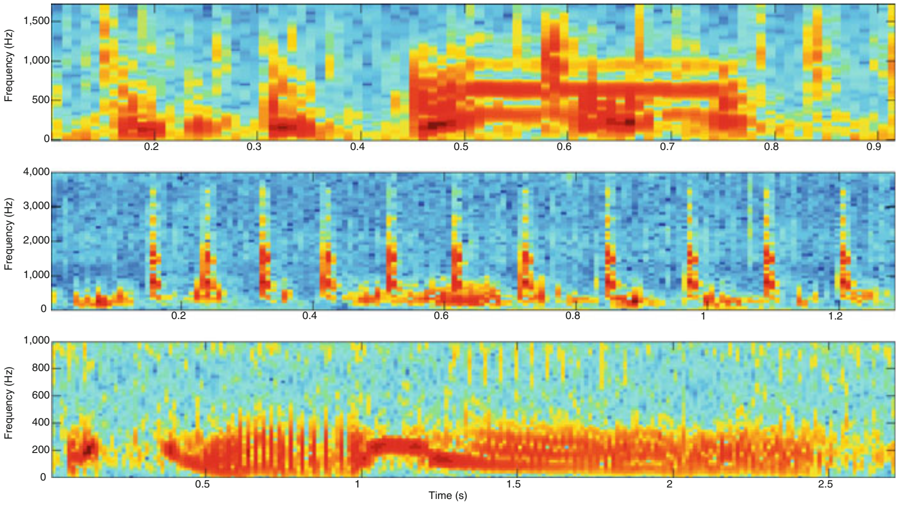

Fig. 81.1 Spectrograms of sounds from gulf toadfish (*top*), silver perch (*middle*), and red hind grouper (*bottom*)

1.1 Toadfish

Toadfish have been used as a model to study acoustic communication at the neural level (e.g., Sisneros and Bass 2005) as well as in field studies of behavior (e.g., Thorson and Fine 2002). There are about 80 species of toadfish, yet the sounds of only a handful have been described (e.g., Tavolga 1958; Amorim et al. 2011). Toadfish produce sounds by contraction of the sonic muscles that are intrinsic to the swim bladder. The rate of muscle contraction is mirrored in the fundamental frequency of the sounds, which ranges from 50 to 400 Hz (Fig. 81.1). There are species-specific differences in the duration and timing of these sounds. In toadfish, males establish a nesting area and vocalize to attract females who lay adhesive eggs in the male's nest. Toadfish communication is likely short range (<10 m) due to the source level of the sounds (126 dB re 1 μPa; Barimo and Fine 1998) and the relatively poor hearing sensitivity of toadfish (Fish and Offutt 1971). Toadfish have been demonstrated to interact with neighbors vocally. Thorson and Fine (2002) showed that the gulf male toadfish will produce a thumping sound, termed tagging, simultaneously with a neighbor's boat whistle.

1.2 Croakers and Drums

There are about 275 species of croakers and drums, which are found coastally in the tropics and subtropics. Although most species produce sounds, there are some species like whiting that lack swim bladder musculature. Croakers and drums typically have sonic muscles that attach between the bone and the swim bladder.

Sounds are typically a series of pulses (e.g., Fig. 81.1), but there are some species where the pulses are rapid and appear tonal in nature (e.g., black drum; Locascio and Mann 2011). Sound production has been described in ~15 species, which leaves the majority unknown. Some croakers will produce sounds in a chorus when many individuals in the same area produce sound simultaneously (Locascio and Mann 2008). In these situations, it can be difficult to discern the call of an individual. In estuarine areas in Florida in the summer, the low-frequency noise floor is often dominated by sound production by croakers and drums, which can be so loud as to be heard above the water. Croakers and drums have a wide diversity of swim bladder structure, which relates to a wide diversity in hearing sensitivity (Ramcharitar et al. 2006). The range of communication is not known. It has been estimated to be 33–108 m for the black drum based on the source level (165 dB re 1 μPa) and audiogram measurements (Locascio and Mann 2011). Even in this very loud species, the detection range was background noise limited. In species that chorus, the detection range for the chorus could be larger than for an individual calling.

1.3 Groupers

Groupers are found in the tropics and subtropics and are a common local food fish. Sound production has been most commonly associated with the family Epinephelidae. There are 159 species of epinephelids, and sounds have been identified from 5 species (e.g., Mann et al. 2010; Nelson et al. 2011; Schärer et al. 2012). Several species, such as red hind and red grouper, produce a relatively complicated sound for a fish, consisting of an introductory set of pulses followed by a pulse train with increasing or decreasing pulse rates (Fig. 81.1).

The sound production mechanism is not well understood; sound production appears to be mediated by muscles on the vertebral column in Nassau grouper (Hazlett and Winn 1962). There are no direct measurements of source level for any grouper sound, although estimates based on nearby recordings suggest it is ~130–140 dB re 1 μPa for red grouper, with a peak frequency of ~180 Hz (Nelson et al. 2011). Video recordings of red grouper and red hind suggest that acoustic communication is relatively short range (<100 m), and signal-to-noise ratios of recordings also suggest detectability to be in the range of 100 m.

2 Potential Effects of Noise

In all of these examples, acoustic communication is an important aspect of reproduction. Acoustic communication ranges are likely relatively short for all species (<100 m). Still, for croakers, drums, and groupers in coastal areas, the background noise rather than hearing sensitivity is most often the limiting factor for communication range. Because toadfish might be mainly sensitive to particle motion, it is possible that their hearing sensitivity limits the communication range. One might expect these relatively short communication ranges to hold for most fish species.

The exceptions might be for chorusing fishes and fishes who live in environments with a lower noise floor (e.g. deep sea and freshwater lakes).

The most likely potential negative impact of noise on fish communication is to reduce communication ranges and potentially disrupt spawning. Many of these species are producing sounds in murky water or at night, and thus acoustic communication may be an important means of locating potential mates. One would expect the largest potential impact to come from chronic, low-frequency (<1,000 Hz), high-level sound sources that raise the background noise floor, such as in harbors where there is consistent engine noise.

Passive acoustic recording could be used to measure the disturbance to fishes. My laboratory has recorded large changes in sciaenid sound production in response to red tide events as well as to hypoxia. In New Jersey, large changes in sound production accompanied large changes in water temperature due to upwelling (Mann and Grothues 2009). Similarly, one could study the impacts of noise exposure from seismic air guns on fish behavior with passive acoustic monitoring. This should be readily achievable by piggybacking on existing seismic surveys.

3 Need for Library of Fish Sounds

Recent recordings made from an underwater glider in the Gulf of Mexico showed the presence of several common sounds that were likely produced by fishes (Wall et al. 2012). This glider track was 135 km in length and took place over a 1-week time period. Indeed, the majority of the sounds recorded came from unknown sources. Of the three groups described in Sections 1.2 and 1.3, recordings have been made in <5% of the species. This demonstrates the comparative ignorance about the sources of sound in marine environments compared with those in terrestrial environments. This ignorance limits the use of passive acoustics to study the effects of noise exposure on fish behavior because in most cases the species being recorded will be unidentified.

A concerted effort is needed to develop a library of fish sounds. This will allow us to learn about the ecology of fishes and also study the impacts of noise using passive acoustic techniques. Many of the sounds produced by fishes take place during courtship and reproduction, which can be difficult to replicate in the laboratory where it can be difficult to impossible to breed fish. For example, the sound produced most commonly by red hind in the field during territorial behavior was nothing like the single pulses recorded as fish were manipulated in captivity (Fish and Mowbray 1970; Mann et al. 2010). For species like the red hind, which live on relatively shallow coral reefs, it was possible to use video cameras with hydrophones to identify sounds. In other environments, where the visibility is poor or the water too deep, video cameras are impractical.

A fish acoustic library will likely contain thousands of species. Thus, new techniques such as implanted tags that record sound production are needed to record sounds directly from fishes.

4 Fish Behavioral Response Tags

Acoustic tags for cetaceans have been very successful in studying natural behavior and sound production during feeding (e.g., Johnson and Tyack 2003). These tags are too large to use directly with fishes. I propose a new type of tag using an accelerometer sampled at a high rate to record fish sound production. An accelerometer may be superior to using a piezoceramic hydrophone to record sound production from an implanted fish because it is directional and would detect motion and not sound pressure. Thus, it will have a lower noise floor from external sound sources such as other fish sounds and boat noise. Current digital accelerometers support sample rates up to 1,200 Hz, which is adequate for covering the typical bandwidth of fish sound production. These tags could be digital storage tags using onboard memory but then they would have to be recovered. Another possibility is to integrate these tags with an acoustic transmitter so that the recorded signals could be transmitted to a receiver that is easy to recover. This tag design could be extended to study behavioral responses to noise exposure by adding a hydrophone to record noise exposure and a magnetometer and depth sensor to record swimming behavior.

5 Challenges

Looking forward, even with the necessary technology and knowledge, it will be a major challenge to disentangle the effects of noise exposure from environmental variability and fishing mortality. In 2008, the Florida west coast commercial red grouper catch was over 5.6 million pounds and the recreational catch was estimated at over 1,30,000 pounds (Southeast Data, Assessment, and Review 2009; National Marine Fisheries Service 2012). Even though this catch is a fraction of that of other fisheries, it is likely going to be nearly impossible to directly ascribe a specific population impact of noise exposure by counting fish. What can be measured? One can envision controlled studies where short-term reproductive output and behavioral correlates of reproduction, such as sound production and fish movement, are measured in the absence and presence of noise exposure. Although it is attractive (and easier) to do these studies in areas with no fishing, it is possible there will be interactive effects from noise exposure coupled with fishing pressure.

By answering this short-term question of whether there is an impact on behavior and reproduction, we can begin to estimate the risk associated with noise exposure to populations. If there is little or no disruption of behavior and reproductive output, then it is unlikely that noise will be an important risk factor, especially in comparison to the effects of fishing. However, if there are large disruptions to behavior, such as movement out of an area or cessation of sound production and spawning, then the risk of noise exposure will be higher and the level of risk will be tied to the spatial and temporal extent of noise exposure in relation to the spatial and temporal extent of spawning.

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