Nýsköpunarsjóður

Final report

The role of sound production in Atlantic cod spawning

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Student: Egill Guðmundsson

Supervisors: Prof. Guðrún Marteinsdóttir and Dr. Tim Grabowski

Abstract

The mating system of the Atlantic cod is complex and thought to consist of a lek system where females select mates from a group of competing males. Recent researches have indicated that sound production plays an important role during the mate selection and that it may vary among individual males in amplitude and quality. By using and assisting in the development of new innovative technology, the role of sound during spawning and mate selection, will be for the first time assessed at a individual level. The Icelandic firm Star Oddi ehf has developed novel data storage tags (DTS) which can detect sounds produced by fish and record the time a tagged individuals was actively producing sound. The tags make it possible to analyze the sounds the cod emits while spawning in a new way and thus helps clarifying the importance of its role as a part of the complex behavior displayed by cod in a spawning event. Due to unexpected technical difficulties during the development of the tags, the project experienced significant delays. The tags were too sensitive to sound and did therefore record all sounds in the vicinity of the cod. The necessary fine tuning and validation of the tags proved somewhat technically difficult and took up most of the experimental time planned for the summer of 2009. Four DST were surgically implanted in four cod in the MRi experimental research station in Grindavík and a hydrophone recorded all the sounds in the tank. That recording was then compared to the data from the tags. The results indicated that the tags worked correctly and recorded only the sounds made by the individual cod. In the next phase of the experiment, either in the spring or the fall of 2010, the tags will be ready to use in further research on the role of sound production in the spawning behavior of the Atlantic cod.

Main objectives and short description of the project

The main objective of this study is to assess the importance of sound production in connection with mate selection and spawning success of the Atlantic cod. Observations and recordings of sounds produced by the spawning cod are registered using new and innovative technologies. One of these state-of-the-art technologies include the development of sound recording data storage tags that can be inserted into the body cavity of the fish where it records duration of all sounds produces by the fish. These tags have been under development by the Icelandic firm Star Oddi and were finalized during the cause of this project. Other innovative technologies not previously used in research on marine fish in such a way, include behavioral observation system by HTI. This system is constructed of hydrophones that sense the transmitted sounds from transmitters implanted into the fish. This way, all positions of the fish are being recorded and analyzed in conjunction with the recordings of the sounds. By analyzing the sounds the cod emits while spawning it will be possible to clarify the importance of its role as a part of the complex behavior displayed by cod while spawning. Because of the individual identification made possible by the sound recording tags it is possible to address the following questions:

- Is the sound different between individuals?
- Do the males that produce louder and longer sounds increase their chance of finding a mate?
- Do the females choose mates based on the sounds they produce?
- Does the size of the individuals matter?
- Do both males and females produce sounds?

Due to unexpected technical difficulties during the development of the tags, the project experienced significant delays. The main cause was due to the fact that the sound recording tags were too sensitive to all sounds and therefore recorded all sounds in the vicinity of the cod, not only those produced by the cod itself. As a result, new experiments were designed where the range and amplitude of individual sounds were established and used to correct the tags. This validation was critical as the body of a fish does not differ appreciably in density from that of water and as such they have similar acoustic properties. If the threshold sensitivity of the tags is not properly set, then they will not be able to distinguish between sounds originating from external sources from those produced internally.

The validation proved to be somewhat technically difficult and took up most of the experimental time planed for the summer 2009. As a result, the tags were not ready in time for the August spawning period. The main experiment involving the recording of the spawning behavior, has therefore been delayed to next spawning period, either in spring 2010 or fall 2010 depending on availability of suitable experimental tanks.

State of the Art

Sound appears to play an important role in the spawning behavior of cod. Sound production in captive Atlantic cod, *Gadus morhua*, seems to be primarily associated with sudden aggressive behavior around three weeks prior to the first observed spawning act (Brawn, 1961). These sounds are comprised of short grunts with peak sound amplitudes at frequencies ranging from 50-500 Hz (Nordeide & Kjellsby, 1999, Engen & Folstad, 1999). By repeated and aggressive approaches accompanied by these low grunting sounds, a big male fish would establish itself in one part of the tank and as a result became the dominant fish in the tank. The other fish would form a shoal in one corner of the tanks. When ready to spawn the females would swim in the dominant fish´s territory which was the first and essential preliminary to spawning. The male would begin it´s flaunting display when it became aware of the female, sometimes approaching and sometimes withdrawing from the female. That flaunting would be accomplished by a low grunt sound which is suspected to excite the female. The female would then swim to the surface, followed by the male who would mount her dorsally before the final ventral mount which led to the immediate spawning of the female. The male also spawned during the ventral mount (Brawn,1961). Until now, proxy measures such as the length of the drumming muscle or its weight have usually been used to assess proxies for cod's fitness. Although other studies have identified general sounds produced when the cod is spawning, the new sound recording tags together with the HTI observation system will provide a much more details information on individual behavior during spawning. This individual identification is essential for the understanding of the role of sound in Atlantic cod spawning. As this study is the first test run of these DTS tags it was necessary to confirm that an individual tag would respond to only the sounds produced by the fish in which it was implanted.

Methods

Four data storage tags were surgically implanted in four cods in the MRi experimental research station in Grindavík on the 30th of July 2009 (Figure 1). The cods were then placed in a tank which was 3 meters in diameter and the water level was 0,8 meters deep. The tags were configured to sense any sound over 130 decibels. Every second the tags would register a binominal signal: 1 if a sound was sensed or a 0 if no sound was sensed.

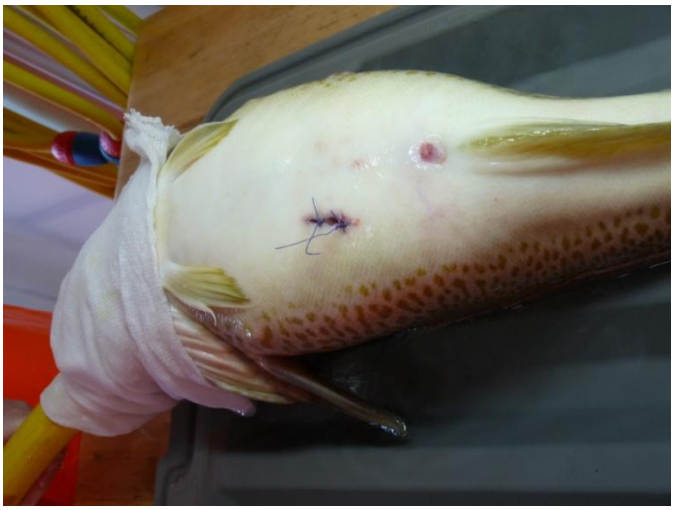

Figure 1: One of the study subjects showing the closed incision site where the DTS was surgically implanted into its abdominal cavity.

The tags were all set to a different sound level. A high sound level means that the tag is less sensitive to sounds. A tag with a high sound level would be less sensitive to sounds in the surroundings and thus more likely not to register them. Table 1 shows the sound level in each tag and the sex and the length of the 4 cods.

Table 1: The sound level with the sex and length of each fish in which the tags were implanted in.

Tag nr.	Sex	Length (cm)	Sound level
22	Female	75	82
23	Male	60	88
24	Female	80	84
25	Male	60	86

A Reson TC4013 hydrophone (RESON A/V, Denmark), which was connected to a computer, was placed in the tank so it would be possible to compare the data from the tags to an actual recording of the sounds in the tank. The program Audacity (http://audacity.sourceforge.net/)

was used for the recordings. The hydrophone, which is a piezo ceramic sensor, senses the sound which then was amplified with an EC6081 Reson VP200 Voltage preamplifier (RESON A/V, Denmark), which got its power from a Hewlett Packard E3611A dc Power Supply (HP, California USA). The sound signal was then imported to the computer.

A sound signal which was 4 seconds long was produced twice with a 15 minutes interval on the 7th of august as some time drift was expected in the DST tags. By doing that it would be possible to connect the data from the tags to the sound recordings as the sound signal should be registered on the tags as well as being audible in the recording. The sound signal (a 300 Hz sinus signal) was produced by a Thurlby TG210 2 MHz function generator (Thurlby Thander Instruments ltd., Huntingdon UK) which was then amplified by a Panasonic SA-CH11 amplifier (Panasonic, USA). The amplifier then sent the signal to a Electrovoice UW-30 underwater speaker (Electrovoice, Minnesota USA) which was situated in the tank.

The data was collected from the 31st of July to the 24th of August 2009. After that the tags were removed from the fish and their content downloaded onto a computer. The program PatternFinder was then used to read the data.

Results

Only the data from tags 22 and 24 were useable as the other two tags did not pick up the two four second signals from the Thurlby TG210 2MHz function generator. Because of that, it was impossible to connect the data from those tags to the sound recording. It was however possible to connect tags 22 and 24 to the sound recordings as both of them picked up the sound signals. Part of the results from tag 22 can be seen in table 2 and for tag 24 in table 3 in the appendix. Both the tables show only the time when the tags registered a sound as most of the time a zero value was registered when no sound was picked up.

Most of the sounds which the tags registered and were audible on the recording were difficult to identify. The column *Detected sound on recording* in tables 2 and 3 is meant to describe what kind of sounds was detected. Sometimes the sound was only visible on the audio track but not audible in the recording, possibly due to the loud background noise. Sometimes it was difficult to comment on what kind of sound was heard and the correct time on the recording was thus registered without a comment. If a sound was heard that could possibly have been a part of the background noise, the correct time on the recording was registered along with a

question mark. Many of the sounds were similar to cod grunts. They were however shorter than sounds produced by cods which have been described before, or about 50 ms instead of 300 ms.

As stated earlier, a sound signal was produced twice for 4 seconds each time. As can be seen in tables 2 and 3, the tags did not register the sound for the full 4 seconds. Tag 22 only registered sound signal II for 2 seconds and tag 24 for 3 seconds. That means that a 3 second difference is possible between the columns *Time on recording* in table 2 and 3 in the appendix. Some of the sounds registered on both the tags could thus possibly have been the same sound if they fall into the 3 second interval. Those possible instances when the two tags could have registered the same sound are listed in table 4 in the appendix.

Figure 2 shows a short segment from the audio track where two sounds audible in the recording are visible. Neither of the sounds was picked up by tag 24 and only the second sound was picked up by tag number 22.

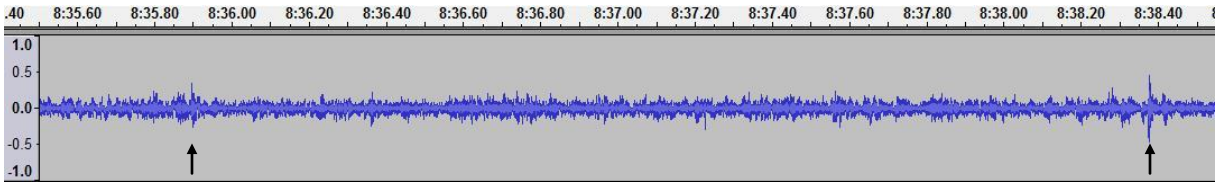

Figure 2: A short segment of the audio track showing two sounds audible in the recording (indicated by the two arrows).

Discussion

Tags 22 and 24 had the lowest sound level (table 1) and thus were more sensitive to the sounds which could explain why they picked up the sound signals I and II and not the other tags. As tag 22 was the most sensitive tag, set at the sound level 82, it doesn't come as a surprise that it registered 33 possible sounds when tag 24 registered only 24.

No audible sounds were though distinguished on the audio recording for a vast majority of the instances when the tags registered that a sound had been detected. It is however likely that the tags pick up vibration in the fish´s body, when they for example make a sudden move which explains the many empty registration and why they aren´t audible in the recording.

The two tags that did work were the ones implanted in the two females (table 1). As it has mostly been the males that have been known to make grunts it´s unfortunate that the tags in them did not work as hoped.

As this is the first time these tags are tested, it does not come as a surprise that some difficulties were faced working with the data from them. Table 4 shows possible instances when tags 22 and 24 would have registered the same sound on the period, but they are very few compared to all the other sounds detected. Video recordings could then also help to solve the few instances where it is uncertain what fish produced a particular sound. The background noise was also louder in the tanks in Grindavík than would have been preferred. That affected the recording greatly and made it difficult to identify sounds of interest. It will be essential to find a more suitable tank to minimize the background noise as much as possible in future experiments.

When table 2 and 3 are compared it is clear that the two tags are not always registering the same sounds. The sounds from the less sensitive tag (tag 24) are not registered on tag 22. If the tags would have been registering sounds from fish they were not situated in, it would have been expected to see a lot of the sounds picked up by tag 24 also picked up by tag number 22 as the latter tag was more sensitive. Figure 2 shows two clearly audible sounds from the recording which is clearly visible on the audio track. Only the second sound was however picked up by tag 22 and neither of the sounds was registered by tag 24. This also shows that the tags are not registering everything that is audible in the tank which implies that the tags are functioning as hoped as it was a possibility that they would all record all the sounds produced in the tank. That does indeed suggest that this technology can be useful thus making the Icelandic DST tags a new interesting tool in the research of fish sounds which has potentials of being applied in different studies on the topic.

Next steps

As stated before, the main experiment involving the recording of the spawning behavior had to be delayed because of the unforeseen technical difficulties with the tags. Following the fine tuning and evaluation of the tags performed last summer the next phase of the experiment will start either in the spring or the fall of 2010 depending on availability of suitable experimental tanks. A number of cods of both sexes will then be tagged and observed over the spawning season. An HTI behavioral observation system (http://www.htisonar.com/acoustic_tags.htm) will be placed in the tank to record, every second, all movements of the fish. If successful, the results are likely generate attention among fish behavioral scientists as this will be a first time that sound production and associated behavior will be recorded for individual cod while spawning.

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Egill Guðmundsson

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Guðrún Marteinsdóttir

Appendix

Table 2: The results from tag 22 compared to the sound recording from 14:50-16:00 on the 7th of August 2009. X means that no sound was audible on the recording at that given time.

Tag time	**Time on recording (+/- 2 seconds)**	**Detected sound on recording**
14:47:14		Signal I
14:47:15		Signal I
14:47:16		Signal I
14:47:17		Signal I
15:02:08		Signal II
15:02:09		Signal II
15:08:05	6:07	Visible on the audio track
15:08:46	6:48	(6:50?)
15:10:35	8:37	(8:38?)
15:11:42	9:44	?
15:11:43	9:45	X
15:11:44	9:46	X
15:11:46	9:48	X
15:12:02	10:04	(10:05)
15:22:19	20:21	X
15:22:22	20:24	X
15:22:37	20:39	X
15:22:49	20:51	X
15:36:56	34:58	Faint cod sound?(34:59)
15:37:44	35:46	X
15:37:47	35:49	X
15:37:48	35:50	X
15:37:49	35:51	X
15:42:19	40:21	X
15:43:15	41:17	X
15:44:24	42:26	Visible on the audio track (42:25)
15:44:25	42:27	Repeated tik tak(*)

		(42:21 – 42:30)
15:44:33	42:35	X
15:46:20	44:22	X
15:48:25	46:27	X
15:49:15	47:17	?
15:51:38	49:40	Cod sound?
15:49:48	57:50	X

(*) This sound was noticed regularly on the recording and is not caused by the fish. It always lasted around 9 seconds and was not picked up by the tags. Here it just happens to occur at the same time when the tag picked some sounds

Table 3: The results from tag 24 compared to the sound recordings from 14:50 to 16:00 on the 7th of August 2009. X means that no sound was audible in the recording at that given time.

Tag time	**Time on recording (+/- 1 second)**	**Detected sound on recording**
14:42:20		Sound signal I
14:42:21		Sound signal I
14:57:55	1:09	Sound signal II
14:57:56	1:10	Sound signal II
14:57:57	1:11	Sound signal II
15:04:45	7:59	(7:56-58?)
15:04:48	8:02	Cod sound?
14:08:49	12:03	Cod sound?
15:10:53	14:07	X
15:11:01	14:15	Cod sound 14:14?
15:17:44	20:58	20:57?
15:20:47	24:01	24:00?
15:21:04	24:18	Short cod sound? 24:17
15:33:34	36:48	Some knocking sound 36:47
15:35:42	38:56	X
15:37:12	40:26	Cod sound? 40:25
15:37:30	40:44	X
15:37:33	40:47	X
15:38:00	41:14	X

15:38:06	41:20	X
15:40:54	44:08	44:09
15:43:15	46:29	X
15:47:34	50:48	X
15:47:46	51:00	X

Table 4: Possible instances when the two tags would have registered the same sound in the time period 14:40 – 16:00 on the 7th of August 2009

Tag 22	**Tag 24**
41:17	41:14
41:17	41:20
46:27	46:29

Reference

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