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The behavioral effects of boat noise on fish populations in Oneida Lake, NY

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ABSTRACT

The impacts of boat noise on various fish species have gained an increasing amount of attention in the scientific community. The objective of this experiment was to determine the behavioral effects of boat noise on fish populations in Oneida Lake. A second objective was to analyze the frequency and audibility of boat noise and compare normal conditions to those during a bass tournament. An underwater camera was used to capture fish behavior and a hydrophone was used to simultaneously record boat noise at the Oneida Lake Shore Park boat launch. A 1–sided paired test determined no significant increase in the number of fish present ($p=0.107$), the number of swimming fish ($p=0.097$), and the number of stationary fish ($p=0.312$) between periods of no boat noise and periods of boat noise. A 1-sided t-test found no significant increase in the number of boats ($p=0.212$) or in the audibility ($p=0.402$) or presence ($p=0.498$) of boats during the bass tournament. These results could imply that these fish have habituated to boat noise or are minimally affected due to low hearing sensitivity. Due to the potential to alter ecosystem functioning, it is important to determine how anthropogenic disturbances such as boat noise can impact the biology of fish populations and to monitor increases in noise pollution over time.

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Glossary of Terms

<u>Auditory threshold</u>: the limit of discriminating sound intensity and pitch

<u>Bioacoustics</u>: the branch of acoustics concerned with sounds produced by or affecting living organisms, especially as relating to communication

<u>Masking</u>: interference of sound caused by the presence of another sound

<u>Noise pollution</u>: harmful or unwanted levels of noise, as from airplanes, industry, etc.

<u>Weberian ossicles</u>: modified vertebrae around the ear that enable sound waves impacting the swim bladder to be carried directly to the ear, allowing for sensitive hearing (wide-frequency range and relatively low thresholds)

Acknowledgements

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Advice to Future Honors Students

- Begin early: Having enough time is the biggest challenge you will face, the more you allow yourself, the easier it will be to design an effective project.
- Stay focused: Give yourself deadlines to keep yourself on track.
- Pick a topic that you are passionate about: You will be dedicating a lot of time and effort into your project so make sure it is something that you are interested in and will care about finishing.

INTRODUCTION

In recent years, conservation has taken a new look at noise pollution as a potential threat to the health of ecosystems. More specifically, the effects of anthropogenic noise from boat traffic have become a large focus in aquatic environments. Studying the effects of boat noise is particularly important since boat traffic on lakes and oceans has risen dramatically in recent years and is continuing to do so (Sebastianutto et al. 2011). Therefore, it is necessary to take into consideration the impact that this increase will inevitably have on the native biota.

Previous studies have looked at the variable significance of boat noise on populations of marine mammals and fish species. There are three primary consequences of noise pollution: masking, decreasing auditory sensitivity, and creating stressful conditions (Graham & Cooke 2008; Vasconcelos et al. 2007; Wysocki et al. 2005; & Sebastianutto et al. 2011). These situations can then cause a number of complicated and undesirable effects in the behavior and/or physiological conditions of aquatic species.

Masking is when a sound produced from one source eclipses the sound produced from another source of similar frequency, often by having greater amplitude. This creates problems for species that communicate bioacoustically or use sound to detect predators or prey. For instance, species such as the goby that use sound to communicate with conspecifics during spawning may be less likely to attract a mate if their vocalizations are masked by ship noise. One study showed that vocalizations in male *Gobius cruentatus* primarily used to ward off other males were less effective because they were masked by the noise disturbance. This caused a decrease in their overall aggressiveness and territoriality towards other males during spawning which can negatively impact reproductive success (Sebastianutto et al. 2011). Another response to masking that is documented in marine mammals such as the right whale, but yet to be studied in fish species, is changing the frequency, amplitude, duration, or timing of vocalizations to compensate for ambient noise pollution (Parks et al. 2010).

Inter- and intra- species communication can also be affected by a decrease in auditory sensitivity which can be the result of overexposure to noise pollution. This was found in a previous laboratory experiment which tested the hearing capability of the Lusitanian toadfish after exposure to recordings of boat noise. With impaired hearing, individuals may not properly receive an acoustic signal, losing some or all of the encoded information. Reduced hearing for vocalizing species can have reproductive and evolutionary implications by inhibiting an individual's ability to attract a mate or to avoid dangerous predators/environments (Vasconcelos et al. 2007).

The stress associated with noise pollution can also have behavioral and physiological complications. Loud and foreign sounds can often be startling for many aquatic species. Noise from boat traffic can create startle responses in fish that can be seen in their reactive behavior. Bluefin tuna were found to show startle responses to boat noise by maintaining less structured schools and swimming upwards, which is typically a response to predators (Sara et al. 2007). Evidence that fish are stressed by boat noise is also supported in a study done by Graham & Cooke (2008) that showed increased heart rate in largemouth bass after exposure to boat noise. Similarly, perch, carp, and gudgeon, were shown to secrete higher levels of cortisone during playbacks of boat noise than standard ambient noise (Wysocki et al. 2005).

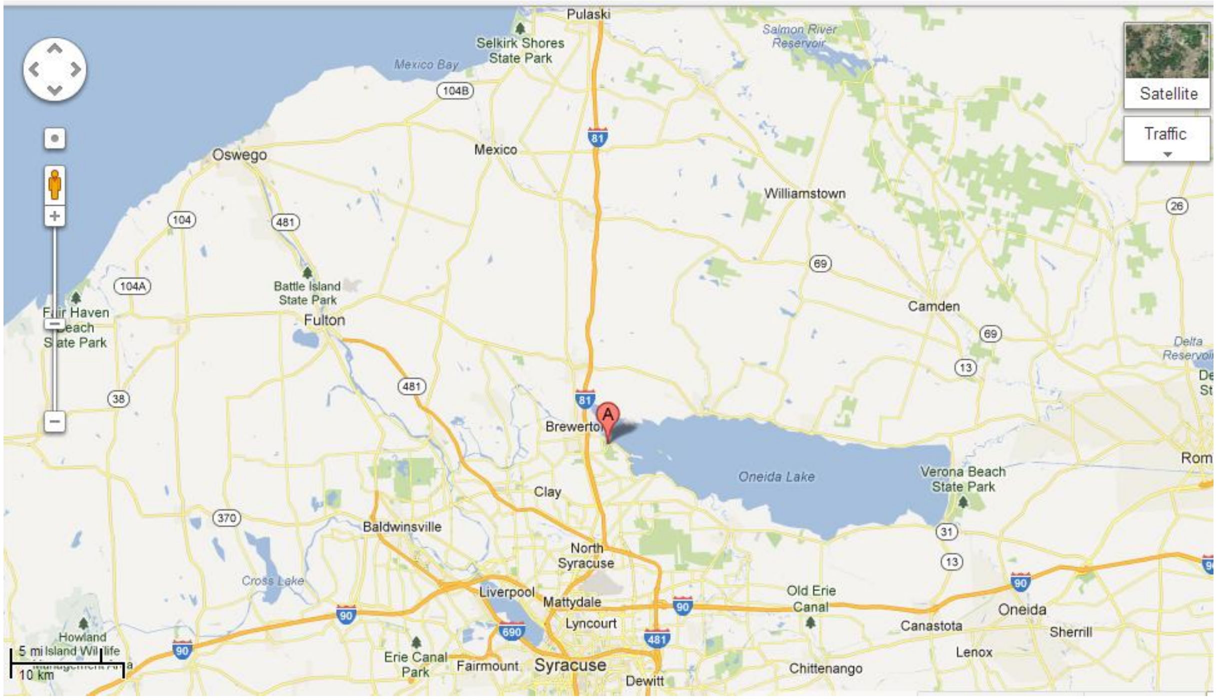
The purpose of this study is to determine the potential behavioral effects of boat noise on fish populations in Oneida Lake. This will give insight into the reactions of different fish species to boat traffic. Previous studies testing the effects of boat noise on the behavior of fish have focused on laboratory setups using playbacks or field experiments in which the test fish are physically restrained. This experiment is designed to observe reactions to boat noise in a completely natural setting. The objectives are as follows: 1) to look at changes in fish behavior as well as the presence of fish between standard periods of no boat noise, followed by boat noise – H0: there is no significant difference in fish behavior or fish presence between these two periods; 2) to determine if fishing tournaments create significantly noisier conditions for fish than in normal conditions – H0: there is no significant increase in the audibility, presence, or number of boats during the fishing tournament versus normal conditions.

METHODS

Study Site

This study was conducted at Oneida Lake Shores Park (Fig. 1). Research focused on the boat launch dock where there is high volume of boat traffic coming in and out of the dock, in addition boats frequently passing by. It contains a paved launch in which multiple boats of all sizes and types may be launched simultaneously – increasing the amount of boat traffic entering and leaving the area at any given time (Fig. 2). Since the boat launch is part of a park with campgrounds and a public beach, it attracts a large amount of people to the area, many of whom have their own boats to take out every day. To the right of the four docks is an area of water enclosed by the dock and a jetty of rocks, creating a circular area closed off on three sides (Fig. 3). This was the area of primary focus – it was a naturally contained area, was directly adjacent to the dock area and likely had high fish presence in the shallower areas.

Figure 1. Map of Oneida Lake Shores Park.



maps.google.com

Figure 2. View of boat launch docks.

Figure 3. View of study area

Figure 4. View of buoys.

Point A Point B

Data Collection

To collect boat noise, a HTI-96-min hydrophone was used to record underwater sounds. The sensitivity of the hydrophone range was -16 dB re: 1V µPa, with a flat frequency response from 20 Hz – 20 kHz. To record fish behavior a black-and-white underwater camera (Marcum VS385) was used. The camera and the hydrophone were placed next to each other facing the open area adjacent to the dock, and were in the same position for every recording session. NCH software (Debut Video Capture Software – standard edition) was used to capture video and audio from the hydrophone and the camera into a single .avi files. The underwater camera comes with a monitor that allows real time viewing of underwater activity. The average depth in the area where the hydrophone and camera were stationed was 0.6 meters.

While recording video and audio, extensive notes were also taken on area boat traffic (see appendix for template of data sheet). Two buoys were chosen as point A and point B to mark the beginning and the end of the study area. Facing the lake, point A was located 74 meters away to the left of the dock, while point B was 32 meters away to the right, directly behind the tip of the rock jetty (Fig. 4). Data was only taken on boats that were in this area. A range finder (Bushnell Yardage Pro Sport 450) was used to calculate the distances of the buoys. A stopwatch was used to record the time (mm:ss) when a boat would enter the study area and when it would leave, as well was the direction it traveled (left, right, circling, or sitting). A note was also made if a boat was entering or leaving the dock and the range finder was used to calculate its distance at the midway point. Photographs were also taken of passing boats for later classification of type.

Data collection began on August 13, 2012 and ended on September 7, 2012. There were a total nine days spent in the field at this site. Data was collected for an hour each day starting around 1700hrs. A log of weather conditions was kept for each day to record: percent cloud cover, humidity, temperature, and wind speed and direction using a Kestrel 4000 weather meter. A secchi disk and a water thermometer were used to measure water clarity, depth, and temperature.

Data Analysis

Boat Noise

During four out of the nine days in the field a bass tournament was being held at Oneida Lake Shores Park. This meant there was an increase in the number of boats at the dock area. To determine if there was a significant increase in boat traffic during the bass tournament days versus the other days, two 1-sided t-tests were used to compare the total number of boats present in the study area, as well as the percentages of time in which at least one boat was present during the study period. Both were calculated from notes on boat presence in the study area.

Another 1-sided t-test was used to determine any significant difference in the percentages of boats within hearing range of the hydrophone. Hearing range was checked by testing for the audibility of boats at various distances. For instance, it was determined that all boats further than 200 yards out were not loud enough to be considered in the study area. (An alpha level of 0.05 was used for all three t-tests.)

Fish Behavior

During analysis, the videos were screened to look for presence of fish. When a fish was captured on the camera, the time it was first spotted was noted, as well as the duration of the time it was visible in the film. The fish was identified to species and its behavior was noted in specific detail: swimming (fast/slow; up/down/horizontal), or sitting. A fish was labeled with a certain behavior if it was in that behavior category for at least 75% of the time it was visible. Any startle reactions were also noted. A startle reaction is defined by Picciulin et al. 2010 as "a powerful flexation of the body followed by a few seconds of faster swimming." As per Sara et al. 2007, a fish was considered to exhibit a startle response if it swam upwards or if it quickly moved from stationary to swimming mode.

Once the data on fish presence and behavior was compiled, the audio was transcribed from the videos into Raven Pro 1.5 to produce a visual spectrogram of the sounds heard underwater. This allowed easy filtering of target times in which boat noise was present at various intensities. To look at the changes in fish behavior in the presence of boat noise, a comparison was made between a 1-minute block of no boat noise (control), and a 1-minute block of boat noise immediately following (experimental). It was hypothesized that there would be a greater number of total fish and swimming fish, and a lesser number of stationary fish during exposure to boat noise.

Three separate 1-sided paired t-tests were used to compare the number of total fish present, the total number of fish swimming, and the total number of fish that remained stationary during the control period (no noise) versus the experimental period (boat noise). There were a total of thirty-eight samples and alpha level of 0.05 was used for all three tests.

RESULTS

Boat Noise

There was a noticeable amount of boat traffic going in and out of the dock area, as well as passing through the study area during the one hour study period. The mean number of different boats present was 49 for all nine days. The mean number for days during the bass tournament was 58 boats, while the mean for normal days was 41.8 boats (Fig. 5). September 1st had the greatest number of boats (86) and was not a bass tournament date. The second and third greatest numbers of boats did fall on bass tournament dates, however, with 84 and 83 boats. The two fewest numbers of boats were seen on non-tournament dates, with 13 and 25 boats.

The mean percent of time boat noise was present for all nine days was 57.59% (Fig. 6). The means for non-tournament dates and tournament dates were essentially the same and also similar to the collective mean: 57.56% and 57.63%, respectively. For five out of the nine days, boats were present for over half of the duration of the study period. The date with the greatest boat traffic (87%) was August 16th, which was not during the bass tournament.

Figure 7 shows the percentage of boats that were either in or passing the study area and that were audible from the hydrophone for each day of data collection. On average, about a third of the boats in the study area were loud enough to be heard from the hydrophone (mean = 32.3%). Only one of the dates (August 24th – during the bass tournament) showed a percentage of higher than 50 percent. Audibility fell between 30 and 40 percent for seven out of the nine days.

There was no significant increase in the total number of boats ($p = 0.212$), the percent of time boats were present ($p = 0.498$), or in the audibility of boats ($p = 0.402$) during the bass tournament compared to normal conditions on the lake.

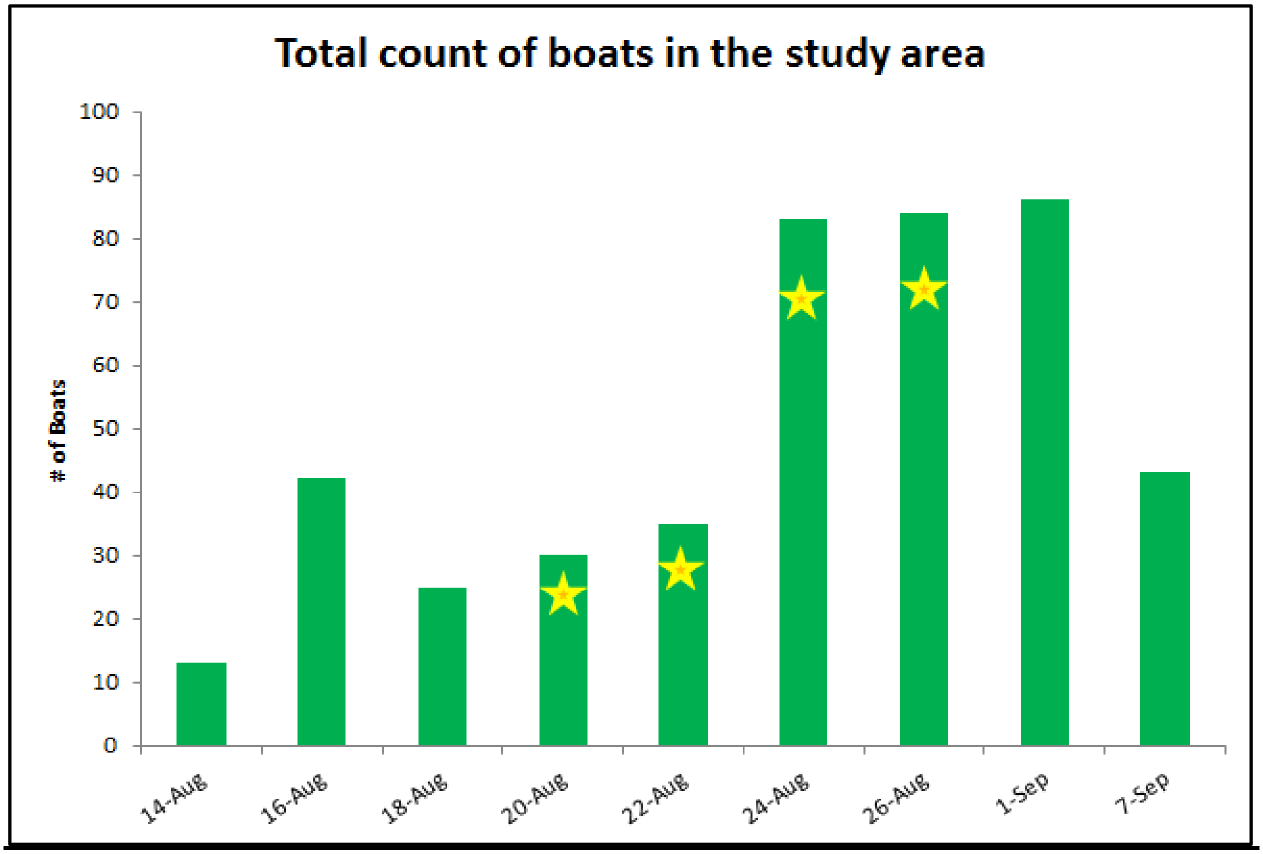


Figure 5. Total counts of boats in study area. (Those marked with a star denote bass tournament dates.)

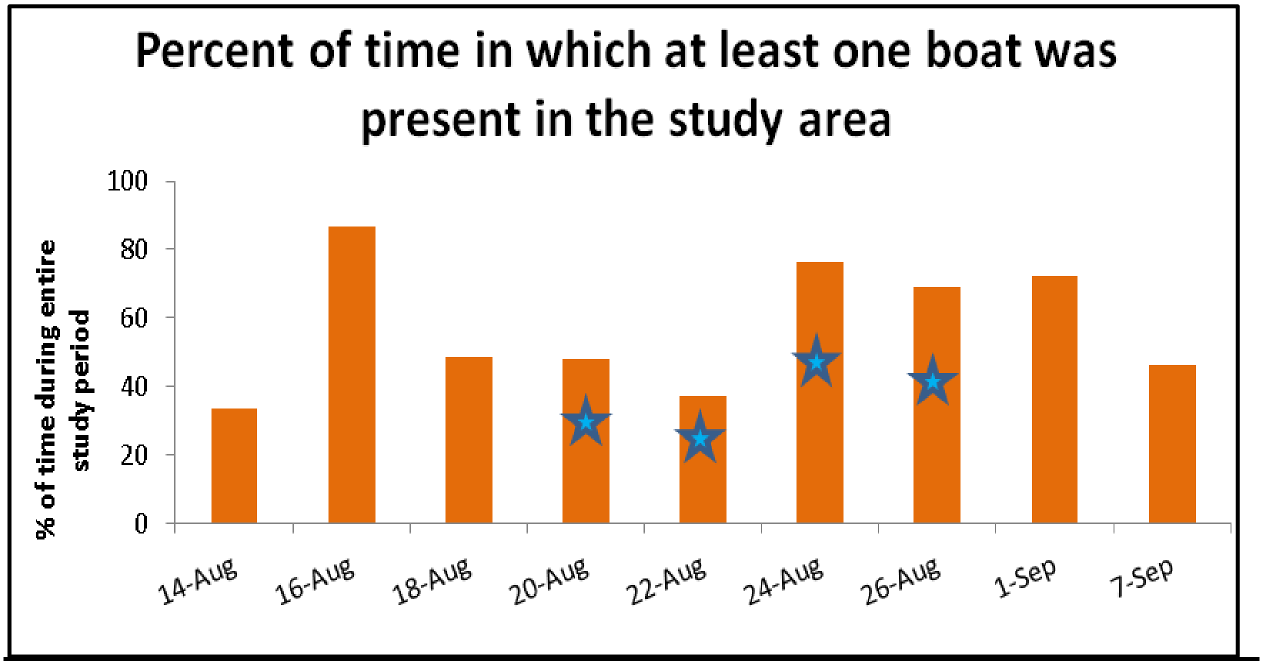


Figure 6. Percent of time in which at least one boat was present in the study area. (Those marked with a star denote bass tournament dates.)

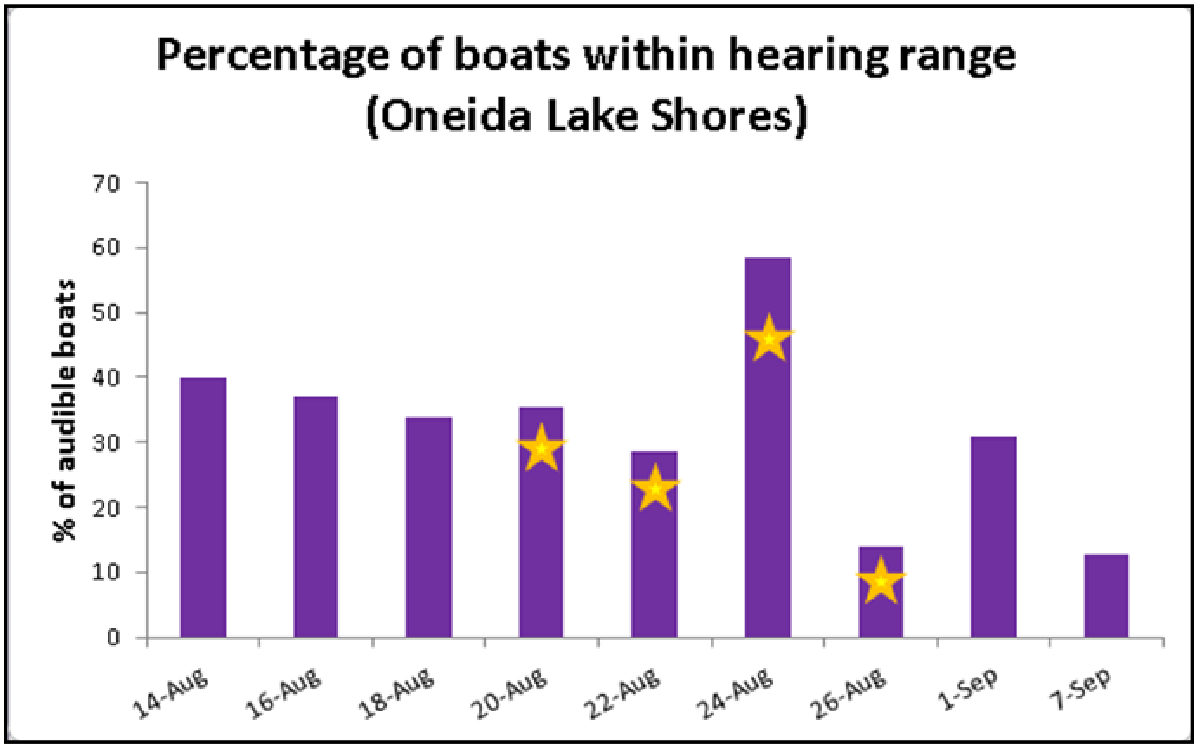


Figure 7. Percentage of boats within hearing range of the hydrophone. (Those marked with a star denote bass tournament dates.)

Fish Behavior

During the onset of boat noise (or during a noticeable increase in amplitude), several fish showed a startled response in which their behavior suddenly and quickly changed from stationary to swimming. In Figure 8, a smallmouth bass demonstrates this behavior by changing from a stationary position (during low noise) to turning and swimming upwards (during an obvious increase in boat noise intensity). This is just one example – the purpose of this experiment was to determine if this is true for most of the fish observed during this study (i.e. if they showed behavioral changes in relation to the presence of boat noise).

Results from three 1-sided paired t-tests all showed no significant difference between the number of fish present ($p = 0.107$), swimming ($p = 0.097$), and stationary ($p = 0.312$) the in different intervals of no noise versus boat noise. The greatest number of total fish and swimming fish occurred during intervals of boat noise (Fig. 9). The fewest fish were seen stationary during boat noise (Table 1). The large variation shown in the graph is due to a couple intervals that contained large schools of fish.

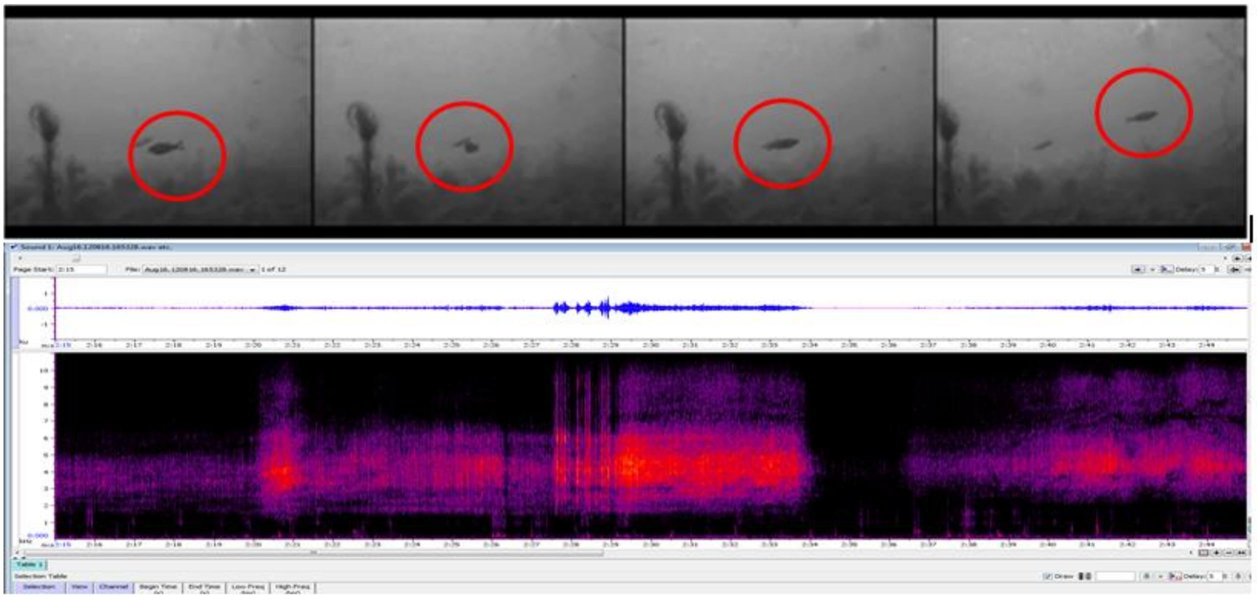


Figure 8. Example of a startled reaction of smallmouth bass to the onset of boat noise. (Spectrogram beneath gives a visual of boat noise presence and intensity at the time.)

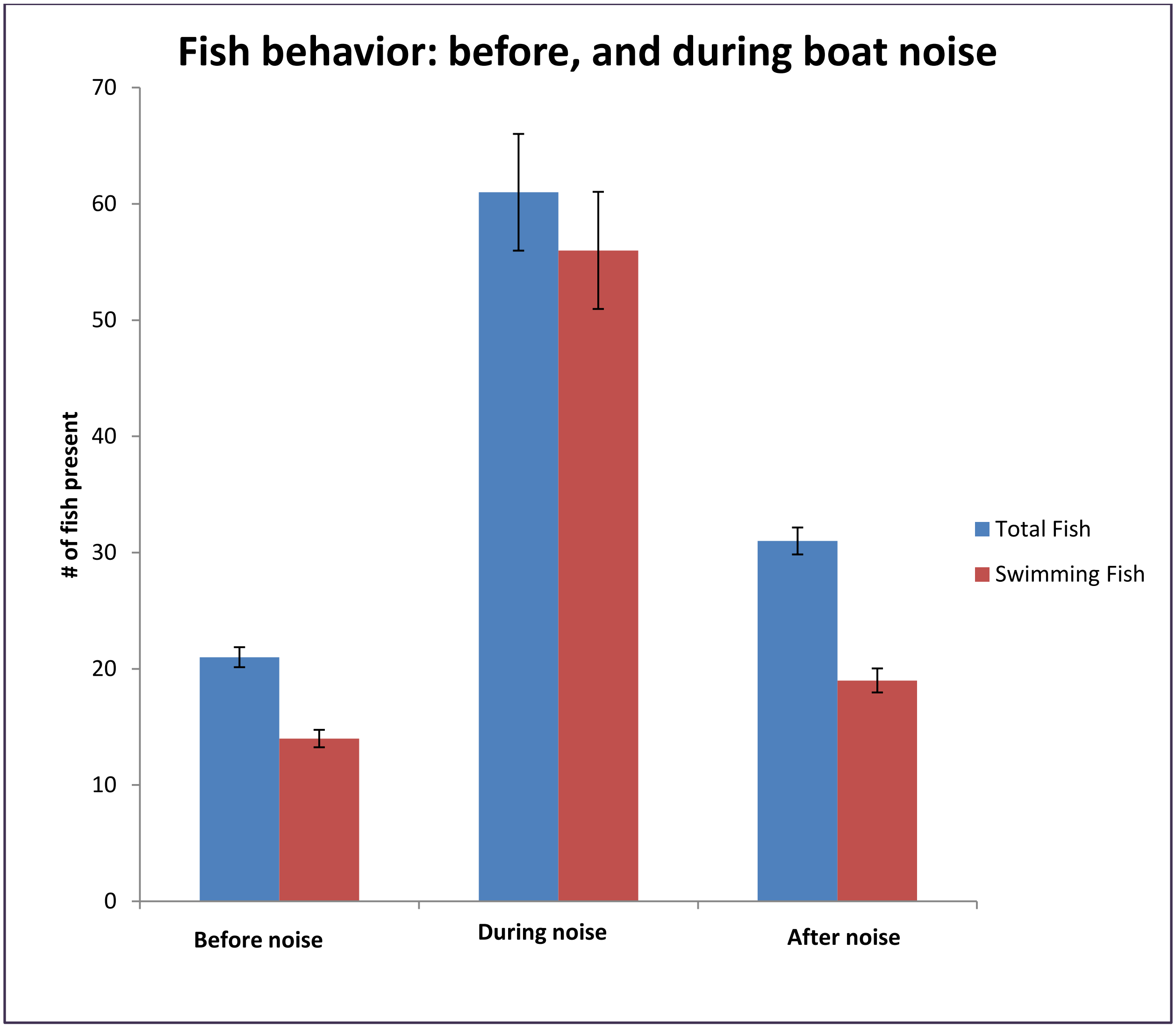


Figure 9. Fish behavior: before and during boat noise. (Bars represent standard deviation.)

Table 1. Mean values for the number of fish present during each interval.

	Before Boat Noise	**During Boat Noise**
Swimming	0.37	1.47
Stationary	0.18	0.13
TOTAL Fish	0.55	1.61

DISCUSSION

Although the results of this study were not statistically significant, there is a lot to gain from the information available. The null hypothesis stating that there was no significant difference in changes in the total number of fish, the number of swimming fish, and the number of stationary fish before and during boat noise failed to be rejected. However, when looking at the averages, though they are not statistically different, there seems to be a trend in behavior. There are more swimming fish as well as a higher number of fish present during intervals of boat noise versus before. Parallel to this data, the fewest stationary fish were seen during boat noise.

One possible explanation for this trend is that boat noise elicits startle responses in fish. If a fish is startled it will usually go from a stationary position to swimming mode (Sara et al., 2007). Therefore, a startle response could cause an increase in both the total number of fish and the number of swimming fish captured in the video at the onset of boat noise. In comparison, during times of no noise there would be no noise-induced startle responses (i.e. no other obvious external factor that could have startled the fish, such as the presence of another fish) and fish would be more likely to settle back down and become more stationary, possibly also causing a reduction in the number of fish visible.

There were several instances of obvious startle responses to noise in which the fish reacts abruptly at the onset of boat noise or when it was greatly intensified. It is probable then that these behavioral responses are not a coincidence. Moreover, Picciulin et al. (2010) mentions in their study that "temporary cessation of activities" may also be behavioral response to boat traffic. It is therefore possible that some of the stationary fish seen during the boat noise may have actually been exhibiting a reaction. If that is indeed a reaction, then the behavioral effects on fish in this study may be underestimated.

Another interesting detail to note on the behavior of the fish during periods of boat noise is the presence of schooling behavior. The only times that fish were present in large groups, or schools, were during periods of boat noise or immediately after noise. A group of fifteen unidentifiable fish and a group of twenty-eight small mouth bass were seen swimming in a school during intervals of boat noise. A group of six fish were seen swimming in the post-noise period. Fish often form schools as a part of the avoidance hypothesis - e.g. to protect themselves against predators (Grobis et al., 2013). These fish may then have grouped together because they perceived the boat noise as a threat.

An explanation for the lack of significant results to support the idea that these fish populations are behaviorally affected by boat noise is that they have become habituated to it (Codarin et. al., 2009). After a certain time of constant exposure, the fish may no longer be startled and therefore cause a decrease in the amount of startle reactions observed. Once it is detected that there is no obvious threat or direct/immediate negative consequence, fish may adapt to the noise - especially in the area near the boat dock at Oneida Lake Shores Park, where noise from boat traffic is a daily occurrence. However, just because these fish that are commonly found in the shallow dock area may be adapted to such conditions, does not necessarily mean that fish found in other areas of the lake are also habituated to the noise. A large percentage of the fish found in shallow areas (e.g. dock areas) are likely to be juvenile or first-year cohorts with auditory thresholds that are not yet fully developed so they may be less affected by boat sounds (Wysocki & Ladich, 2001).

The most common fish seen in this study were smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), and yellow perch (*Perca flavescens*). Looking into the bioacoustics ecology of these fishes can help explain why there was no significant change in fish behavior in the presence of boat noise. These species have low auditory sensitivity, and the noise from the boats do not have the same effects as they would for other fish species or aquatic biota. Some fish are considered to be hearing specialists (they have higher sensitivity) while the rest are hearing generalists and are less affected by ambient noise and are only able to detect low-frequency sounds (Smith et al., 2004; Wysocki & Ladich, 2001). Fish with Weberian ossicles are more likely to have sensitive hearing, meaning they can hear a wider range of frequencies and have a lower auditory threshold. This is only found in otophysine fishes, not including bass or perch, which is why these species are not able to hear as well and therefore may be less affected by boat noise (Ladich 2012). Alternatively, the constant exposure to boat noise could have lowered these populations' auditory threshold, and therefore caused them to become more "deaf" to the noise pollution, as Scholik & Yan (2002) found in their study on shifts in the auditory threshold of fathead minnow after exposure to noise.

Although the p-values for these statistical tests were not significant for the total number of fish and for the number of swimming fish, they were relatively close to 0.05 (0.107 and 0.097, respectively). With continued experiments demonstrating a greater number of samples and possibly larger comparison intervals of control and experimental noise, a significant impact on the behavior of fish due to boat noise may become more obvious.

It is difficult to make assumptions based on these boat noise data. By stating that there is no significant increase in the boat traffic from the bass tournament or in the audibility of those boats, one could formulate hypotheses in opposing directions. For instance, one could conclude that this implies that Oneida Lake Shores Park has such high boat traffic that it is equivalent to the boat traffic seen during a nationwide bass tournament. On the other hand, one could also conclude that bass tournaments do not exhibit such an increase in boat traffic compared to normal days as one would think. One important thing to note as well is that even though September 1st was not one of the dates for the bass tournament, it did fall on Labor Day weekend. This is likely the cause of such a high flow of boat traffic, and may be considered an outlier to normal boat traffic at the lake. Either way, the boat traffic at Oneida Lake Shores Park was not negligible; there was hardly a few minutes would go by without a single boat to record data on.

Comparing the data between the number of boats present and the amount of time at least one boat was present shows that they seem to follow the same pattern. However, greater numbers of boats does not necessarily mean that there will be a greater percentage of time in which boat noise is present or audible. At the very least, this data could act as a foundation for monitoring boat traffic and its audibility on Oneida Lake. This is important too, as recreational boat traffic continues to increase (Slabbekoorn et. al., 2010) and it will become useful to keep track of this kind of data.

CONCLUSION

The results of this study illuminate the need for continued research in this field. Bioacoustics is a growing division in the world of science and noise pollution is a growing result of increased human activity and development (Slabbekoorn et. al., 2010). Underwater noise can travel kilometers before it completely dissipates, so it has the potential to profoundly influence life underwater (Scholik & Yan, 2002). It is important to determine the auditory sensitivities of various fish populations across different water bodies to understand how boat noise may affect them. Studying the behavior of these organisms can give a more direct and initial look into their reactions to noise pollution. Gaining new insights into bioacoustics and developing continued research on the effects of noise pollution will help create a more conscientious human population and healthier ecosystems.

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APPENDIX: Sample of data collection sheet

Date	Location	Time Start	Time End	Water Clarity (m)	Cloud Cover (%)	Temp (°C)	Wind Speed (mph) & Direction	Water Temp (°C)	**Distance to Point A**	**Distance to Point B**	**Summary? (Y/N)**

Fish Observations			**Boat Observations**								
Fish Species present (* if react)	# of individuals present for each species	# of individuals that react	Boat #	Time Passed Point A/B	Time Passed Point B/A	**Type** of Boat	**Direction** of Travel (L/R) - circling?	Photo? (Y/N)	**Distance** (m)	Boat Coming Into Dock?	**Comments**