Feeding Behavior of Striped Bass, *Morone saxatilis*, in Magnetic Fields

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Question

Do static magnetic fields affect the feeding behavior of striped bass, *Morone saxatilis,* in their natural habitat?

Background

Many animal species have been found to respond to the Earth's magnetic field. Cows align their bodies northward when grazing, dogs point north or south when urinating, and even when caged birds will orient toward the direction which they wish to migrate as first seen in 1966 by Wolfgang Wiltschko at the University of Frankfurt (Begall et al., 2013; Nordmann et al., 2017). Animals that undergo long distance migration such as fish, birds, and insects are most cited for the use of magnetoreception as a navigational tool, but recently several less adventurous species have been identified as using magnetoreception as well, including lobsters, worms, snails, frogs, newts, and small mammals including wood mice and mole rats (Tyson, 2003; Mouritsen, 2018).

Many animals use magnetoreception to supplement their sense of direction, but "the mechanisms by which animals sense the geomagnetic field remains one of the most fundamentally important questions of sensory biology" (Mouritsen, 2018). One predominant hypothesis (see Hore and Mouritsen, 2016 and Mouritsen, 2018 for other hypotheses) involves the presence of magnetic particles or magnetite within cells that might act as a compass needle (Nordmann et al., 2017). For example, rainbow trout have been shown to have 10-50 highly magnetic cells containing magnetite in their olfactory epithelium, which most likely are important in trout migration (Eder et al., 2012).

Adult striped bass, *Morone saxatilis*, undergo a spawning migration where they travel from salt to fresh water (anadromous) to reproduce in the spring. The majority of fish breed in the Chesapeake Bay and the Delaware and Hudson Rivers. The fish then move back into salt water and begin a coastal migration of over 700 miles in a northerly direction. In the fall the fish reverse their course and travel south off of the Carolinas (http://www.vims.edu/research/departments/fisheries/programs/striped_bass_assessment_program/life_history/index.php). Due to the long distances that these fish migrate, they may use magnetoreception as one of their navigational tools. However, striped bass have not been studied to determine whether magnetism affects their behavior.

This study focuses on whether striped bass are affected by static magnetic fields during feeding. If striped bass have magnetic sense, I reasoned that the magnets might inhibit or delay the feeding when compared to controls.

Figure 1 Left: Wall behind the Marine Resources Center at the Marine Biological Laboratory where experiments were conducted. Right: view from the wall of the population of striped bass used in this study.

The study was conducted behind the Marine Resources Center at the Marine Biological Laboratory (MBL) in Woods Hole where a population of about 28 striped bass dwell in the shallow waters, as seen in Figure 1. These fish are fed regularly with leftover squid from various experiments being conducted by scientists at the MBL, and are thus accustomed to dwelling near the wall and feeding on squid scraps thrown to them. The fish usually stay 10-20 feet away from the wall, especially during low tide, possibly to remain hidden and better protected from avian predators. However, during feeding, they will swim right up to the wall to retrieve a piece of squid. There is moderate foot traffic in this region throughout the day so the fish are accustomed to seeing people, and squid are thrown out multiple times per day, even during a set of trials on two separate occasions.

Hypothesis

Striped bass feeding is affected by a localized, static magnetic field.

Variables

i. Independent: Presence of magnet, strength of magnet
ii. Dependent: Time taken to eat bait
iii. Control: Rocks instead of magnets are placed in a bait box and covered with tin foil.

Materials

The following items were assembled:

General

bucket of chopped squid (8-10 small squid chopped into one inch pieces); fishing rod and 80lb test line (reel not necessary); paper and pencil; stopwatch

Magnets

Magnet 1: 350lbs pulling force Neodymium Magnet, 2.3inch diameter
Magnet 2: 1146lbs pulling force N52 Round Neodymium Magnet, 4.72inch diameter

Materials for bait boxes

1. bucket of golf ball to tennis ball-sized rocks (for control and weight balancing)
2. 4 lure clips
3. 3 bait clips (orange clip in picture)
4. 3 tupperware-type containers (must have strong lids that don't come off easily)
5. drill and ⅛-¼" drill bit
6. tin foil to wrap magnets and rocks so that fish can not distinguish between the two.

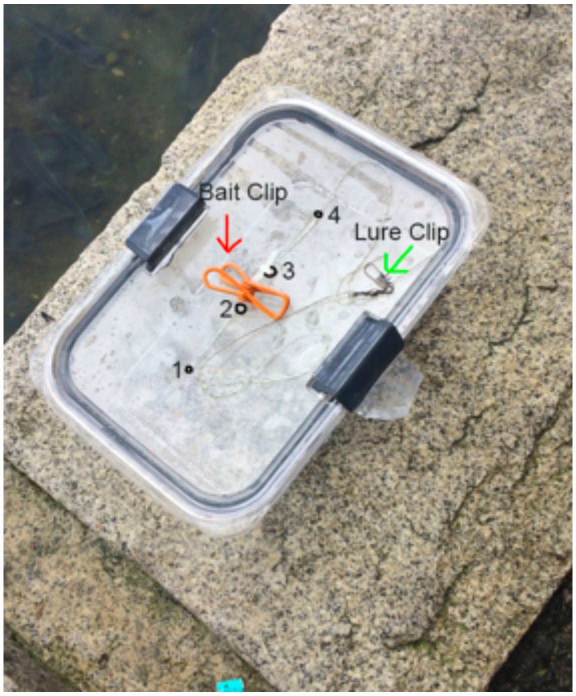


Figure 2. One of the "bait boxes" used in the study. Magnets or rocks (control) were covered with tin foil and placed in the box. Bait was placed on top of the box in the bait clip. The box was lowered into the water by attaching fishing line to the lure clip.

<u>Preparation:</u>

1. Drill 4 holes into each bait box container as seen (marked 1-4 on Figure 2).
2. Thread a zip tie through the two middle holes and through a bait clip, securing the bait clip on top of the container in the middle with the clip facing perpendicular to the holes (indicated with red arrow).
3. Thread 2 feet of fishing line through the two outer holes with the ends outside the container, then securely tie the fishing line to a swivel clip (indicated with green arrow).
4. Inside control container1 place an amount of rocks equal in weight to magnet2 (bigger magnet). Wrap the rocks in tin foil so they are not visible. Place the rocks and tin foil in container1. This is the control.
5. Inside container2 place magnet1 and enough rocks for the weight of the rocks and the magnet together to equal that of magnet2. Place magnet1 on packing foam so that it presses against the top of the container through the tin foil when the container is closed. Then wrap magnet1, the foam, and the rocks in tin foil so they are not visible, and place it all in container2. The objective is to have the magnet as close to the bait as possible.
6. Inside container3 place magnet2 on top of packing foam so that it presses against the top of the container when the container is closed. Wrap the magnet and foam in tin foil so they are not visible, and place it all in container3.
7. Each container should now have a bait clip and fishing line tied to a swivel clip, both exposed on the outside of the container. On the inside should either be rocks in tin foil, magnet1, foam, and rocks in tin foil, or magnet2 and foam in tin foil.
8. Fill each container with water so it does not float when placed in water.
9. Double up the fishing line and tie 10 feet (20 feet total) to the end of the fishing rod. On the other end of the fishing line secure a swivel clip.

Pretrials:

1. Using just the control container containing rocks, place a piece of squid in the bait clip.
2. Attach the swivel clip on the container to the swivel clip on the end of fishing line attached to a fishing rod.
3. Slowly lower the container into the water and allow it to sink to the bottom. It should be lowered from the same spot for each trial, and about the same distance away from the wall. Start the timer when the bait becomes submerged, not when the container reaches the bottom.
4. Observe the behavior of the fish while the container is in the water. Observe how they approach the container and how they take the bait.
5. Stop the timer once the bait has been eaten.
6. Bring the container back up.
7. Repeat 6-10 times, or until you have a good idea of how the fish react to taking bait from a clip on top of a container.

Trials:

1. Randomly choose a container to place into the water (or ideally, have a partner randomly choose).
2. Place a piece of squid in the bait clip.
3. Attach the lure clip on the container to the lure clip on the end of fishing line.
4. Slowly lower the container into the water and allow it to sink to the bottom. It should be lowered from the same spot for each trial, and about the same distance away from the wall. Start the timer when the bait becomes submerged, not when the container reaches the bottom.
5. Stop the timer once the bait has been eaten. Record results.
6. Bring the container back up.
7. Repeat steps 1-6 until each container has 10 trials (30 trials total).
8. The above procedure should be repeated on at least two different days. If more than 30 trials are performed in one day, the fish may become satiated, which could influence results.

Results

Striped bass were exposed to bait boxes over three days to acclimate them to eating from the containers. Ten pretrials were done on Day 0 with rocks in the containers. The fish initially took up to two minutes to take the bait from the container, but by the tenth trial took no more than 10 seconds as they became accustomed to the new delivery system.

Twenty-five trials were run over 3 days; five trials were conducted for each container on Day 1. Ten trials were done for each container on Days 2 and 3. The average time taken to eat the bait for the control container was about 9 seconds. The average for magnet1 was about 22 seconds, and about 17 seconds for magnet2.

The longest interval from presentation of the bait box to removal of bait recorded from controls occurred in trial 8 at 35 seconds. Magnet1 The longest interval for Magnet1occurred in trial 9 at 124 seconds while the longest interval for occurred in trial 8 at 127 seconds. The shortest intervals were 2, 3, and 2 seconds, respectively.

During trials 8, 15, 16, 20, and 22 for magnet1, the fish exhibited a behavior of approaching the bait to within 6 inches and then abruptly turning away. The same behavior was observed during trials 5 and 12 for magnet2. This behavior was never observed in control trials. A similar behavior was seen in all three containers multiple times, where the fish swam towards the bait and then veered off after getting within 3 feet of it.

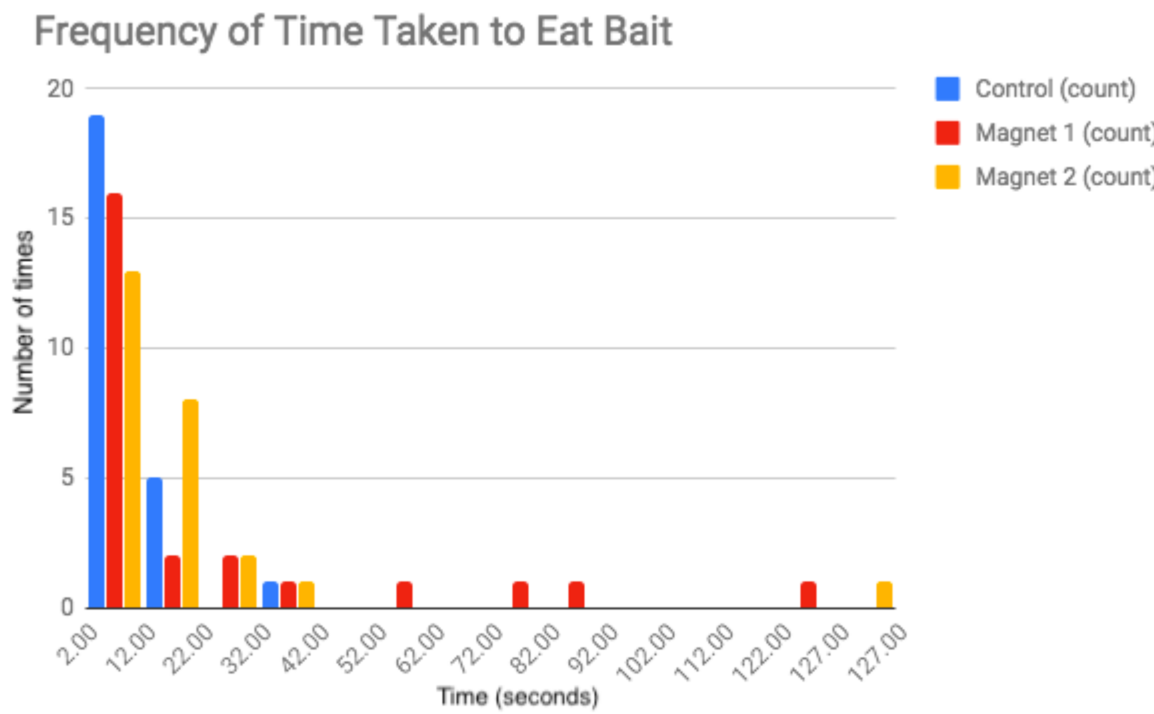
During some of the trials when there was a long delay, larger fish would approach the container and bump the side with their body, without taking the bait. Additionally, after the container was left in the water after the bait was taken, a fish would swim to the container and nibble on a corner of the container. I did not record which trial or for which container this behavior was observed.

Table

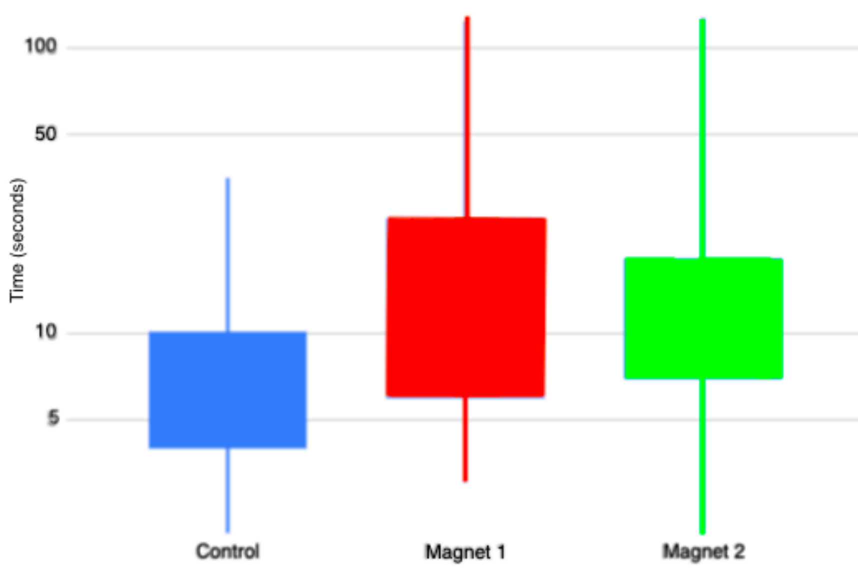
Time taken to eat bait on clip on each container			
	Control	Magnet 1	Magnet 2
Trial 1	17	6	8
Trial 2	4	3	2
Trial 3	8	8	8
Trial 4	10	7	7
Trial 5	5	4	13
Trial 6	4	4	5
Trial 7	15	3	37
Trial 8	35	25	127
Trial 9	19	124	9
Trial 10	18	83	8
Trial 11	9	4	3
Trial 12	4	11	12

Trial 13	7	11	28
Trial 14	7	25	18
Trial 15	4	7	3
Trial 16	2	13	21
Trial 17	6	5	18
Trial 18	8	8	9
Trial 19	6	8	14
Trial 20	12	32	24
Trial 21	5	80	4
Trial 22	5	52	7
Trial 23	4	11	20
Trial 24	4	13	6
Trial 25	4	11	12
Average	8.88	22.32	16.92
Total	209.88	571.32	429.92
Maximum	35	124	127
Minimum	2	3	2

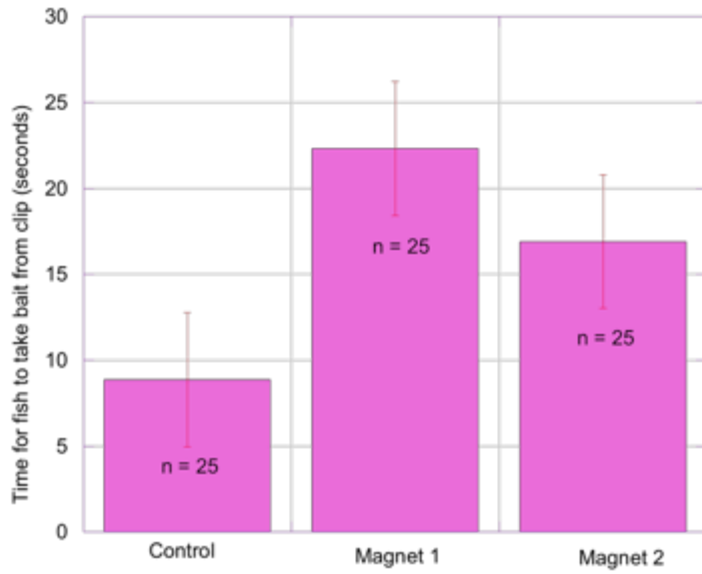
Graph 1: Histogram showing frequency of time from introduction of the container to bait removal within 10 second intervals.



Graph 2: Time to removal of bait with minimum, first quartile, third quartile, and maximum (log scale)



Graph 3: Time to removal of bait (mean + standard error)



Analysis and Interpretation of Data

The average time for fish to take bait from the control box was 9 seconds, whereas it was 22 seconds for magnet1 and 17 seconds for magnet2. Magnet1 and magnet2 both had at least one outlier trial, with magnet1 reaching 124 and 80 seconds in two of the trials, and magnet2 reaching 127 seconds in one trial. However, even if these outliers are removed from the data, the average time is 15 seconds for magnet1 and 12 seconds for magnet2, is greater than the 8 second average for the control. Magnet1 is not as strong as magnet2, but it had a higher average time taken to eat the bait. This may suggest that striped bass have a preference for varying strengths of magnetism, disliking one more than another. A One-Way ANOVA indicated no significant difference between any conditions whether the outlier values were included ($p = 0.12$) or not ($p = 0.09$).

Discussion

The purpose of this experiment was to determine whether a localized static, magnetic field would affect the feeding behavior of striped bass. My hypothesis was that the magnetic field would negatively affect feeding. Fish took longer to take bait which was accompanied by a magnetic field but the mean times were not significantly different from controls. However the trend of longer times to feed in magnetic fields when compared to controls suggests that this experiment is worth continuing. Experiments using "magnetic hooks" support our findings. The red drum (*Sciaenops ocellatus*) and black drum (*Pogonias cromis*) and the sea catfish (*Ariopsis felis*) preferred control hooks over magnetic hooks while the gafftopsail catfish (*Bagre marinus*) showed no preference (Courtney and Courtenay, 2015)

The magnetic field may have caused other behavioral changes. In a number of trials experimental but not control fish approached a container with a magnet and then abruptly turned away when near the container. Other interesting behaviors such as nibbling or bumping the bait box were observed but were not correlated to the presence or absence of a magnet.

A number of variables may have affected my results. The size and anatomical location of the squid pieces varied. Fish may be preferentially attracted to a bigger piece or they may prefer one part of the squid over another. Visitors were another variable, as multiple times during testing a group came out and observed the experiment. The fish are conditioned to expect food when they see visitors because they are fed multiple times a day with squid scraps, so the presence of visitors during testing may have skewed the results for those particular trials. Three times during testing, the container dropped into the water either because it opened or it detached from the fishing line. These mistrials may have scared the fish, impacting their overall behavior. For each trial, the container was lowered into the water in the same place but there was no way to place it in an exact location each time, so the speed and precise way in which the container entered the water is another small variable. Environmental factors such as the tide and water temperature varied on testing days and may have impacted the behavior of the fish. If the container was not completely full with water, it would not sink to the bottom and instead turned on its side with the bait in the water. This variable most likely impacted the time it took for the fish to take the bait as it was floating sideways instead of sitting on the bottom with the bait facing up.

If this experiment were to be conducted again, I recommend the following modifications:

1. Choose a time or location when visitors are less likely to be present during experiments.
2. Perform testing during or near high tide. This is when the fish come closest to the wall, making it easier to observe their behavior and it is less likely that the results will be impacted by the hesitance of the fish to enter shallow water.
3. Standardize the size and morphological position of squid pieces. That is, only use pieces cut from the main body.
4. Record all behavior in addition to timing for each trial. Interesting behavior (e.g., bumping) was observed but not closely recorded during this experiment, making it more difficult to interpret.
5. Develop a better way to deliver the bait that does not require raising and lowering the bait boxes. If containers are used, reduce their size. The size of

the containers made them heavy when filled with rocks, magnets, and water, so it would be easier if they were smaller.

6. Make sure the swivel clips are strong enough to hold the container and all strings are securely attached.In order to reduce bias, the observer should not know what is in each container (have a partner set up each container and record which container is used for each trial). Results can thus be recorded objectively and only later analyzed.

Another approach is to adapt the magnetic hook model of Courtney and Courtney, 2015 where a magnet is placed on a hook and the ability to catch fish is assessed. The hook might be replaced with bait tied to a string to see if the fish strikes the bait.

Applications and Recommendations for Further Study

Studying the impact of magnetism on *Morone saxatilis* will help our understanding how these fish navigate over 700 miles north in the spring/summer and south in the fall. In addition it will help clarify how these fish find their way back to specific locations like Eel Pond from year to year. Such results can have implications in the conservation of this species resulting in a sustainable recreational and commercial fisheries.

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