Virginia Ocean Plan and Atlantic Sturgeon EMF Study
FY14 Task 95.01
Final Report, Grant Period October 1, 2014 to September 30, 2016
Grant# NA14NOS4190141
Compiled by Todd Janeski, VCU, Department of Life Sciences

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Overview
The VCU Environmental Scientist/Analyst, as retained by the Virginia Department of Environmental Quality, Coastal Zone Management Program, served as the Ocean Planning Stakeholder Coordinator for the grant reporting period under the VACZM Section 309 Ocean Resources Strategy. During this period, two primary tasks were undertaken: Ocean Stakeholder Engagement with the Virginia CZM Program in the Commonwealth's Ocean Planning initiative and the analysis of electromagnetic field impacts on sturgeon (*Acipenser oxyrinchus*).

Ocean planning in the Commonwealth includes a partnership, the Mid-Atlantic Regional Council on the Ocean (MARCO), which includes representatives from the States of New York, New Jersey, Delaware, Maryland and Virginia. The broader MARCO effort is being supported through several contractors such as Monmouth University, University of Delaware, Rutgers University, Nature Conservancy, and NatureServe. Primarily, ocean planning brings together the sectors of Ports and Navigation, Military, Commercial Fisheries, Recreational Users, Alternative and Traditional Energy, Conservation, Tourism, and Local Government. These sectors have been brought together both in the Commonwealth as well as in the region to share information regarding ocean uses for the purpose of understanding the complexity of overlapping and abutting uses.

The VCU Center for Environmental Studies organized and lead a research team to evaluate and quantify behavioral responses by subadult Atlantic Sturgeon to electromagnetic fields (EMF) under controlled (laboratory) conditions. No published studies have evaluated behavioral responses to artificial electro-magnetic fields by sturgeons. Many EMF effects studies (e.g. Tricas and Sisneros 2004) have focused on elasmobranch fishes, which may possess unique sensory capabilities and responses to EMF stimuli, compared to teleosts. Hence, the unknown effects of EMF on electric/magnetic detection in other commercially important or protected fishes (e.g. sturgeons, eels, salmonids, clupeids, tunas) along the U.S. Atlantic slope make definite conclusions about environmental risks to fish and fisheries from offshore wind generation elusive.

Ocean Planning
The VCU Ocean Planning Stakeholder Outreach (OPSE) Coordinator worked with the CZM Director, the Accomack-Northampton Planning District Commission and the seafood industry to engage the commercial fishing industry to better understand those areas most used for commercial purposes. Building social capital is a key strategy to advance the commercial industry and a critical strategic partnership was established with the Virginia Seafood Council (VSC). The VSC provided project credibility and direct support to the VCU Outreach Coordinator to successfully engage a critical community stakeholder to advance ocean planning. The commercial fishing industry, an often overlooked and underrepresented constituent, is a

keystone stakeholder for Virginia's coast by which establishing a credible relationship is vital to a successful outcome in coastal management.

The OPSE Coordinator conducted outreach and communication to the commercial sector in a meaningful manner through an on-the-ground approach of direct engagement of commercial fishers. Through this direct, personal engagement process, the industries contacted including those from the spiny dogfish, conch, scallop, black seabass, menhaden and pelagic fisheries. The specific focus was the vetting of the Community at Sea Maps, as created by the Rutgers University to translate Vessel Trip Report (VTR) data with vessel permit data into a visually consumable product to display fishing intensity. The Community at Sea data also include the number of individuals on the vessel, sea time, home port and species landed as a means to display the effort of fishing as opposed to economic value of the landed fish. The OPSE Coordinator focused on the ports of Virginia Beach, Newport News, and Hampton to vet the grouped gear types of dredge, gillnet, and pots and traps. Direct communication with wholesalers, processors, fishing companies and captains was used to verify the validity of these data.

Additionally, during the reporting period, the OPSE Coordinator prepared for the initiation of the Collaborative Fisheries Planning in the VA Wind Energy Area (WEA) Project through direct communication and coordination with project team members and industry representatives. The OPSE Coordinator began to communicate with representatives outside of the state of Virginia, guided by the interpreted data from the National Marine Fisheries Service (NMFS) Draft Fisheries Exposure report. Those data identify the ports from the states of North Carolina to Massachusetts which are fishing in the VA WEA. To identify those in New England, additional communication was had with the NROC Ocean Planning Director and representatives from national conservation NGOs in RI and MA. For North Carolina, the North Carolina Fisheries Association was reached to lay the foundation for work to commence under the BOEM-DMME Collaborative Fisheries Planning grant. The OPSE Coordinator was supported primarily by the BOEM-DMME Collaborative Fisheries Planning grant during the project reporting period, however, a small amount from Section 309 will continue to support other ocean planning outreach.

During the latter part of the reporting period, the OPSE Coordinator focused the majority of time to the BOEM-DMME funded Collaborative Fisheries Planning in the VA Wind Energy Area (WEA) Project through direct communication and coordination with project team members and industry representatives. Reporting on these actions are covered under that grant.

Atlantic Sturgeon Study

Due to the availability of funding to support the OPSE Coordinator for the Collaborative Fisheries Planning project, the Section 309 grant was reprogrammed to include research relevant to the collection of data demonstrating any electromagnetic field impacts on migratory, Federally-listed, endangered Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*). A partnership between the VCU Center for Environmental Studies and the VCU Department of Electrical and Computer Engineering forged to conduct the study.

VCU Engineering modeled, designed, and built a high-precision Magnetic and Electromagnetic

(M/EM) Field Generator as well as an array of magnetometers (sensors) that allow researchers to track and record M/EM values continuously during each experiment. In the laboratory, sturgeon biologists from the VCU Center for Environmental Studies utilized visual tracking software and data gathered by high-speed cameras to quantify and evaluate a range of fish behaviors in response to magnitude and orientation of M/EM fields. The VCU research team focused on the collection of data to continue to inform a response to the hypothesis that EMF should affect behavior of Atlantic Sturgeon.

This study sought to evaluate and quantify behavioral responses by sub-adult Atlantic Sturgeon to generated M/EM fields under controlled (laboratory) conditions, based on the study objectives outlined below. The study was to attempt to emulate the EMF conditions that migratory fishes might encounter near proposed marine HV sources originating from the Virginia WEA. By designing, building, and testing an EMF generator capable of producing a range of fields comparable to fields that might be experienced by Atlantic Sturgeon under natural conditions and in the vicinity of HV cables the research team exposed experimental animals to generated EMFs and measure responses based on a suite of simple behaviors under control and EMF conditions. This is the first published study to experimentally evaluate the effects of M/EM fields from submarine HV cables on Atlantic Sturgeon behavior. Results of the study suggest that, under laboratory conditions, the types and ranges of M/EM fields to which Atlantic Sturgeon were exposed in the laboratory did not result in biologically relevant changes to simple behaviors in sub-adult individuals. Hence, these results are not consistent with the hypothesis that localized M/EM fields from anthropogenic sources—specifically benthic HV cables—in coastal ocean habitats may negatively impact behavior of migrating or foraging wild Atlantic Sturgeon.

The full report can be found below:

Behavioral responses of sub-adult Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus)* to electromagnetic and magnetic fields under laboratory conditions

Andrew McIntyre, Todd Janeski, and Dr. Greg Garman, Center for Environmental Studies, Virginia Commonwealth University

Christopher Deloglos and Dr. Afroditi Filippas, Department of Electrical and Computer Engineering, Virginia Commonwealth University

Final Grant Report to the Virginia Coastal Zone Management Program

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Background

In the last few decades a growing body of published research suggests that, in addition to environmental impacts associated with the extraction and production of fossil fuels, increasing concentrations of atmospheric CO_2 from fossil fuel combustion is affecting the earth's climate (Pachauri et al. 2014). Concerns about environmental impacts associated with the use of fossil fuels have created a demand for sustainable and 'clean' energy sources. Energy technologies based on wind, water, solar, geothermal gradients, and tidal dynamics offer great promise for reducing reliance on fossil fuels, but each of these alternative energy approaches must be evaluated for possible negative environmental consequences prior to widespread implementation.

Construction of experimental offshore wind turbines in the Virginia Wind Energy Area (WEA) is planned for the Virginia Beach, Virginia area (VOWTAP Research Activities Plan 2016). WEA would potentially be the first wind-powered electric generation facility in United States coastal waters. Although implementation of the WEA plan in Virginia was recently postponed, similar projects elsewhere (e.g. Block Island Wind Farm, Deepwater One South Fork Wind Farm) suggest that—eventually—wind power may become a new energy resource from coastal waters of the U.S. Although coastal wind farms could be a step toward reducing carbon emissions, turbines and associated infrastructure may pose new and poorly understood threats to marine living resources (Boehlert and Gill 2010). Some of the potential impacts to marine species that have been linked to the development of offshore wind capacity include habitat loss, collision risks, noise pollution, and electromagnetic fields (Inger et al. 2009). Magnetic and electromagnetic (M/EM) fields produced by high voltage (HV) transmission cables leading from offshore wind turbines could alter critical behaviors (e.g. migration, feeding) of electro-sensitive fishes including elasmobranchs, eels, and sturgeons (Gill et al. 2014). High voltage transmission cables leading from offshore wind farms could be buried or placed directly on the sea floor. Magnetic or electromagnetic fields generated by HV submarine or benthic transmission cables vary greatly in strength, depending on cable shielding, distance from cable, strength of electric current, current type and other factors (Woodruff et al. 2012). Measured values of M/EM fields from HV marine transmission cables in one study ranged from a few microTesla (μT) to 8 milliTesla (mT; Woodruff et al. 2012).

Research focused on responses by EMF-sensitive fish species to EMF characteristics is still evolving, so it is unclear how some fish species may respond to M/EM fields produced by HV transmission cables (Gill et al. 2014). EMF-receptive fishes can be classified into two categories: electro-receptive and magneto-receptive. The first category includes primarily non-teleost fish species, such as Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*), that possess electro-receptive ampullary or tuberous sensory organs (Tricas 2012). The functional roles of these organs include environmental orientation and navigation, as well as detection of weak bio-electric fields from prey species (Basov 1999). In the case of Atlantic Sturgeon, there are no published studies addressing the possible effects of EMF exposure from offshore HV transmission lines (Tricas 2012) on fish behavior. The Atlantic Sturgeon is a large (up to 4 m TL), long-lived (50+ y) fish that ranges from New Brunswick to Florida along the Atlantic Slope; the species is both anadromous and iteroparous (Bain 1997). Because of these life-history traits, adult Atlantic Sturgeon may return frequently to natal, coastal rivers to spawn (Balazik et al. 2012). Although sturgeons were once abundant on North America's east coast, unsustainable commercial harvest, riverine habitat loss, and pollution during the late 19th and early 20th centuries caused serious declines in Atlantic Sturgeon populations (Boreman 1997; Murdy 1977). Declines in Atlantic sturgeon abundance caused Virginia to declare a moratorium on both recreational and commercial harvest of Atlantic Sturgeon in 1974, and the Atlantic States Marine Fisheries Commission (ASMFC) enacted a moratorium on Atlantic Sturgeon fishing coast-wide in 1998 (ASMFC 1998). Five genetically distinct population segments (DPS) of Atlantic Sturgeon are recognized within the United States, and all but the Gulf of Maine population were recently listed as *endangered* under the Endangered Species Act (King et al. 2001).

Recent research indicates that Atlantic Sturgeon in the Chesapeake Bay DPS spawn in the tidal freshwater reaches of the James, Rappahannock, and York river systems (Garman and Balazik 2016). Adult Atlantic Sturgeon entering coastal rivers of Virginia to spawn must first cross from the open ocean into Chesapeake Bay. During the near-shore phase of their migration, fish might be exposed to EMF from HV voltage transmission cables that connect the Virginia WEA to onshore distribution facilities.

Study Objectives

This study sought to evaluate and quantify behavioral responses by sub-adult Atlantic Sturgeon to generated M/EM fields under controlled (laboratory) conditions, based on the study objectives outlined below. First, the study evaluated the Dominion proposals (VOWTAP and Commercial Lease) for placing HV transmission cables from wind turbines in the vicinity of Atlantic Sturgeon migration corridors near Virginia Beach, Virginia. Using these data, we attempted to emulate the EMF conditions that migratory fishes might encounter near proposed marine HV sources originating from the Virginia WEA. The second objective was to design, build, and test an EMF generator capable of producing a range of fields comparable to fields that might be experienced by Atlantic Sturgeon under natural conditions and in the vicinity of HV cables. A third objective of the study required the research team to expose experimental animals to generated EMFs and measure responses based on a suite of simple behaviors under control and EMF conditions. Results of this study should help managers and policy-makers to evaluate the possible ecological effects of offshore wind energy projects on living marine resources, including the endangered Atlantic Sturgeon.

Methods

Experimental Subjects and Holding Facilities

Sub-adult Atlantic Sturgeon (age-3; 40 cm, mean FL) for this study were sourced from the University of Maryland's Horn Point Research Facility, were of Canadian origin, and were acclimated at the Virginia Commonwealth University Aquatics Facility (1000 W. Cary Street, Richmond, VA) for a minimum of two weeks before testing. All captive sturgeon were maintained and used in strict accordance with VCU IACUC (AD520115) protocols. Each fish was uniquely identified by a subcutaneous passive integrated transponder (PIT) tag. Up to 20 experimental fish were held in a 600-g circular fiberglass tank supplied with an orientation current. Single, randomly chosen animals were transferred to a 250-g circular fiberglass tank for control and experimental trials, after which fish were returned to the holding tank. Salinity in both tanks was held at 5 ppt (artificial seawater) and the holding facility maintained a seasonally appropriate photoperiod with artificial lighting; water temperature in both tanks was maintained at 18-20° C. Water quality (e.g. ammonium and nitrate) for both the holding and experimental tanks were maintained at optimal conditions by occasional partial water changes and monitored at least 3x weekly. Fish were fed a commercial diet (Ziegler Finfish Silver) at a maintenance ration of approximately 3% bw/d. Fish were monitored regularly for signs of stress or other health-related problems.

Electromagnetic Field Generating and Monitoring Equipment

High-precision current generators were purchased from a commercial source (ValueTronics) and connected to a coil of 20-gauge magnetic wire wrapped around a rectangular wood frame. The frame was mounted to a circular wood table that allowed researchers to rotate the coil and control field orientation. The coil and frame system was mounted beneath the experimental tank leaving 2.5 cm of space from the coil frame to the tank bottom (Figure 1). The EMF generator system used was capable of producing fields comparable to those produced by offshore underwater transmission cables. To determine specific M/EM field strengths used in experimental trials, we evaluated published wind farm proposals (Dominion VOWTAP and Commercial Lease) for placing HV transmission cables from offshore wind turbines. Published data on cable type, depth of burial, and the characteristics of the M/EM fields likely to be generated by proposed HV cables were used to emulate experimentally the EMF conditions that migratory fishes might encounter in the field (Guidi 2012; Green 2007; Kirby 2002).

The research team also constructed a magnetometer array to measure and record magnetic field values during experimental trials. The array consisted of six, triple-axis digital magnetometer sensors orientated across the base of the experimental tank, allowing the magnetic field to be measured in multiple directions and to be calculated via established magnetic/EM equations. The sensors were connected to extension wires attached to a commercial microcontroller (Arduino MEGA 2560). In order to record and quantify fish movements in the area of the experimental tank subjected to generated M/EM fields, a high definition Panasonic camcorder was mounted above the experimental tank using a Joby flexible mounting system.

Experimental Protocol

Single experimental animals were selected at random from a pool of twelve individual fish for the direct current (DC) trials and nine fish for the alternating current (AC) trials. Study animals were transferred from the holding tank to the experimental tank 24h prior to conducting study trials. All trials were conducted in the evening hours between 5 pm and 9 pm, during which no personnel access to the facility was allowed to minimize disturbance. Following acclimation to the experimental tank, fish behavior was recorded for 1 h in the absence of any generated fields to record baseline (control) behavior. Study subjects were then subjected to a preselected EMF trial for an additional 1 h, during which swimming behavior was recorded by camcorder. Hence, each experimental trial involved recording the behavior of a single fish during a 2-h period. After each trial, the study animal's PIT tag number was recorded and the subject was returned to the holding tank.

Magnetic and Electromagnetic Field Trials

A total of 45 trials were conducted during the study using a range of field types, strengths, and orientations. Thirty trials used generated DC fields and, of these, 15 were conducted using 0° field orientation (field generated perpendicular to tank area), and 15 were conducted using 90° field orientation (field generated perpendicular to tank area). Different field orientations were used to simulate fish in the wild passing directly over, or parallel to, HV submarine cables. Three M/EM field strengths were generated during DC trials: 5μT, 100μT, and 1mT (five replicates each). Fifteen AC trials (also five replicates) were conducted using 0° field orientation and the same field strengths as the DC trials. For all trials, the M/EM field strengths were measured with magnetometers (described above). The region of the experimental tank with measured field strengths ≥ 50% of the target field strength was deemed 'affected' and marked with tape prior to each trial for later visual reference (Figure 2). All other areas of the circular experimental tank were determined to be unaffected by the generated field.

Analysis of Video Footage

Approximately 90 hours of digital imagery were reviewed and analyzed to compute three simple metrics of fish behavior within the experimental field: time (in seconds) spent within the designated field area, number of passes through the designated field area, and mean swimming speed (m/s) within the designated field area. For each trial, measurements from videography were made separately for one 'control' hour (field off) and for one 'experimental hour' (field on). For each combination of field type (AC *versus* DC), orientation (90° *versus* 0°), and maximum field strength (5μT, 100μT, or 1mT), mean values for each behavior metric (n=5 replicates) were calculated. Hypothesis testing (control *versus* experimental means; α= 0.05) was conducted using paired t-tests with **R** statistical software.

Results and Conclusions

Figures 3-5 present comparisons between control and experimental tests for behavioral metrics and the relevant combinations of generated field attributes. Only three comparisons resulted in statistically significant differences between control and experimental pairs (Fig. 3a, 100μT; Fig. 4b, 5μT; Fig. 5c, 5μT). Results of hypothesis testing for all trials and all behavioral metrics are summarized in Tables 1-3 and these analyses did not demonstrate any clear patterns in the data among field strengths, field orientations, or field types.

This is the first published study to experimentally evaluate the effects of M/EM fields from submarine HV cables on Atlantic Sturgeon behavior. Results of the study suggest that, under laboratory conditions, the types and ranges of M/EM fields to which Atlantic Sturgeon were exposed in the laboratory did not result in biologically relevant changes to simple behaviors in sub-adult individuals. Fields used in this study were chosen to emulate conditions to which wild sturgeon might be exposed in the immediate vicinity of benthic HV transmission cables from coastal wind turbines. Hence, these results are not consistent with the hypothesis that localized M/EM fields from anthropogenic sources—specifically benthic HV cables—in coastal ocean habitats may negatively impact behavior of migrating or foraging wild Atlantic Sturgeon. However, conclusions from this laboratory study are qualified by limitations in the study design. For example, only one age cohort (sub-adults) of Atlantic Sturgeon was available for the study and fish were exposed individually (cp. in groups) to experimental fields. In addition, the transferability of laboratory-based M/EM field exposures and subsequent behavioral responses to real-world conditions, including higher ocean salinities and a broader range of water temperatures, is unknown.

Future studies would be improved by more precise, real-time measurements of field area in the experimental tank, improvements to the magnetometer-based sensor array, the use of multiple, synchronized cameras, and the application of digital image processing and recognition software. Sturgeons and other taxonomic groups of marine and anadromous fishes that possess electromagnetic sensory organs may have a threshold field strength—not achieved by the current study—that will evoke behavioral or physiological responses. Measured values of M/EM fields from HV marine transmission cables in a study by Woodruff, et al. (2012) ranged from a few microTesla (μT) to 8 milliTesla (mT), substantially greater than the upper limit of field strength in the current study. Furthermore, even if anthropogenic M/EM fields from offshore wind energy facilities do not directly influence Atlantic Sturgeon behaviors, other factors associated with offshore wind production could pose risks to Atlantic Sturgeon and other benthic marine and anadromous fishes. In a recent study by Love, et al. (2016), fish assemblage structure and density over energized *versus* un-energized benthic, HV transmission cables were not significantly different, but estimates of density for some fish species were higher in the vicinity of both cables, compared to adjacent, natural benthic habitat.

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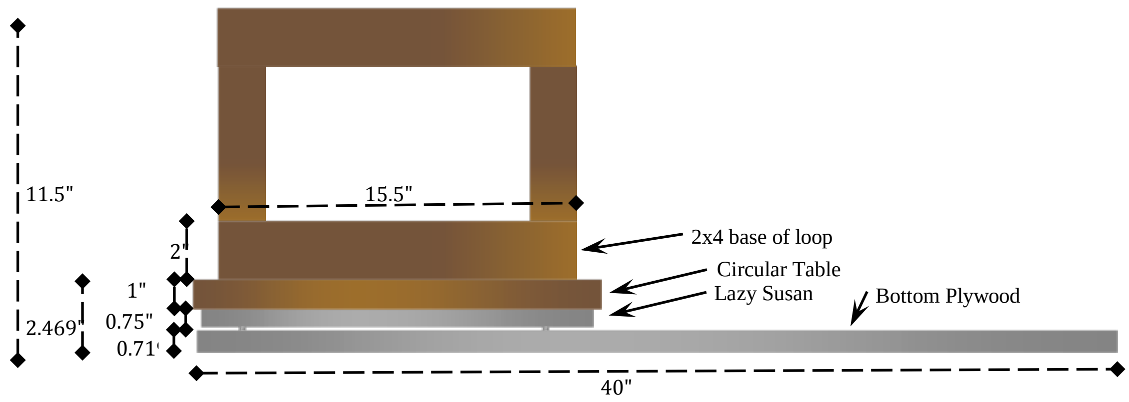

Figure 1. Diagram showing coil housing and rotating platform.

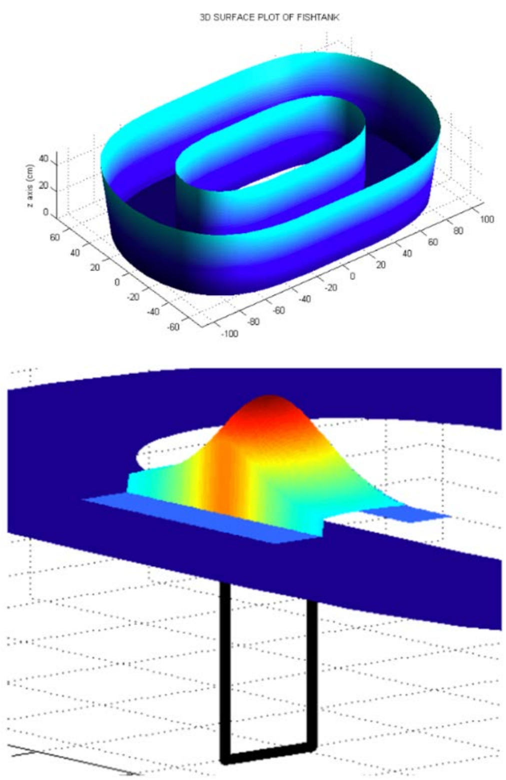

Figure 2. Graphical representation of a generated DC field in the experimental tank.

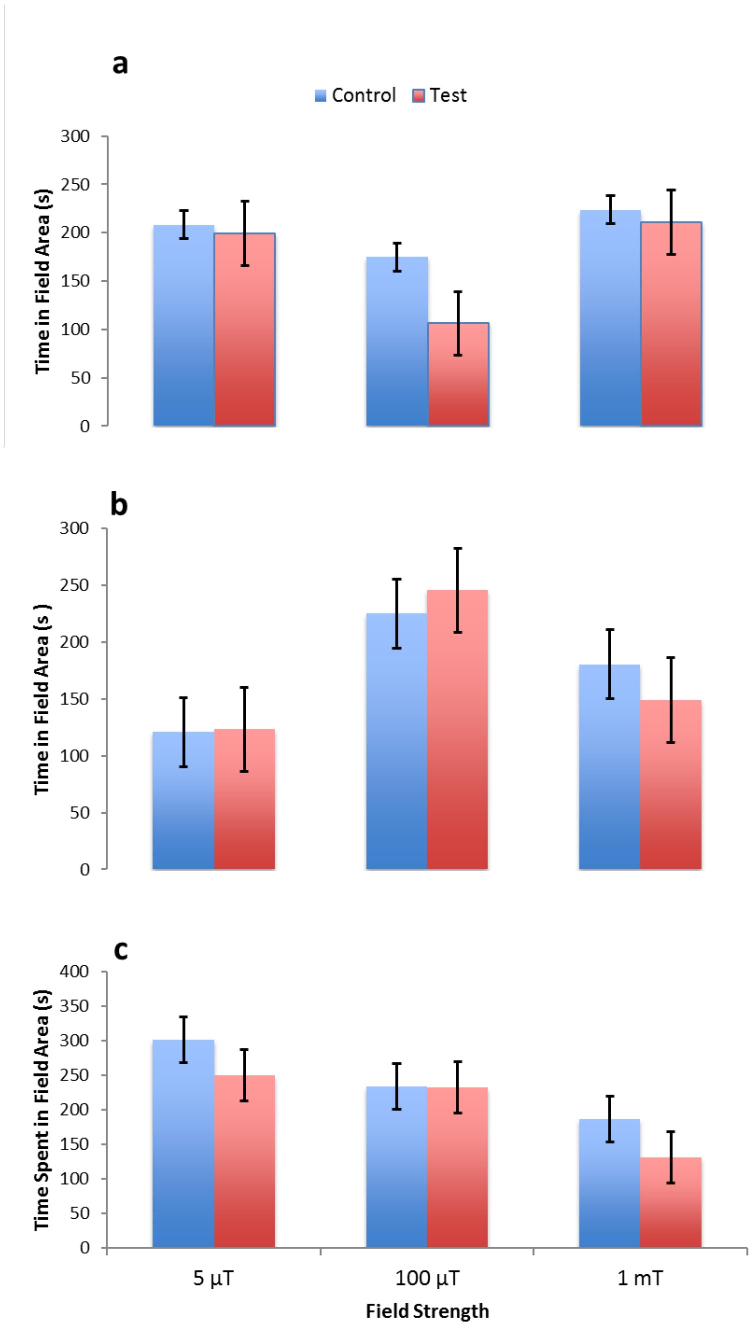

Figure 3. Observed time spent in M/ EM field area during control and experimental tests. Experimental animals were first exposed to no field for 1 h (control), followed by exposure to one of three field strengths (5 µT, 100 µT, 1 mT) for 1 h. Each control and test column pair represents five replicates using different individuals, chosen randomly. Bars represent 1 standard error of the mean; a) direct current (DC) with 0° field orientation; b) DC with 90° field orientation; c) alternating current (AC) with 0° field orientation.

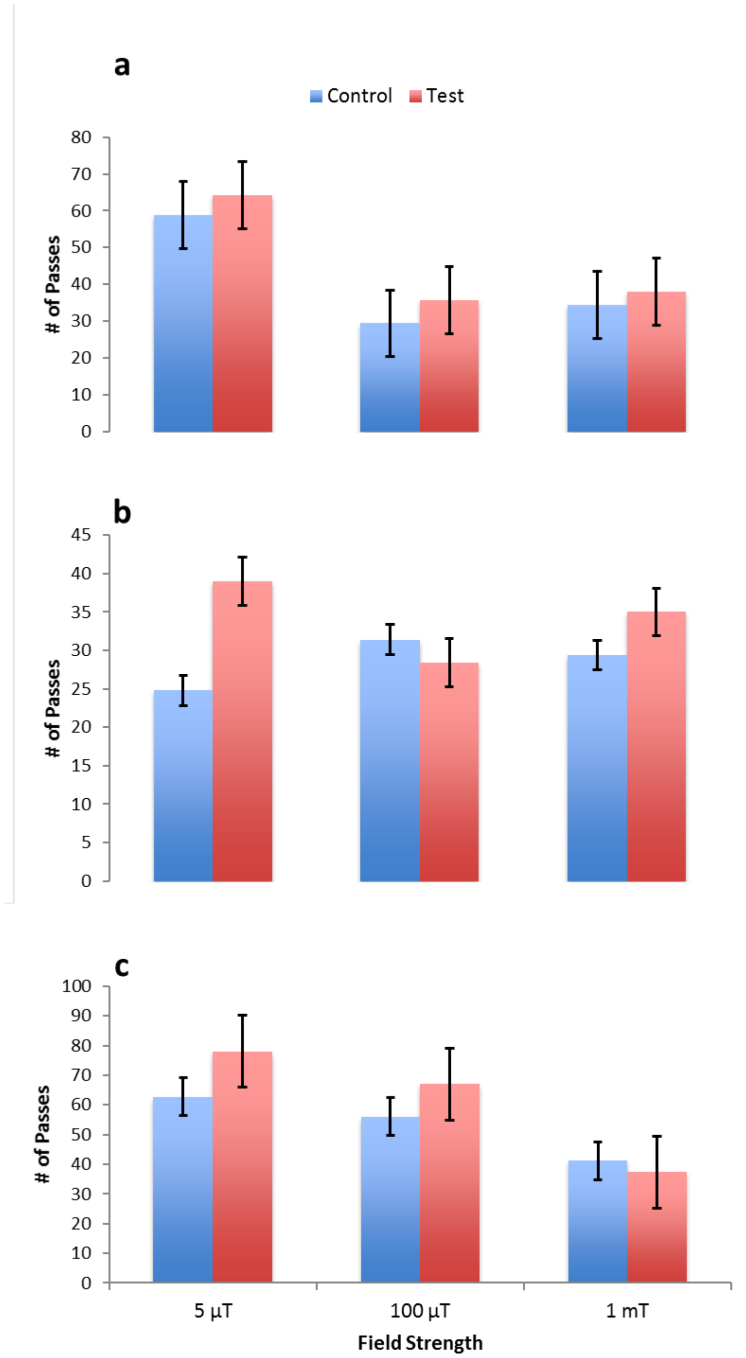

Figure 4. Observed number of passes through M/ EM field area during control and experimental tests. Experimental animals were first exposed to no field for 1 h (control), followed by exposure to one of three field strengths (5 µT, 100 µT, 1 mT) for 1 h. Each control and test column pair represents five replicates using different individuals, chosen randomly. Bars represent 1 standard error of the mean; a) direct current (DC) with 0° field orientation; b) DC with 90° field orientation; c) alternating current (AC) with 0° field orientation.

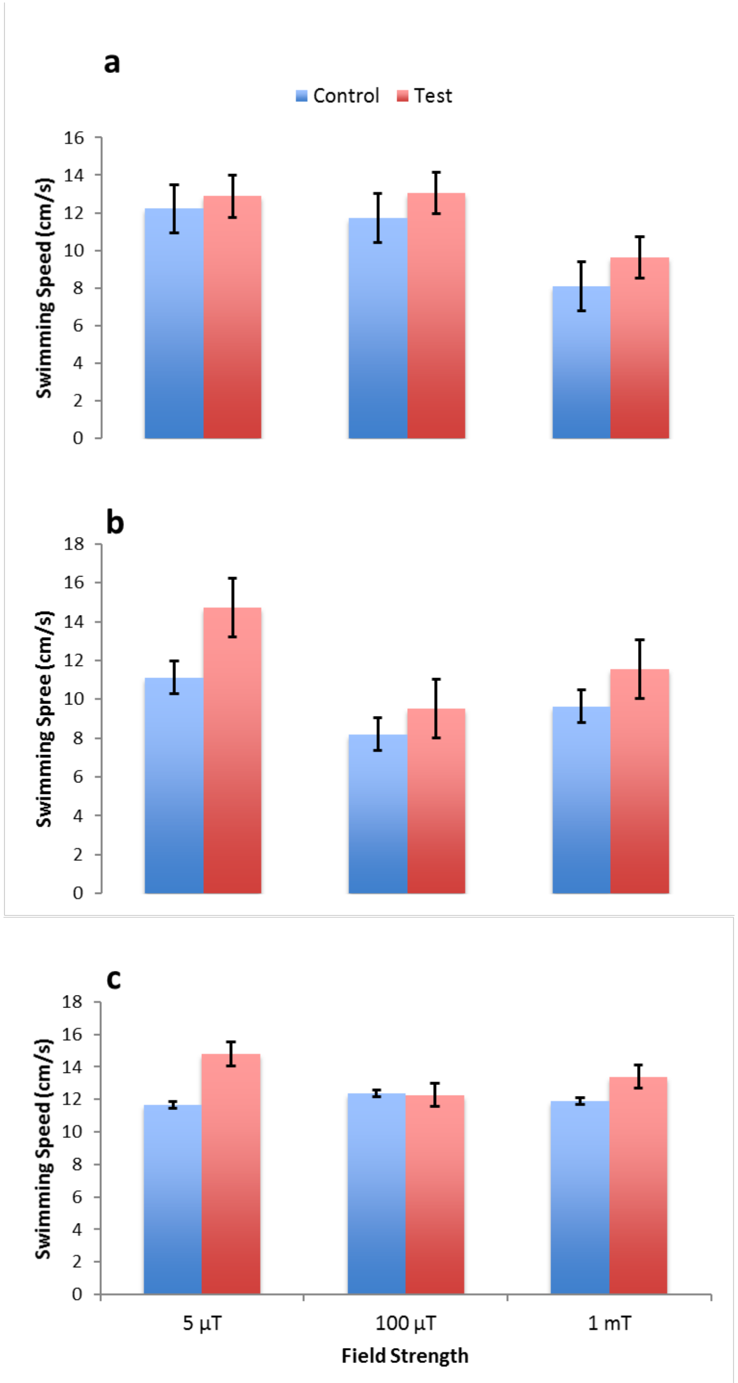

Figure 5. Observed swimming speed in centimeters per second through EM field area during control and experimental tests. Experimental animals were first exposed to no field for 1 h (control), followed by exposure to one of three field strengths (5 µT, 100 µT, 1 mT) for 1 h. Each control and test column pair represents five replicates using different individuals, chosen randomly. Bars represent 1 standard error of the mean; a) direct current (DC) with 0° field orientation; b) DC with 90° field orientation; c) alternating current (AC) with 0° field orientation.

Table 1. Summary data for Time Spent in Field Area, # of Passes, and Swimming Speed paired t-tests for DC, 0° orientation trials. Measurements based on group status.

DC, 0°, 5μT, Time in Field Area (s)				
Group	n	Mean	SE	Range
Control	5	208.4	39.3	(104, 309)
Test	5	199.2	45.4	(86, 309)
Difference (T-C)		-9.2		(-18, 0)
p-value	0.84			

DC, 0°, 5μT, # Passes				
Group	n	Mean	SE	Range
Control	5	58.8	22.2	(21, 145)
Test	5	64.2	21.2	(27, 131)
Difference (T-C)		5.4		(6, -14)
p-value	0.72			

DC, 0°, 5μT, Swimming Speed (cm/s)				
Group	n	Mean	SE	Range
Control	5	12.2	1.8	(6.7, 17.2)
Test	5	12.9	1.2	(9.7, 16.8)
Difference (T-C)		0.7		(3, -0.4)
p-value	0.56			

Table 1 (continued). Summary data for Time Spent in Field Area, # of Passes, and Swimming Speed paired t-tests for DC, 0° orientation trials. Measurements based on group status.

DC, 0°, 100µT, Time in Field Area (s)				
Group	n	Mean	SE	Range
Control	5	175	74	(29, 436)
Test	5	106.3	18.8	(59, 167.5)
Difference (T-C)		-68.7		(30, -268.5)
p-value	0.36			

DC, 0°, 100µT, # Passes				
Group	n	Mean	SE	Range
Control	5	29.4	16	(3, 90)
Test	5	35.6	21.4	(2, 118)
Difference (T-C)		6.2		(-1, 28)
p-value	0.58			

DC, 0°, 100µT, Swimming Speed (cm/s)				
Group	n	Mean	SE	Range
Control	5	11.7	3	(6, 22)
Test	5	13.1	4.6	(3.5, 30)
Difference (T-C)		1.3		(-2.4, 8)
p-value	0.71			

DC, 0°, 1mT, Time in Field Area (s)				
Group	n	Mean	SE	Range
Control	5	223.7	93.4	(0, 542)
Test	5	211.2	35.2	(96, 294)
Difference (T-C)		-12.5		(96, -248)
p-value	0.87			

Table 1 (continued). Summary data for Time Spent in Field Area, # of Passes, and Swimming Speed paired t-tests for DC, 0° orientation trials. Measurements based on group status.

DC, 0°, 1mT, # Passes				
Group	n	Mean	SE	Range
Control	5	34.4	12.3	(0, 68)
Test	5	38	10.7	(4, 59)
Difference (T-C)		3.6		(4, -9)
p-value	0.75			

DC, 0°, 1mT, Swimming Speed (cm/s)				
Group	n	Mean	SE	Range
Control	5	8.1	2.1	(0, 11.3)
Test	5	9.6	1.4	(4.8, 12.9)
Difference (T-C)		1.5		(4.8, 1.7)
p-value	0.37			

Table 2. Summary data for Time Spent in Field Area, # of Passes, and Swimming Speed paired t-tests for DC, 90° orientation trials. Measurements based on group status.

DC, 90°, 5µT, Time in Field Area (s)				
Group	n	Mean	SE	Range
Control	5	120.8	41.1	(7, 239)
Test	5	123.2	35.9	(12, 203)
Difference (T-C)		2.4		(5, -36)
p-value	0.82			

DC, 90°, 5µT, # Passes				
Group	n	Mean	SE	Range
Control	5	24.8	10.3	(2, 61)
Test	5	39	19.7	(3, 113)
Difference (T-C)		14.2		(1, 52)
p-value	0.22			

DC, 90°, 5µT, Swimming Speed (cm/s)				
Group	n	Mean	SE	Range
Control	5	11.1	2	(6, 15.9)
Test	5	14.7	2.7	(7.8, 24.2)
Difference (T-C)		3.6		(1.8, 8.3)
p-value	0.09			

Table 2 (continued). Summary data for Time Spent in Field Area, # of Passes, and Swimming Speed paired t-tests for DC, 0° orientation trials. Measurements based on group status.

DC, 90°, 100µT, Time in Field Area (s)				
Group	n	Mean	SE	Range
Control	5	225.3	28.1	(155, 322)
Test	5	245.6	2.7	(9, 509)
Difference (T-C)		20.3		(-146, 187)
p-value	0.84			

DC, 90°, 100µT, # Passes				
Group	n	Mean	SE	Range
Control	5	31.4	13.1	(1, 76)
Test	5	28.4	85.8	(2, 70)
Difference (T-C)		-3.0		(1, -6)
p-value	0.68			

DC, 90°, 100µT, Swimming Speed (cm/s)				
Group	n	Mean	SE	Range
Control	5	8.2	2.8	(0.1, 14.1)
Test	5	9.5	11.4	(5.6, 13.2)
Difference (T-C)		1.3		(5.5, -0.8)
p-value	0.51			

Table 2 (continued). Summary data for Time Spent in Field Area, # of Passes, and Swimming Speed paired t-tests for DC, 0° orientation trials. Measurements based on group status.

DC, 90°, 1mT, Time in Field Area (s)				
Group	n	Mean	SE	Range
Control	5	180.6	56.7	(23, 375)
Test	5	149.0	33.4	(29, 225)
Difference (T-C)		-31.6		(6, -150)
p-value	0.47			

DC, 90°, 1mT, # Passes				
Group	n	Mean	SE	Range
Control	5	29.4	15.3	(4, 84)
Test	5	35.0	20.6	(4, 112)
Difference (T-C)		5.6		(0, 28)
p-value	0.39			

DC, 90°, 1mT, Swimming Speed (cm/s)				
Group	n	Mean	SE	Range
Control	5	9.6	2.5	(3.3, 17.8)
Test	5	11.5	3.2	(2.3, 21.9)
Difference (T-C)		1.9		(-1, 41)
p-value	0.16			

Table 3. Summary data for Time Spent in Field Area, # of Passes, and Swimming Speed paired t-tests for AC, 0° orientation trials. Measurements based on group status.

AC, 0°, 5μT, Time in Field Area (s)				
Group	n	Mean	SE	Range
Control	5	301.4	33.9	(261, 437)
Test	5	250.2	23.9	(189, 316)
Difference (T-C)		-51.2		(-72, -121)
p-value	0.36			

AC, 0°, 5μT, # Passes				
Group	n	Mean	SE	Range
Control	5	62.8	10.4	(37, 91)
Test	5	78	9.2	(44, 97)
Difference (T-C)		15.2		(7, 6)
p-value	0.11			

AC, 0°, 5μT, Swimming Speed (cm/s)				
Group	n	Mean	SE	Range
Control	5	11.7	1.5	(7.8, 15.2)
Test	5	14.8	1.8	(11.4, 21.1)
Difference (T-C)		3.1		(3.6, 5.9)
p-value	0.11			

AC, 0°, 100μT, Time in Field Area (s)				
Group	n	Mean	SE	Range
Control	5	233.6	23.5	(163, 311)
Test	5	232.9	38.2	(85, 300.5)
Difference (T-C)		-0.7		(-78, -10.5)
p-value	0.99			

Table 3 (continued). Summary data for Time Spent in Field Area, # of Passes, and Swimming Speed paired t-tests for DC, 0° orientation trials. Measurements based on group status.

AC, 0°, 100µT, # Passes				
Group	n	Mean	SE	Range
Control	5	56	20.9	(26, 139)
Test	5	67	21.9	(12, 146)
Difference (T-C)		11.0		(-14, 7)
p-value	0.20			

AC, 0°, 100µT, Swimming Speed (cm/s)				
Group	n	Mean	SE	Range
Control	5	12.4	2.0	(9.1, 20.1)
Test	5	12.3	2.2	(8.2, 20.7)
Difference (T-C)	0	-0.1	3.0	(-0.9, 0.6)
p-value	0.92			

AC, 0°, 1mT, Time in Field Area (s)				
Group	n	Mean	SE	Range
Control	5	187.3	45.1	(64, 322)
Test	5	131.1	36.3	(76, 262.5)
Difference (T-C)		-56.2		(12, -59.5)
p-value	0.34			

AC, 0°, 1mT, # Passes				
Group	n	Mean	SE	Range
Control	5	41.2	19.0	(7, 114)
Test	5	37.4	22.1	(3, 122)
Difference (T-C)		-3.8		(-4, 8)
p-value	0.54			

Table 3 (continued). Summary data for Time Spent in Field Area, # of Passes, and Swimming Speed paired t-tests for DC, 0° orientation trials. Measurements based on group status.

AC, 0°, 1mT, Swimming Speed (cm/s)				
Group	n	Mean	SE	Range
Control	5	11.9	3.2	(4.3, 21.8)
Test	5	13.4	2.8	(6.6, 22.4)
Difference (T-C)		1.5		(2.3, 0.6)
p-value	0.59			

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