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Supplementary material

Individual variation influences avoidance behaviour of invasive common carp (*Cyprinus carpio*) and native buffalo (*Ictiobus*) to stroboscopic and acoustic deterrents

Paul A. Bzonek[A,B,C], *Jaewoo Kim*[B] *and Nicholas E. Mandrak*[A,B]

[A]Department of Ecology and Evolutionary Biology, University of Toronto,
25 Willcocks Street, Toronto, ON, M5S 3B2, Canada.

[B]Department of Biological Sciences, University of Toronto – Scarborough, 1265 Military Trail,
Scarborough, ON, M1C 1A4, Canada.

[C]Corresponding author. Email: paul.bzonek@mail.utoronto.ca

Supplementary materials

Methods

Acoustic profile measurements

Prior to experimentation, sound-pressure levels were measured for 60 s using two hydrophones (M8E51-C0, sensitivity @ 250 Hz = -199 dBV; M8E51-C35, sensitivity @ 250 Hz = –164 dBV, GeoSpectrum Technologies Inc., Dartmouth, NS, USA) connected to a JASCO Ocean Sound Meter. The higher sensitivity hydrophone (M8E51-C0) was used to record ambient sound pressures; the lower sensitivity hydrophone (M8E51-C35) was used to record the louder motor and stimulus sound pressures. The hydrophones were manually moved from point to point to collect a series of sound-pressure measurements across space. Root mean square (RMS) sound pressure was measured at all frequencies detected by the hydrophone. Ambient sound pressure was measured at seven points, ~ 15 m apart, along the centered length of the mesocosm. Stimulus sound pressure was measured along seven five-point transects spanning the width of the mesocosm. All sound pressure was measured at a depth of 4 m. Peak illuminance (lux) was measured for ambient and motivation plus opposition treatments with a lux meter (model number MW700, Milwaukee Electronics Kft., Rocky Mount, NC, USA).

Position estimates and data filtration

Individuals were identified by the frequency of their ping with periods ranging from 2.146 to 3.448 s. A detection location was estimated for every ping, which means that the temporal resolution of fish movement was 2.1–3.4 s, depending on the individual. Acoustic signals from the hydrophone array were converted into 2D positional estimates using MarkTags software (HTI, NY, USA). Three stationary acoustic tags were used to measure the precision of our telemetry array. The true position of a tag fell within 2.01 m ± 0.8979 (mean ± s.d.) of the estimated GPS location for 95% of detections. A post-processing data filter was used to remove erroneous detection data inherent to acoustic telemetry data and to maximise accuracy of location estimates. Detections that occurred over 1 s off of their expected periodicity were removed, as the hydrophone was likely detecting rebound or background noise. Next, any detection >12 m away from the previous detection was removed, as fishes would not likely travel that distance within the 2–3-s period between detections. Finally, if the number of fish detections did not fall within 0.75-1.1× the expected number of detections for that individual and trial period, the trial data for that fish were removed. The resultant data produced a series of tracks depicting fish movement across time (Figure S3).

Supplementary figures

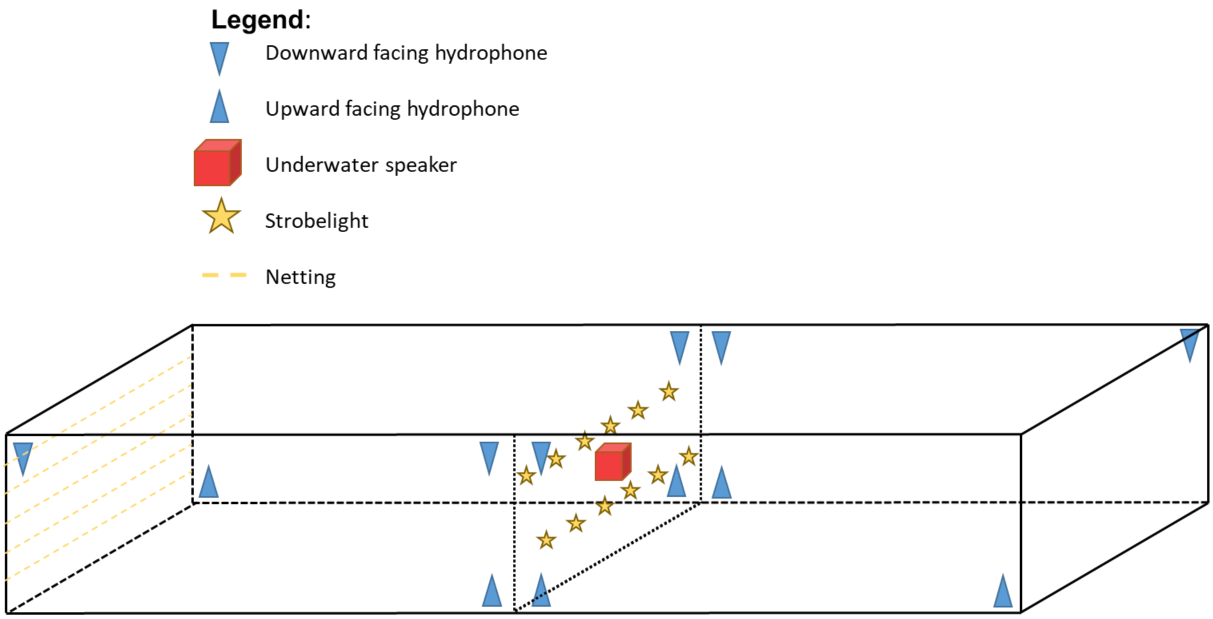

Figure S1: Schematic diagram of the ship-slip deterrent and telemetry array. The mesocosm is a ship slip enclosed with concrete on three sides. The entrance is blocked with a net to contain acoustically tagged subjects. The acoustic deterrent was placed in the center of the mesocosm. Two lines of strobe lights bisected the mesocosm at 3- and 6-m depths. Twelve hydrophones attuned to the acoustic tags were installed within the mesocosm to record the location the tagged Common Carp and *Ictiobus*. Six hydrophones were installed near the surface aiming downwards and six other hydrophones were installed at 7.5 m deep aiming upwards. Hydrophones were biased towards the acoustic deterrent to improve detection redundancy.

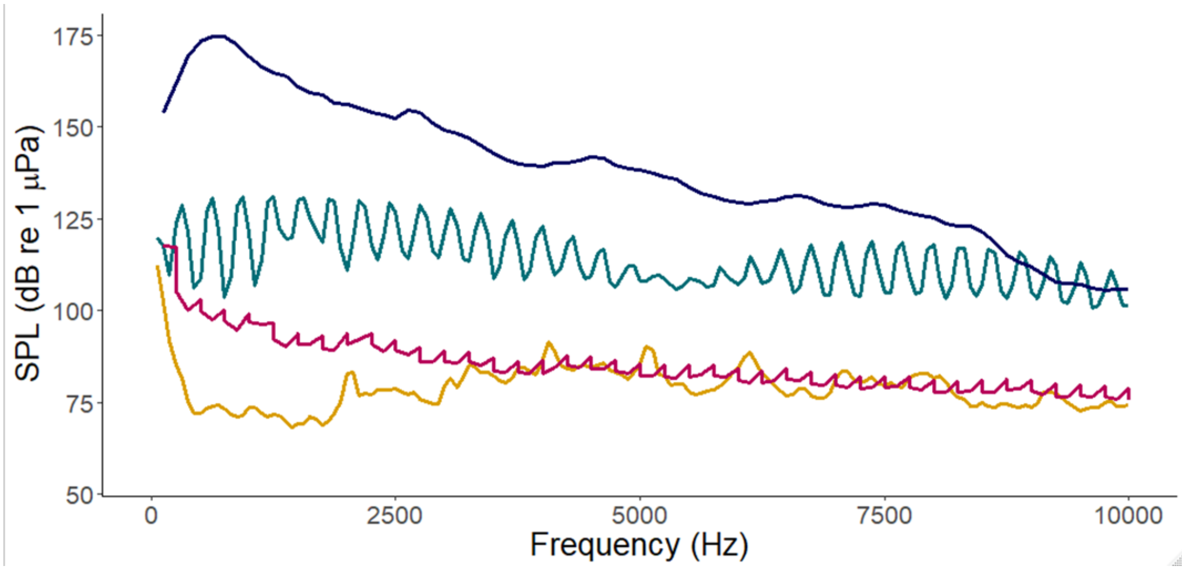

Figure S2: Power spectrum for the RMS sound-pressure level of the acoustic stimulus (dark blue line), the ambient mesocosm (purple line), holding tank (light blue line), and Hamilton Harbour (yellow line).

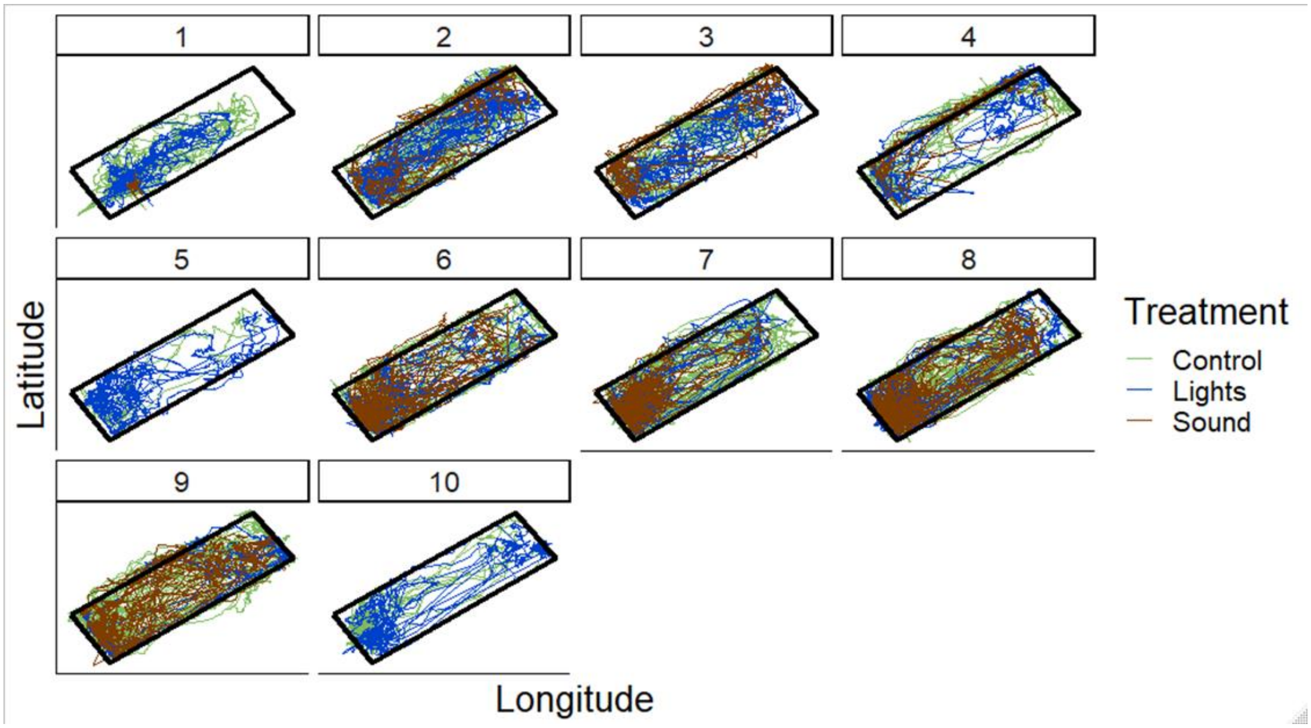

Figure S3: Movement tracks of acoustically tagged buffalo (id: 1-4) and Common Carp (id: 5-10) within the mesocosm. Lines represent movement paths under control (green), stroboscopic (blue), and acoustic (brown) treatments.

Table S1: Statistical summary table for the optimal linear model describing fish avoidance radius size

Parameter estimates, standard error, confidence intervals, F statistic and P-values are included

Predictors	Estimates	s.e.	CI	F-statistic	P
Intercept (Control, Ictiobus, N)	–260.25	133.34	–522.44 – 1.94	–1.95	0.052
Treatment [Acoustic]	–3.72	2.72	–9.07 – 1.64	–1.37	0.173
Treatment [Stroboscopic]	1.87	1.64	–1.35 – 5.09	1.14	0.255
Species [Common Carp]	28.34	9.67	9.33 – 47.35	2.93	**0.004**
TrialNumber	–0.09	0.08	–0.26 – 0.08	–1.06	0.291
Count	0.07	0.01	0.06 – 0.08	10.51	**<0.001**
WindSpeed	–0.81	0.24	–1.28 – –0.33	–3.34	**0.001**
WindDirection [NE]	0.84	2.40	–3.88 – 5.57	0.35	0.726
WindDirection [SW]	–1.91	3.50	–8.80 – 4.98	–0.54	0.587
WindDirection [W]	–6.19	2.26	–10.64 – –1.75	–2.74	**0.006**
ForkLength	0.39	0.23	–0.07 – 0.84	1.68	0.093
Observations			394		
R^2 / R^2 adjusted			0.389 / 0.362		