Supplementary files

Immune-challenged wild mallards move less and spend more time in sheltered habitats

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Supplementary figures

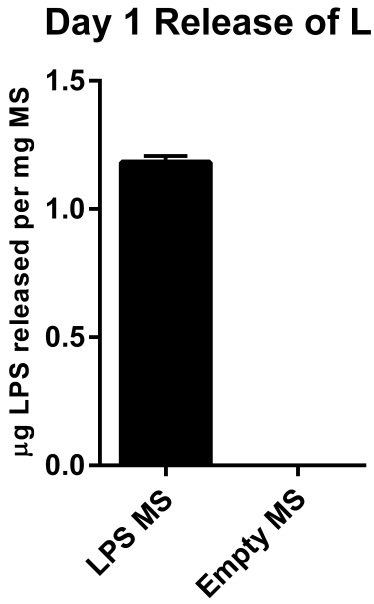


Figure S1. ***In vitro*** **release of LPS from PLGA-microspheres.** Released LPS was detected using a LAL chromogenic endotoxin test, with empty PLGA-microspheres as a negative control.

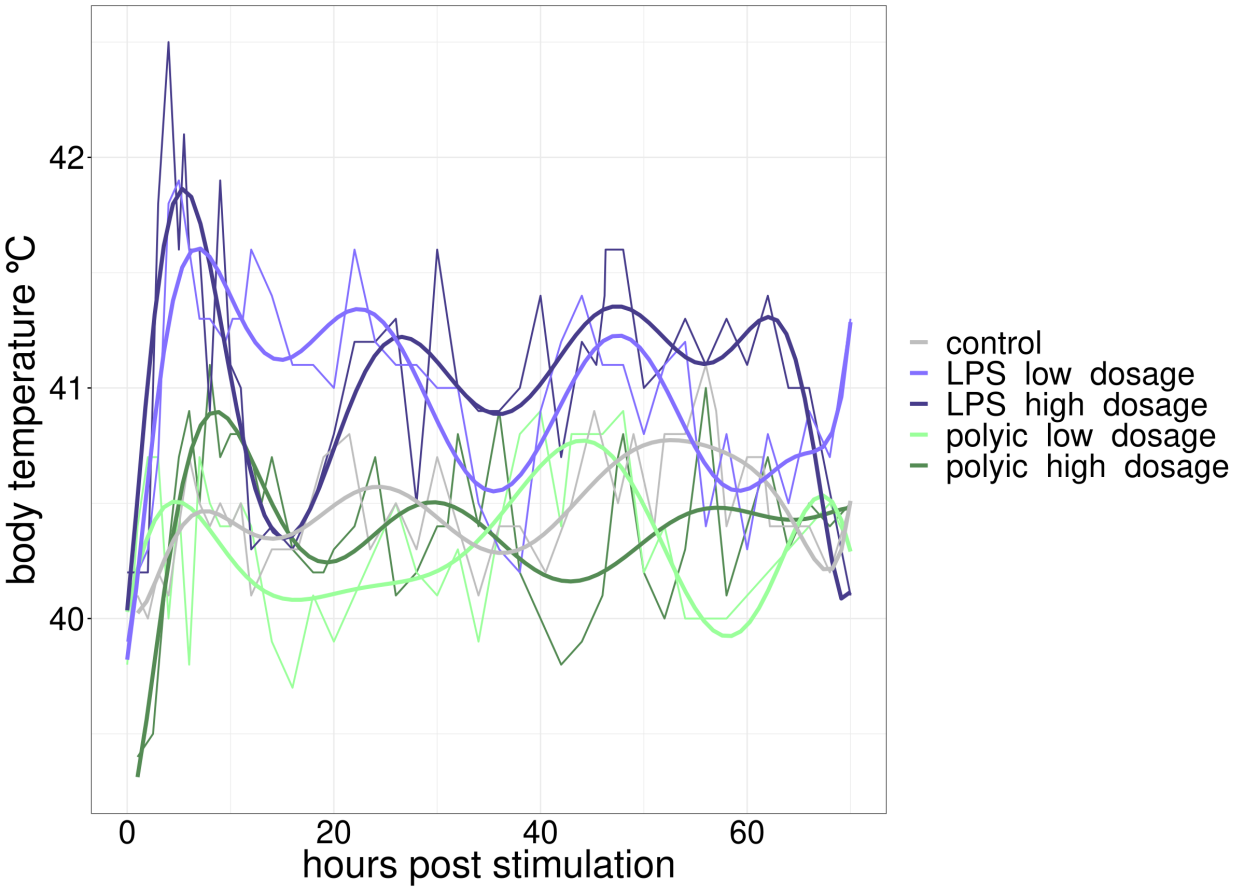


Figure S2. Changes in body temperature in five individuals following challenge with microsphere embedded immune stimulants of different dosages. Thin lines show the raw data, and the thick lines the smoothed conditional means estimated using the stat_smooth() function and the lm smoothing method from the ggplot2 R package, until 72 hours post stimulation.
LPS low dosage = 300 ug LPS/kg bodyweight (60 mg MS diluted in 3mL PBS)
LPS high dosage = 900 ug LPS/kg (180 mg MS diluted in 6mL PBS)
poly I:C low dosage = 3mg poly I:C/kg (60 mg MS diluted in 3mL PBS)
poly I:C high dosage = 9mg poly I:C/kg (180 mg MS diluted in 6mL PBS)
control = 180 mg empty microspheres diluted in 6mL PBS

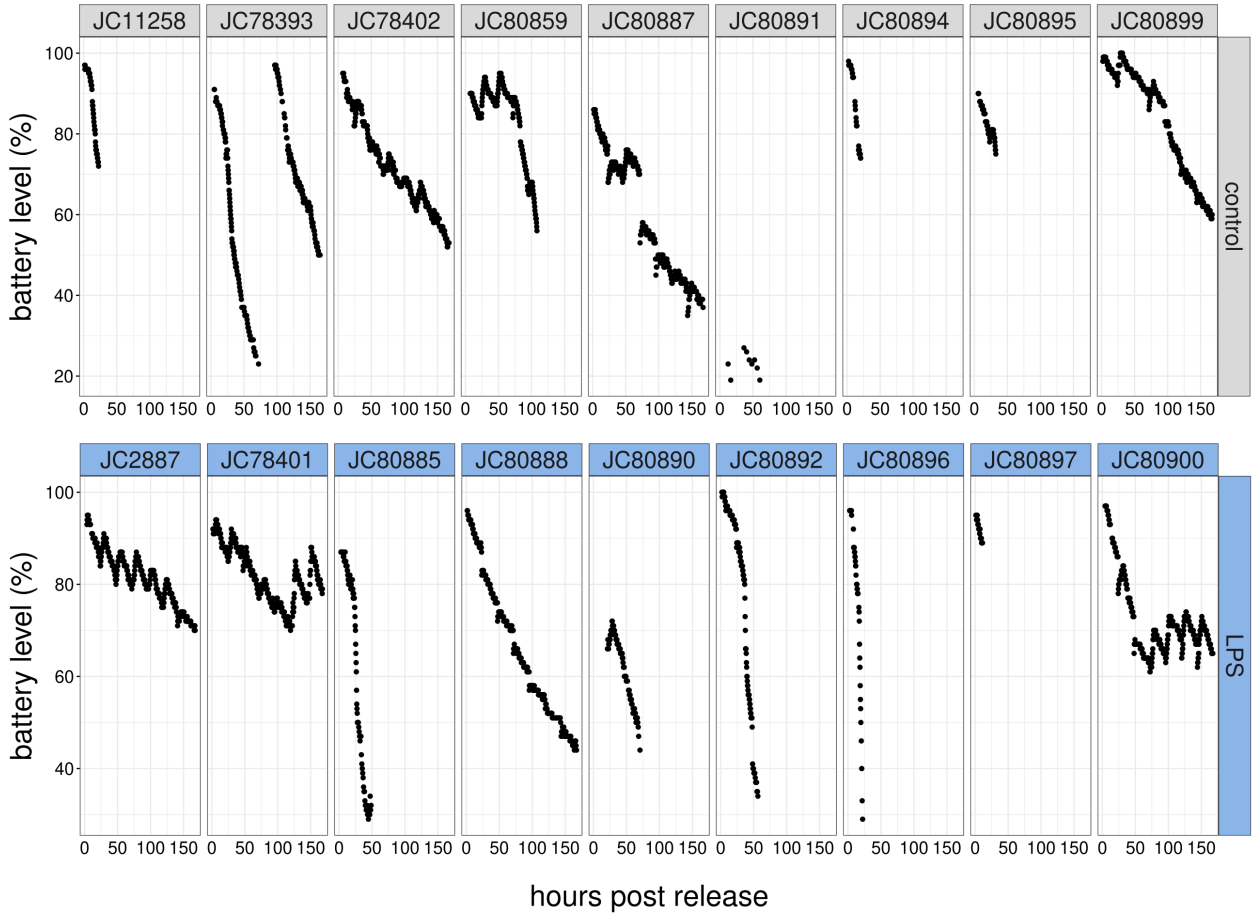


Figure S3. Battery level of biologgers for each recorded GPS fix (HDOP≤2) one week post release. Individual JC78393 was recaptured during the study period whereas its initial biologger was exchanged for new fully changed one.

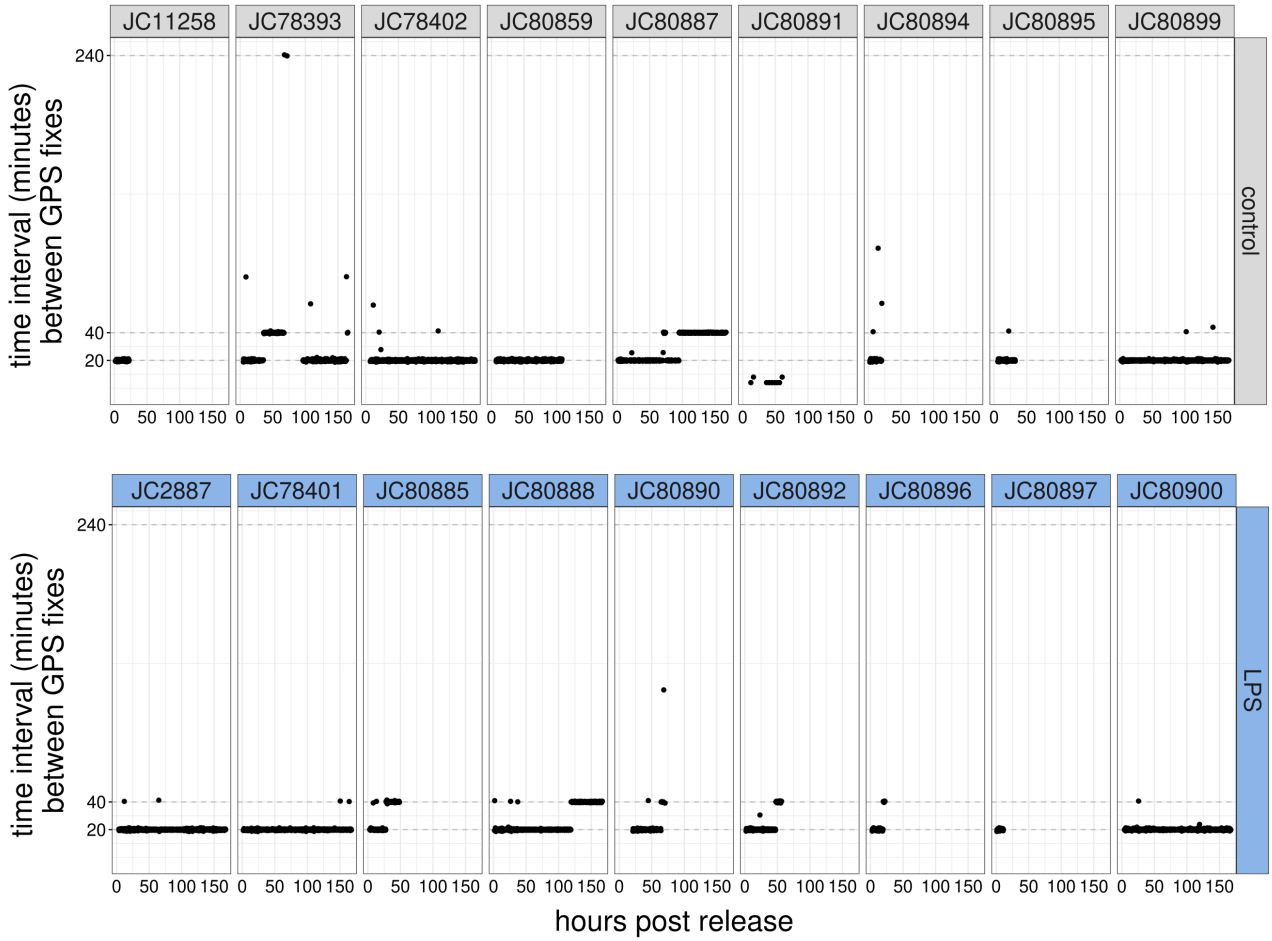


Figure S4. Time interval between consecutive GPS fixes (HDOP≤2) one week post release. Individual JC78393 was recaptured during the study period whereas its initial biologger was exchanged for new fully changed one.

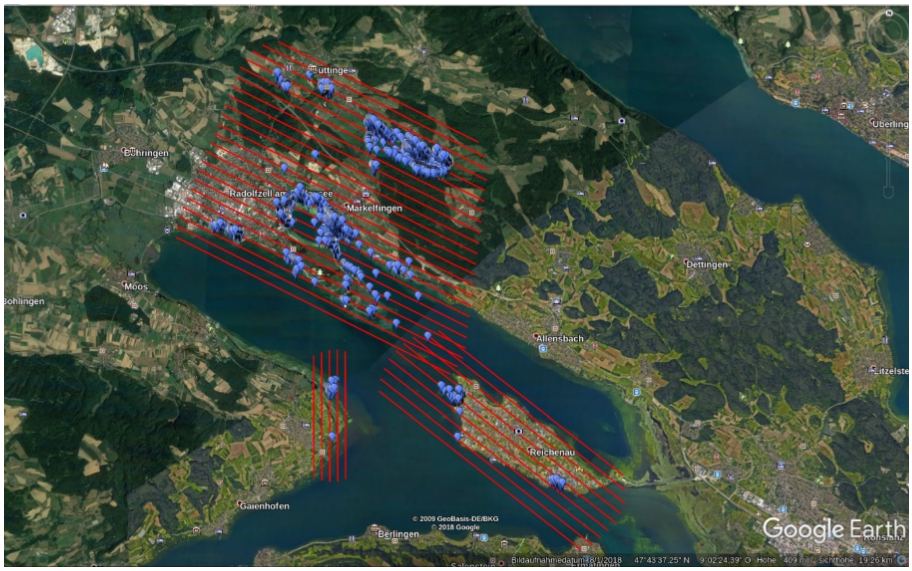


Figure S5. Map showing GPS locations (blue dots) and the area covered by air plane. Satellite image of the study area from Google Earth. (2019).

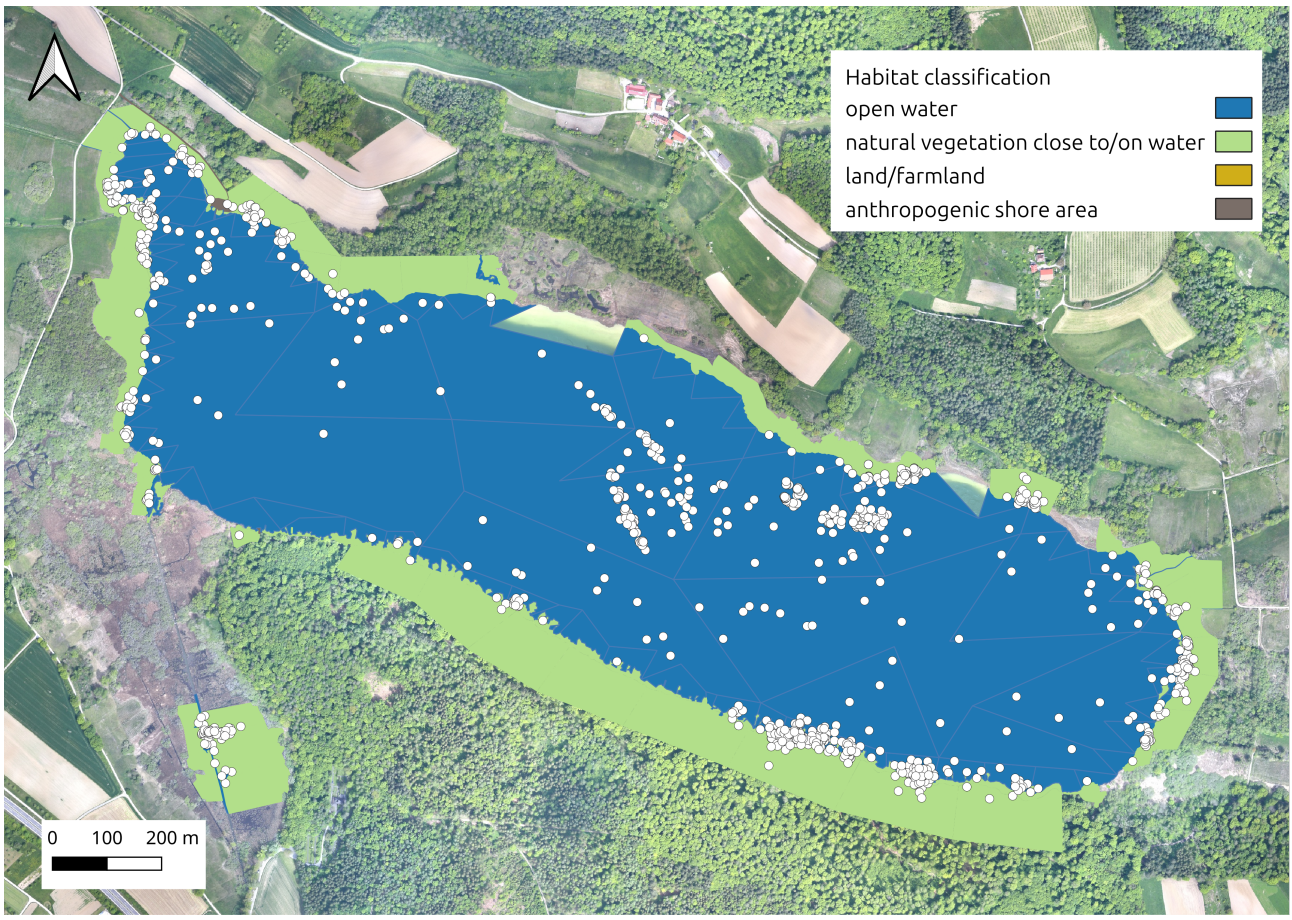


Figure S6. Land cover map visualised on aerial photos for one of the lakes commonly visited by the mallards in the study area, the Mindelsee. The white dots show recorded GPS locations of different mallards observed at this particular lake during the study. The legend shows the four habitat types used by the mallards across the whole study area (the land cover map generated for this part of the study area contains three of the four habitats).

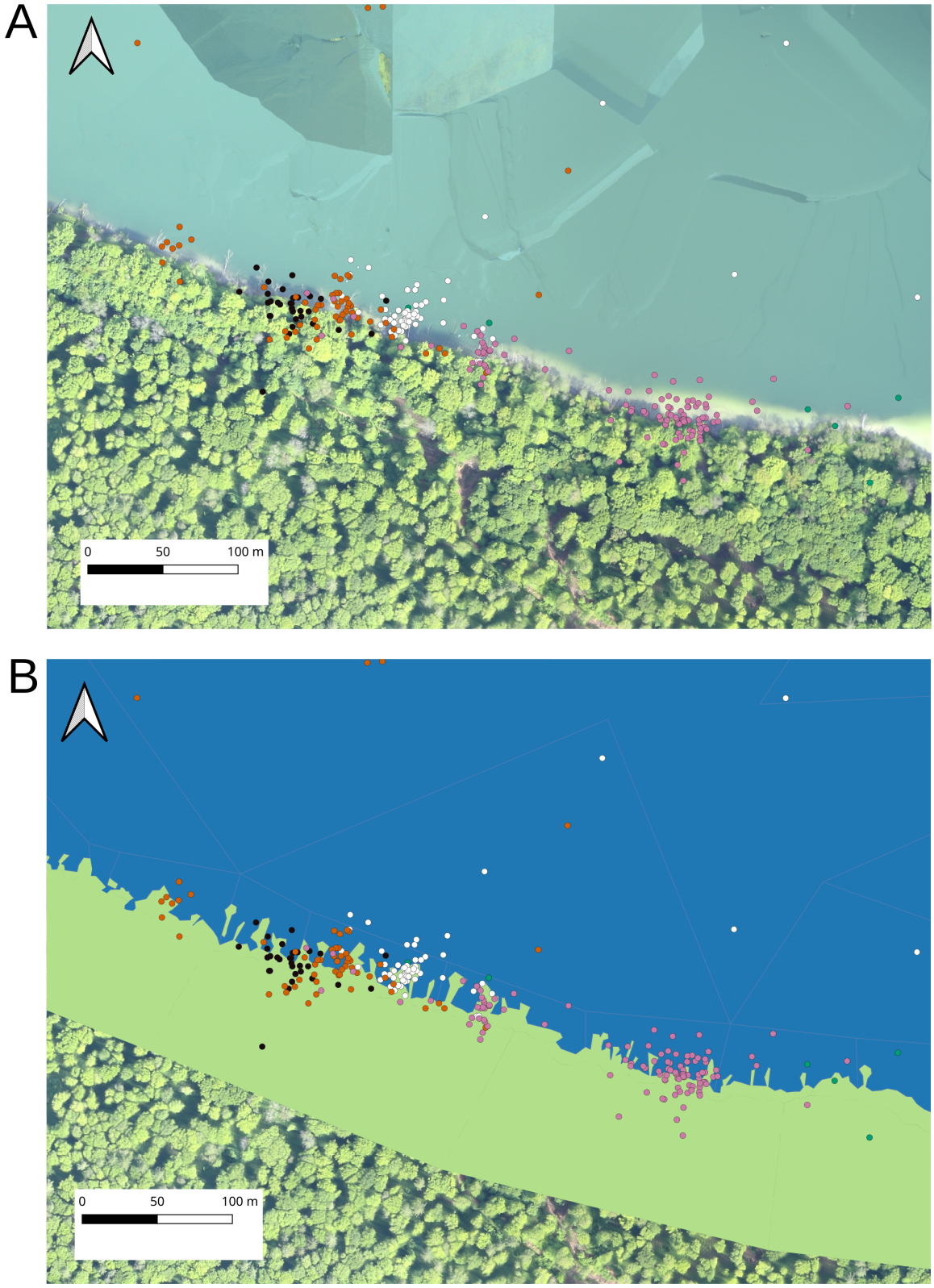


Figure S7. Land cover map visualised on aerial photos - showing a close-up of the habitat classification along the shoreline of Lake Mindelsee. Overhanging trees and/or logs in the water, as well as forest in close proximity to open water were classified as "(Semi)natural vegetation close to/on water" whereas a uncovered water surfaces were classified as "Open water". High quality GPS fixes recorded from mallards are visualised on the map, each colour represents one individual mallard. Once areas to be classified had been identified, dots representing GPS fixes from mallards were removed to allow for detailed classification without knowledge of exact positions of the birds.

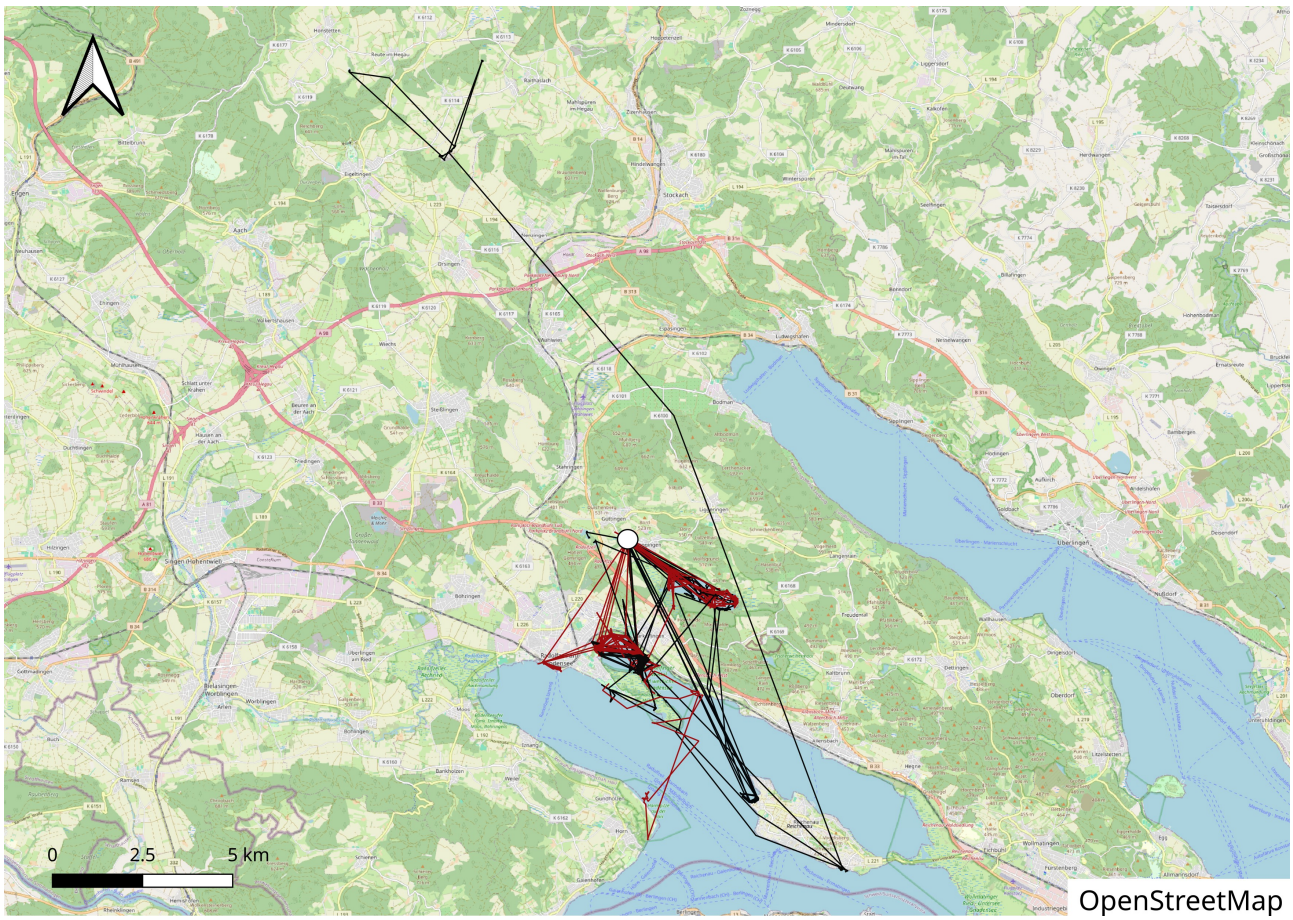


Figure S8. Tracks showing movements of the mallards one week post release in the Lake Constance area, Germany. Tracks from control birds are shown in black (n=9) and from LPS challenged birds in red (n=9). The site of capture and release is shown as white circle. Map data from OpenStreetMap 2026-02-09

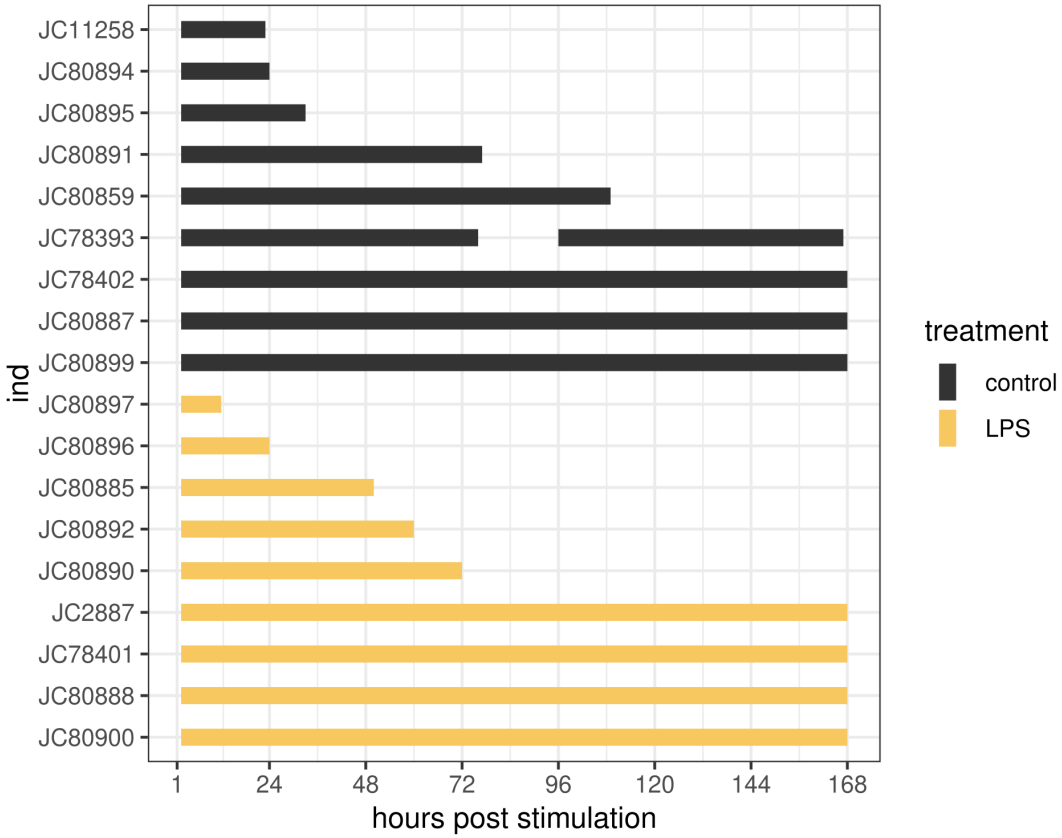


Figure S9. Duration of available ACC data for the activity level analysis. The availability of data decreased over the duration of the study due to rapidly decreasing battery levels in the loggers (Figure S3-4). In total, 25160 ACC bursts were recorded from the loggers. Individual JC78393 was recaptured during the study period whereas its initial biologger was exchanged for new fully changed one.

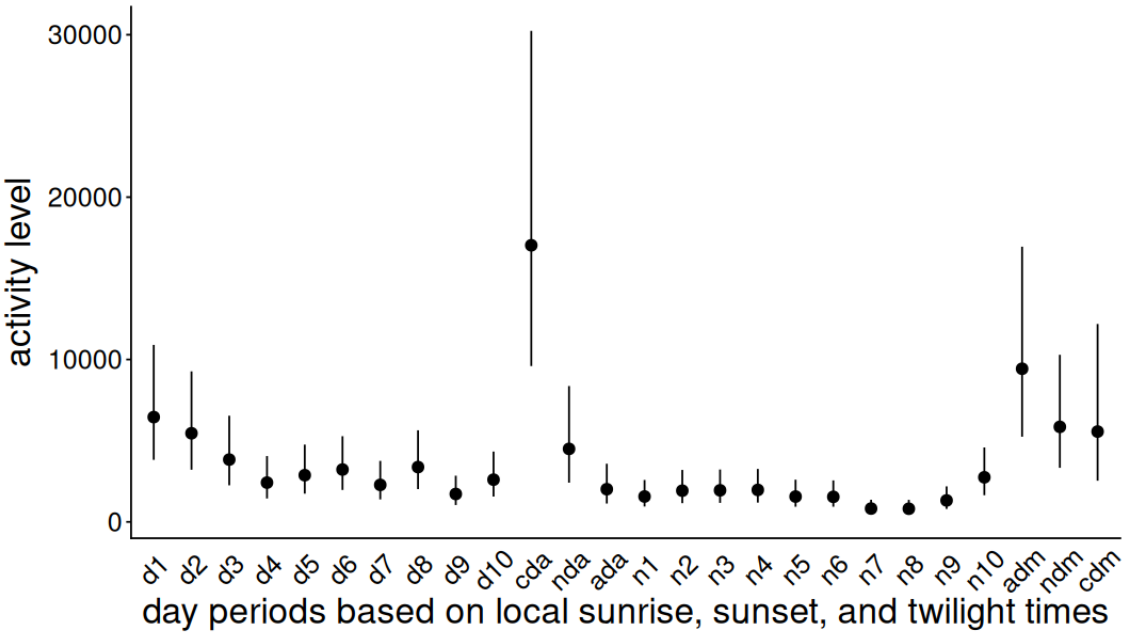


Figure S10. Estimated activity level across different day periods. Model-predicted mean activity level and 95% confidence interval for each day period. An activity value of 0 means no activity. The number of individuals with available logger data decreased from 18 to eight over the seven-day study period (Figure 1 and S9, and Table S1). In total, 1726 data points containing information on activity level per hour (calculated from 25160 ACC bursts) were included in the analysis. adm - Astronomical twilight morning, cda - Civil twilight evening, cdm - Civil twilight morning, nda - Nautical twilight evening, ndm - Nautical twilight morning, n - night, d - day

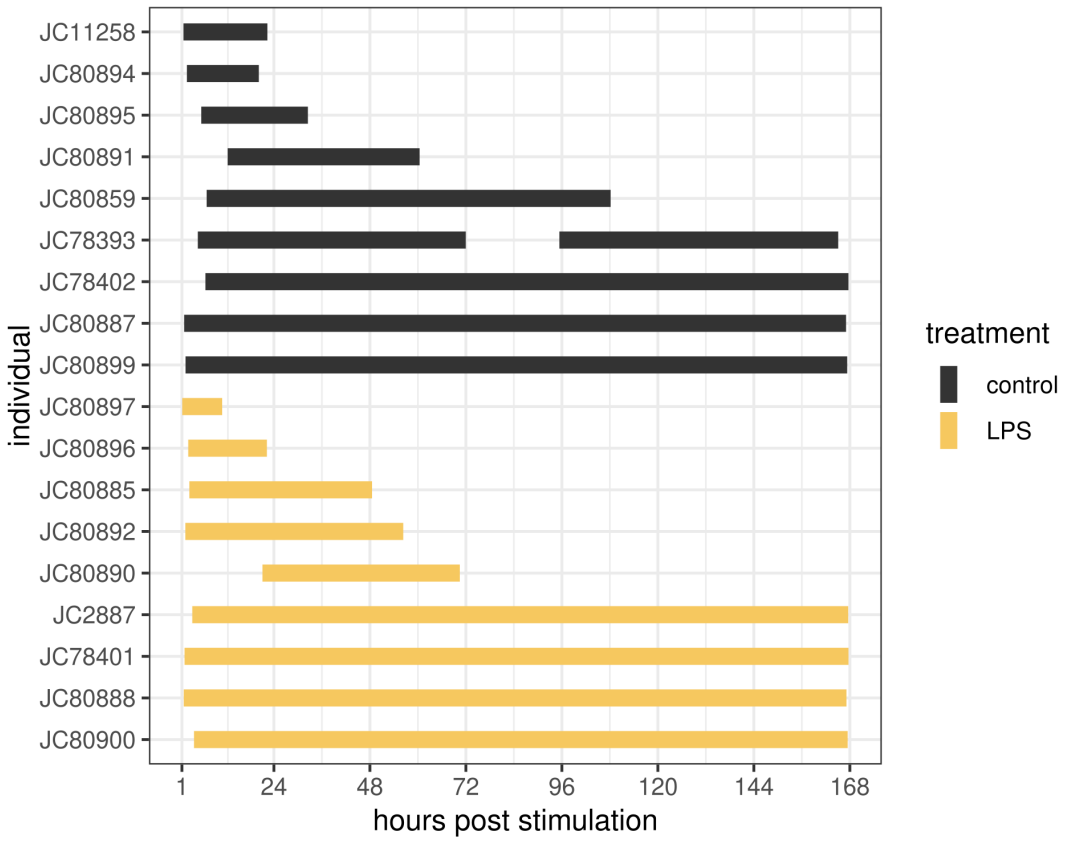


Figure S11. Duration of available GPS data for the speed and habitat analysis. Only GPS data with a Horizontal Dilution of Precision (HDOP) ≤ 2 were included in the habitat use analysis. The availability of data decreased over the duration of the study due to rapidly decreasing battery levels in the loggers (Figure S3-4). Individual JC78393 was recaptured during the study period whereas its initial biologger was exchanged for new fully changed one.

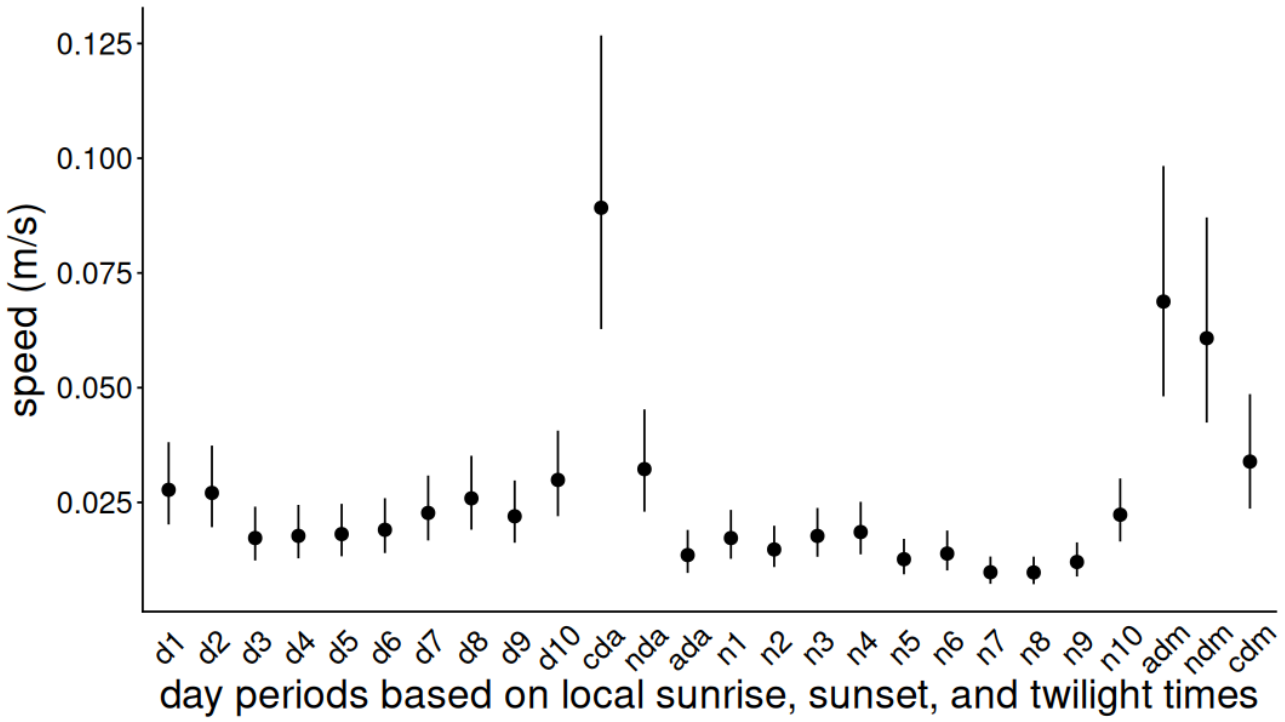


Figure S12. Estimated speed across different day periods. Model-predicted mean speed and 95% confidence interval for each day period. The number of individuals with available logger data decreased from 18 to eight over the seven-day study period (Figure 1 and S11, and Table S1). In total, 4378 high quality GPS points were included in the speed analysis. adm - Astronomical twilight morning, cda - Civil twilight evening, cdm - Civil twilight morning, nda - Nautical twilight evening, ndm - Nautical twilight morning, n - night, d - day

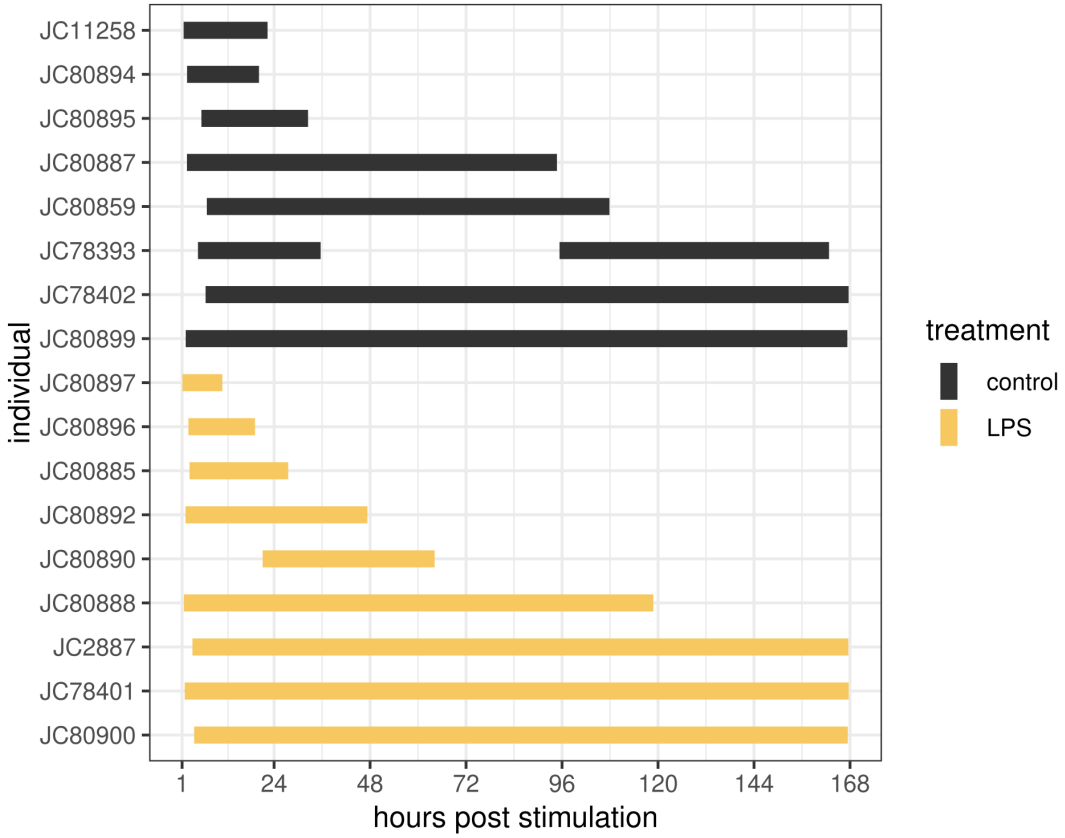


Figure S13. Duration of available GPS data for the distance (step length) analysis. Only GPS data with a Horizontal Dilution of Precision (HDOP) ≤ 2 and with distances measured between GPS fixes recorded 18 to 22 minutes apart were included in the distance analysis. In total, 3914 high quality GPS points remained for the distance analysis after filtering. The availability of data decreased over the duration of the study due to rapidly decreasing battery levels in the loggers (Figures S3-4). Individual JC78393 was recaptured during the study period whereas its initial biologger was exchanged for new fully changed one.

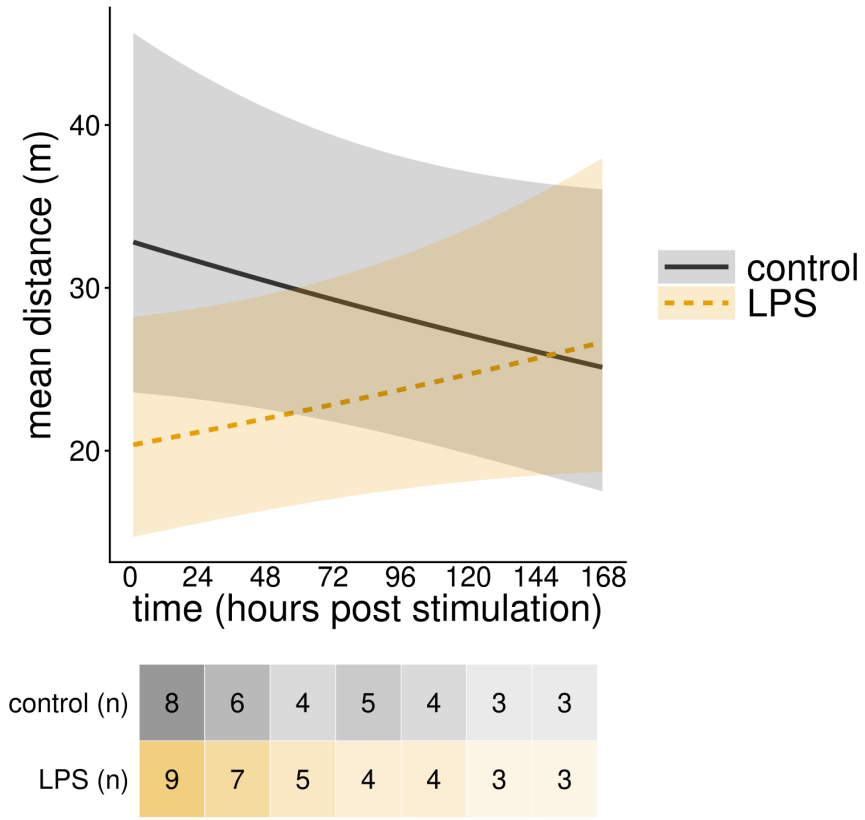


Figure S14. Distance travelled (step length) following challenge with LPS stimulants. Changes in distance travelled (meters per 20 minutes) measured remotely using bio-loggers. Model-predicted mean and 95% confidence interval for each treatment group is plotted until one week post stimulation. After filtering (HDOP > 2 and exclusion of intervals <18 min or >22 min), 3914 high-quality GPS locations remained for the distance analysis. The number of individuals contributing data declined from 8 to 3 in the control group and from 9 to 3 in the LPS treatment group (Figure S13). Numbers below the plot indicate the number of tracked individuals with at least one data point per day.

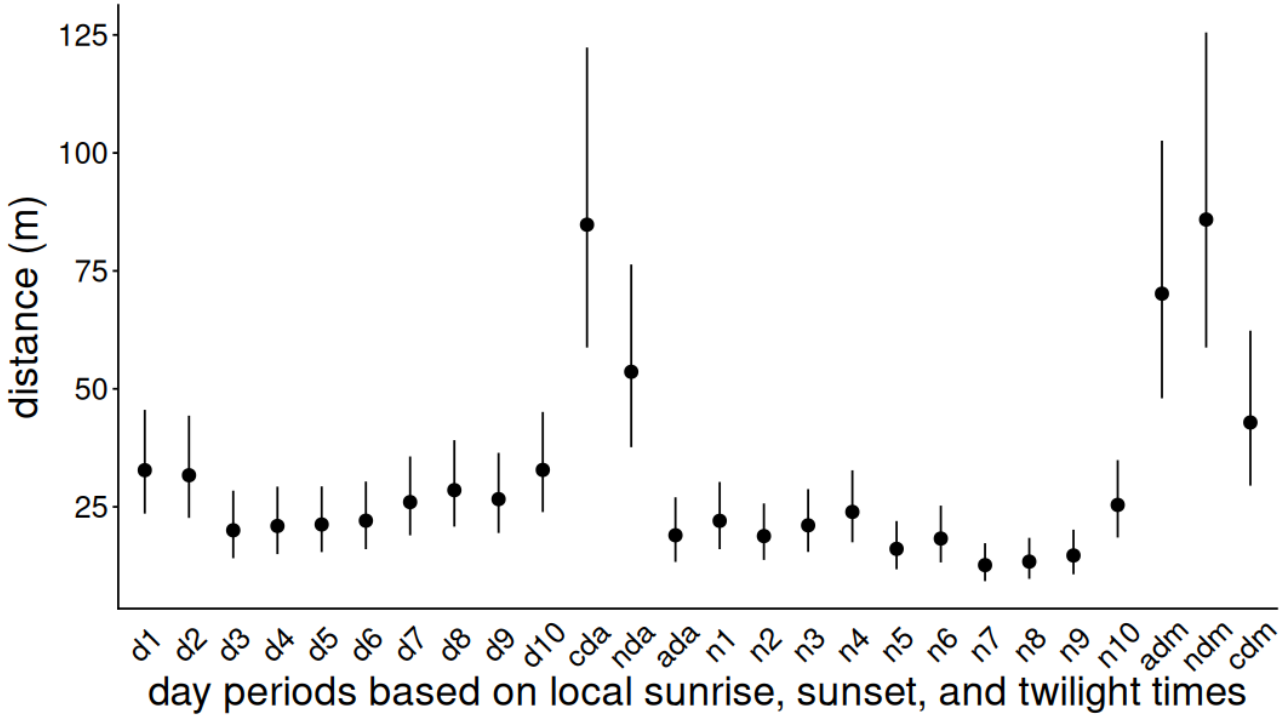


Figure S15. Estimated distances travelled (meters per 20 minutes) across different day periods. Model-predicted mean distance travelled (meters per 20 minutes) and 95% confidence interval for each day period. The number of individuals with available logger data decreased from 18 to six over the seven-day study period (Figure 1 and S13, and Table S1). After filtering (HDOP > 2 and exclusion of intervals <18 min or >22 min), 3914 high-quality GPS locations remained for the distance analysis. adm - Astronomical twilight morning, cda - Civil twilight evening, cdm - Civil twilight morning, nda - Nautical twilight evening, ndm - Nautical twilight morning, n - night, d - day

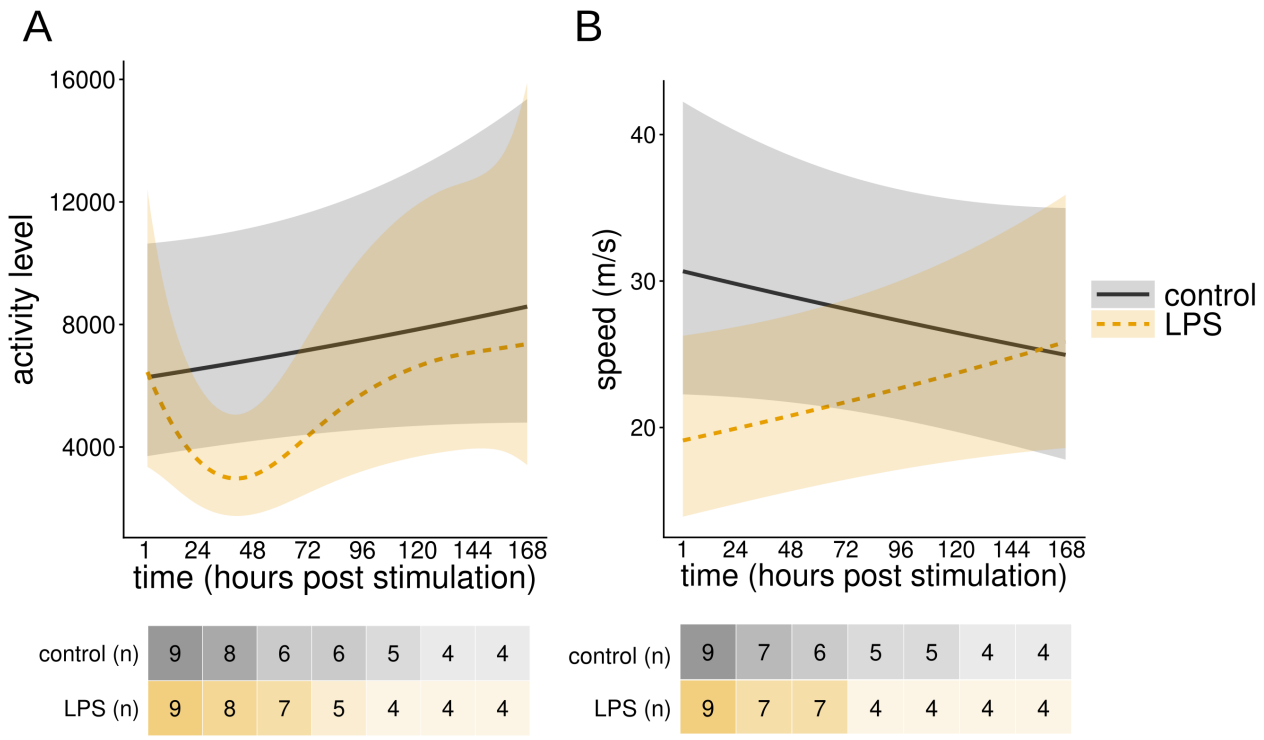


Figure S16. Movement patterns following challenge with LPS stimulants: model predictions accounting for sex. Changes in (A) activity level and (B) minimum speed (meters per second) were measured remotely using bio-loggers. This figure is based on generalized additive mixed models (GAMMs) fitted to the same datasets used for the original analyses, with sex included as an additional fixed effect. For the activity analysis, 1726 hourly data points containing information on activity level (calculated from 25,160 ACC bursts) were included in the model. For the speed analysis, 4378 high-quality GPS points remained after filtering. An activity value of 0 indicates no activity. Although the GAMMs were fitted using data from all individuals with sex included as an additional fixed effect, model predictions (mean ± 95% confidence intervals) are shown for males only (n = 16), as the number of female individuals contributing data was limited and did not allow for equally robust sex-specific visualization. Accordingly, the numbers below the plot indicate the number of male individuals contributing data on each day.

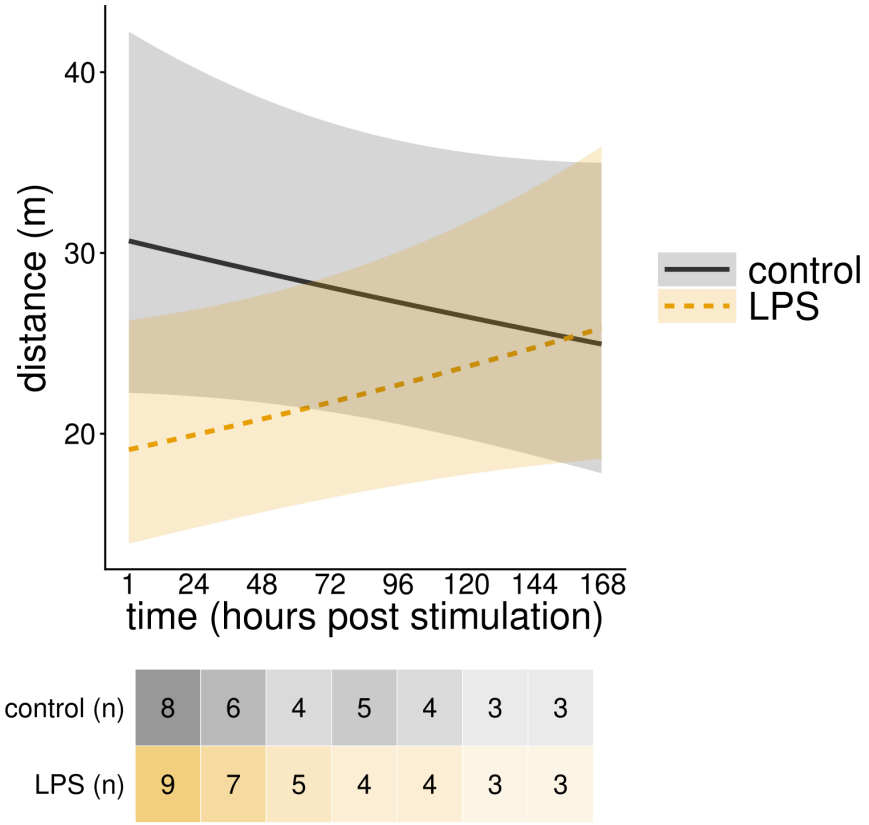


Figure S17. Distance travelled (step length) following challenge with LPS stimulants: model predictions accounting for sex. Changes in distance travelled (meters per 20 minutes) were measured remotely using bio-loggers. This figure is based on generalized additive mixed models (GAMMs) fitted to the same filtered GPS dataset used for the analysis shown in Figure S14, with sex included as an additional fixed effect. After filtering (HDOP > 2 and exclusion of intervals <18 min or >22 min), 3914 high-quality GPS locations from 17 individuals remained for the distance analysis. Predictions are plotted until one week post stimulation. Although the GAMM was fitted using data from all individuals with sex included as an additional fixed effect, model predictions (mean ± 95% confidence intervals) are shown for males only (n = 17), as the number of female individuals contributing data was limited and did not allow for equally robust sex-specific visualization. Accordingly, the numbers below the plot indicate the number of male individuals contributing data on each day.

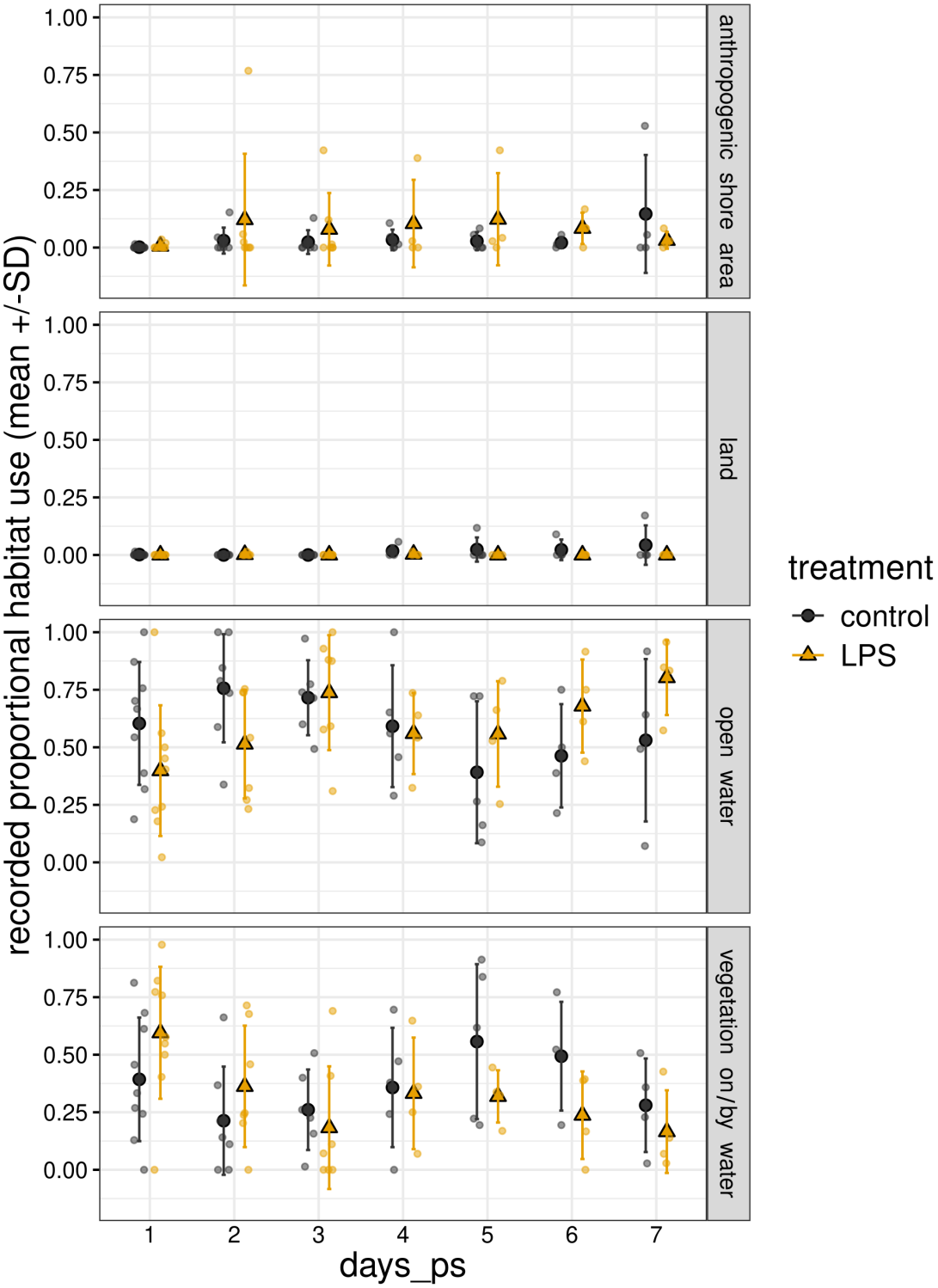


Figure S18. Recorded proportional use of habitat types for each treatment group and time point when using the land cover map from R.T.K.. Mean and standard deviation for the observed proportional use of each habitat for each treatment group and time point (days after stimulation). The observed proportional habitat use for each individual is shown as small circles.

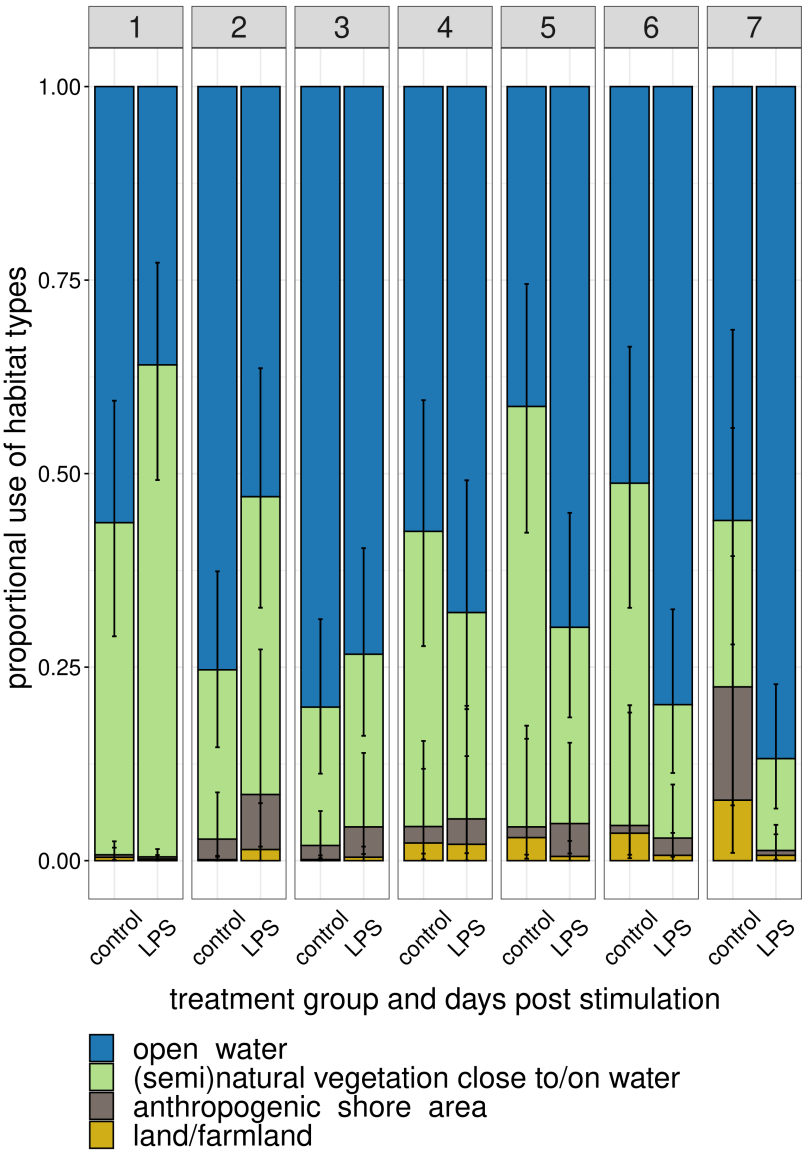


Figure S19. Habitat use following challenge with LPS stimulants when using classification from E.J. Cumulative mean proportion of the habitat types used by the mallards and cumulative 95% Credible Interval as estimated from the posterior distribution of the multinomial model when ran using the land cover map from E.J.. Habitat categories are shown in a consistent order from top to bottom as open water, (semi-)natural vegetation close to/on water, anthropogenic shore area, and land/farmland. The number of individuals included in the habitat use analysis decreased from 9 to 4 in each treatment group during the 7 days which the study took place (Figure S11). In total, habitat type information for 4394 GPS fixes (HDOP≤2) was included in the analysis.

Supplementary tables

Table S1. Overview of study inclusion period and logger data availability for each individual included in the main study.
start and end = time and date when the first and last data point was transmitted from each bio-logger.
hours of data = hours between the first and last transmitted data point from each bio-logger.
datapoints GPS = the total number of transmitted high-quality GPS fixes per bio-logger
datapoints ACC_agg = the number of hours with aggregated acceleration (ACC) data available for each individual
* Individual JC78393 was recaptured during the study period and equipped with a fully charged replacement logger. Therefore, the number of GPS fixes and aggregated ACC records are presented separately for each logger deployment.

individual	device id	treatment	sex	start	end	hours of data	datapoints GPS	datapointsACC_agg
JC80882	182892	LPS	F	2019-01-28 10:00:00		0	0	0
JC80888	171010	LPS	F	2019-01-29 10:57:14	2019-02-05 09:19:35	166.4	423	167
JC80887	180090	control	M	2019-01-29 11:23:05	2019-02-05 09:33:35	166.2	383	167
JC80889	182922	control	F	2019-01-30 10:30:00		0	0	0
JC80885	182934	LPS	M	2019-01-30 11:21:16	2019-02-01 09:41:56	46.3	101	49
JC80891	182898	control	M	2019-01-30 21:13:59	2019-02-02 05:13:59	56.0	10	71
JC80890	182926	LPS	M	2019-01-31 06:17:53	2019-02-02 08:17:50	50.0	126	71
JC80892	182899	LPS	M	2019-01-31 11:26:08	2019-02-02 18:35:35	55.2	148	59
JC11258	182924	control	M	2019-02-05 10:27:15	2019-02-06 07:46:20	21.3	62	22
JC80894	182920	control	M	2019-02-05 11:11:20	2019-02-06 05:30:07	18.3	37	23
JC80896	182919	LPS	M	2019-02-06 11:27:44	2019-02-07 07:47:43	20.3	44	23
JC80895	182918	control	M	2019-02-06 15:04:43	2019-02-07 18:04:03	27.0	71	32
JC80897	182917	LPS	M	2019-02-07 11:13:59	2019-02-07 21:32:50	10.3	28	11
JC78393*	182925	control	M	2019-02-07 15:15:11	2019-02-10 14:15:04	71.0	130	75
JC80859	182896	control	F	2019-02-07 17:14:39	2019-02-11 22:55:05	101.7	288	108
JC78393*	182895	control	M	2019-02-11 10:38:02	2019-02-14 08:02:33	69.4	169	72
JC80899	182901	control	M	2019-02-14 10:49:02	2019-02-21 08:35:43	165.8	484	167
JC2887	182893	LPS	M	2019-02-14 12:35:05	2019-02-21 08:55:59	164.3	473	167
JC80900	182900	LPS	M	2019-02-15 12:16:05	2019-02-22 08:02:41	163.8	459	167
JC78401	182904	LPS	M	2019-02-20	2019-02-27	166.3	490	167

				10:31:08 2019-02-20	08:51:24 2019-02-27			
JC78402	182897	control	M	15:37:09	08:43:02	161.1	468	167

Table S2. Habitats included in the four habitat type categories.

Habitat class	Habitats included in class
open water	open water, artificial water body, streams
(semi)natural vegetation close to/on water	forest close to water, reed bed, forested marsh, marsh, logs on water, trees overhanging water, pond lilies
anthropogenic shore area	urban area, populated lakeside
land/farmland	farmland, grassland

Table S3. Mean proportion of the habitat types used by the mallards and 95% Credible Interval for each day post stimulation and treatment group as estimated from the posterior distribution of the multinomial model. Results from the multinomial model when using the land cover map from R.T.K. (results shown in manuscript).

	treat_days	habitat_type	mean	sd	2.5%	97.5%	Rhat	n.eff
pfit[1,1]	control 1	open_water	0.570	0.078	0.410	0.716	1.001	63000
pfit[1,2]	control 1	vegetation_on_by_water	0.424	0.078	0.276	0.584	1.001	23000
pfit[1,3]	control 1	anthropogenic_shore_area	0.002	0.003	0.000	0.008	1.001	54000
pfit[1,4]	control 1	land	0.004	0.026	0.000	0.015	1.001	7900
pfit[2,1]	control 2	open_water	0.765	0.057	0.639	0.863	1.001	40000
pfit[2,2]	control 2	vegetation_on_by_water	0.204	0.055	0.112	0.326	1.001	18000
pfit[2,3]	control 2	anthropogenic_shore_area	0.029	0.027	0.005	0.099	1.001	34000
pfit[2,4]	control 2	land	0.001	0.011	0.000	0.006	1.001	76000
pfit[3,1]	control 3	open_water	0.812	0.050	0.699	0.894	1.001	86000
pfit[3,2]	control 3	vegetation_on_by_water	0.167	0.048	0.088	0.276	1.001	20000
pfit[3,3]	control 3	anthropogenic_shore_area	0.020	0.020	0.003	0.071	1.001	58000
pfit[3,4]	control 3	land	0.001	0.011	0.000	0.006	1.001	140000
pfit[4,1]	control 4	open_water	0.576	0.084	0.405	0.723	1.007	8800
pfit[4,2]	control 4	vegetation_on_by_water	0.375	0.083	0.220	0.542	1.003	5700
pfit[4,3]	control 4	anthropogenic_shore_area	0.023	0.023	0.003	0.082	1.001	39000
pfit[4,4]	control 4	land	0.025	0.064	0.002	0.122	1.001	5600
pfit[5,1]	control 5	open_water	0.430	0.084	0.267	0.592	1.004	15000
pfit[5,2]	control 5	vegetation_on_by_water	0.519	0.092	0.332	0.686	1.006	3900
pfit[5,3]	control 5	anthropogenic_shore_area	0.015	0.017	0.002	0.057	1.001	23000
pfit[5,4]	control 5	land	0.035	0.075	0.004	0.176	1.001	6800
pfit[6,1]	control 6	open_water	0.540	0.087	0.365	0.696	1.006	10000
pfit[6,2]	control 6	vegetation_on_by_water	0.417	0.087	0.251	0.588	1.004	5300
pfit[6,3]	control 6	anthropogenic_shore_area	0.014	0.016	0.002	0.055	1.001	34000
pfit[6,4]	control 6	land	0.029	0.068	0.003	0.142	1.001	8400
pfit[7,1]	control 7	open_water	0.586	0.105	0.335	0.746	1.009	4300
pfit[7,2]	control 7	vegetation_on_by_water	0.195	0.063	0.084	0.332	1.003	4600
pfit[7,3]	control 7	anthropogenic_shore_area	0.160	0.105	0.032	0.433	1.001	19000
pfit[7,4]	control 7	land	0.059	0.094	0.007	0.292	1.001	6800
pfit[8,1]	LPS 1	open_water	0.352	0.072	0.219	0.500	1.001	55000
pfit[8,2]	LPS 1	vegetation_on_by_water	0.644	0.073	0.492	0.778	1.001	22000
pfit[8,3]	LPS 1	anthropogenic_shore_area	0.003	0.004	0.000	0.012	1.001	22000
pfit[8,4]	LPS 1	land	0.002	0.021	0.000	0.007	1.001	21000
pfit[9,1]	LPS 2	open_water	0.540	0.083	0.373	0.683	1.002	12000
pfit[9,2]	LPS 2	vegetation_on_by_water	0.373	0.081	0.220	0.536	1.001	11000
pfit[9,3]	LPS 2	anthropogenic_shore_area	0.075	0.057	0.015	0.224	1.001	35000
pfit[9,4]	LPS 2	land	0.012	0.068	0.000	0.054	1.001	42000
pfit[10,1]	LPS 3	open_water	0.733	0.066	0.592	0.839	1.003	17000
pfit[10,2]	LPS 3	vegetation_on_by_water	0.221	0.058	0.122	0.350	1.001	28000
pfit[10,3]	LPS 3	anthropogenic_shore_area	0.043	0.036	0.008	0.135	1.001	15000
pfit[10,4]	LPS 3	land	0.004	0.033	0.000	0.015	1.001	140000
pfit[11,1]	LPS 4	open_water	0.682	0.084	0.515	0.806	1.004	13000
pfit[11,2]	LPS 4	vegetation_on_by_water	0.266	0.069	0.144	0.412	1.002	13000
pfit[11,3]	LPS 4	anthropogenic_shore_area	0.034	0.031	0.006	0.111	1.001	29000
pfit[11,4]	LPS 4	land	0.018	0.076	0.000	0.104	1.001	34000
pfit[12,1]	LPS 5	open_water	0.691	0.072	0.540	0.811	1.002	23000
pfit[12,2]	LPS 5	vegetation_on_by_water	0.260	0.066	0.145	0.403	1.001	20000

pfit[12,3]	LPS 5	anthropogenic_shore_area	0.044	0.038	0.008	0.141	1.001	19000
pfit[12,4]	LPS 5	land	0.005	0.036	0.000	0.022	1.001	140000
pfit[13,1]	LPS 6	open_water	0.790	0.062	0.663	0.882	1.004	19000
pfit[13,2]	LPS 6	vegetation_on_by_water	0.181	0.052	0.095	0.298	1.001	35000
pfit[13,3]	LPS 6	anthropogenic_shore_area	0.023	0.022	0.004	0.077	1.001	13000
pfit[13,4]	LPS 6	land	0.006	0.040	0.000	0.030	1.001	77000
pfit[14,1]	LPS 7	open_water	0.870	0.051	0.774	0.933	1.010	22000
pfit[14,2]	LPS 7	vegetation_on_by_water	0.117	0.038	0.058	0.205	1.001	86000
pfit[14,3]	LPS 7	anthropogenic_shore_area	0.007	0.008	0.001	0.026	1.001	20000
pfit[14,4]	LPS 7	land	0.006	0.039	0.000	0.028	1.001	29000

Table S4. Mean proportion of the habitat types used by the mallards and 95% Credible Interval for each day post stimulation and treatment group as estimated from the posterior distribution of the multinomial model. Results from the multinomial model when using the land cover map from E.J. (results shown for comparison to those in main manuscript).

	treat_days	habitat_type	mean	sd	2.5%	97.5%	Rhat	n.eff
pfit[1,1]	control 1	open_water	0.563	0.078	0.406	0.710	1.001	140000
pfit[1,2]	control 1	vegetation_on_by_water	0.429	0.078	0.281	0.586	1.001	33000
pfit[1,3]	control 1	anthropogenic_shore_area	0.003	0.004	0.000	0.013	1.001	43000
pfit[1,4]	control 1	land	0.004	0.026	0.000	0.017	1.001	16000
pfit[2,1]	control 2	open_water	0.753	0.058	0.626	0.853	1.001	110000
pfit[2,2]	control 2	vegetation_on_by_water	0.219	0.057	0.121	0.344	1.001	140000
pfit[2,3]	control 2	anthropogenic_shore_area	0.027	0.023	0.005	0.085	1.001	33000
pfit[2,4]	control 2	land	0.001	0.010	0.000	0.006	1.001	39000
pfit[3,1]	control 3	open_water	0.802	0.051	0.688	0.888	1.001	60000
pfit[3,2]	control 3	vegetation_on_by_water	0.179	0.050	0.095	0.290	1.001	65000
pfit[3,3]	control 3	anthropogenic_shore_area	0.018	0.017	0.003	0.060	1.001	19000
pfit[3,4]	control 3	land	0.001	0.011	0.000	0.007	1.001	110000
pfit[4,1]	control 4	open_water	0.575	0.083	0.405	0.723	1.006	17000
pfit[4,2]	control 4	vegetation_on_by_water	0.381	0.082	0.226	0.546	1.002	12000
pfit[4,3]	control 4	anthropogenic_shore_area	0.021	0.019	0.003	0.071	1.001	21000
pfit[4,4]	control 4	land	0.023	0.062	0.002	0.119	1.001	12000
pfit[5,1]	control 5	open_water	0.413	0.083	0.255	0.576	1.003	26000
pfit[5,2]	control 5	vegetation_on_by_water	0.543	0.091	0.356	0.706	1.006	8000
pfit[5,3]	control 5	anthropogenic_shore_area	0.014	0.014	0.002	0.050	1.001	12000
pfit[5,4]	control 5	land	0.030	0.070	0.003	0.158	1.001	14000
pfit[6,1]	control 6	open_water	0.512	0.088	0.336	0.673	1.005	12000
pfit[6,2]	control 6	vegetation_on_by_water	0.442	0.089	0.266	0.612	1.004	11000
pfit[6,3]	control 6	anthropogenic_shore_area	0.010	0.011	0.001	0.039	1.001	26000
pfit[6,4]	control 6	land	0.035	0.076	0.003	0.191	1.001	25000
pfit[7,1]	control 7	open_water	0.561	0.103	0.314	0.721	1.008	8800
pfit[7,2]	control 7	vegetation_on_by_water	0.215	0.068	0.093	0.359	1.003	9500
pfit[7,3]	control 7	anthropogenic_shore_area	0.146	0.094	0.027	0.390	1.001	11000
pfit[7,4]	control 7	land	0.078	0.110	0.010	0.393	1.001	11000
pfit[8,1]	LPS 1	open_water	0.360	0.072	0.228	0.508	1.001	43000
pfit[8,2]	LPS 1	vegetation_on_by_water	0.636	0.073	0.484	0.769	1.005	14000
pfit[8,3]	LPS 1	anthropogenic_shore_area	0.003	0.003	0.000	0.011	1.002	3600
pfit[8,4]	LPS 1	land	0.002	0.024	0.000	0.007	1.001	140000
pfit[9,1]	LPS 2	open_water	0.530	0.084	0.364	0.673	1.013	11000
pfit[9,2]	LPS 2	vegetation_on_by_water	0.385	0.083	0.227	0.546	1.008	9300
pfit[9,3]	LPS 2	anthropogenic_shore_area	0.071	0.054	0.014	0.214	1.002	1800
pfit[9,4]	LPS 2	land	0.014	0.077	0.000	0.074	1.001	51000
pfit[10,1]	LPS 3	open_water	0.733	0.065	0.596	0.839	1.004	140000
pfit[10,2]	LPS 3	vegetation_on_by_water	0.223	0.058	0.124	0.351	1.001	28000
pfit[10,3]	LPS 3	anthropogenic_shore_area	0.039	0.033	0.007	0.124	1.002	2200
pfit[10,4]	LPS 3	land	0.004	0.035	0.000	0.018	1.001	94000
pfit[11,1]	LPS 4	open_water	0.679	0.088	0.509	0.804	1.013	8000
pfit[11,2]	LPS 4	vegetation_on_by_water	0.267	0.069	0.143	0.411	1.005	9300
pfit[11,3]	LPS 4	anthropogenic_shore_area	0.033	0.029	0.006	0.106	1.002	2000
pfit[11,4]	LPS 4	land	0.021	0.086	0.000	0.135	1.001	140000
pfit[12,1]	LPS 5	open_water	0.699	0.071	0.551	0.815	1.006	47000
pfit[12,2]	LPS 5	vegetation_on_by_water	0.254	0.064	0.142	0.393	1.001	21000
pfit[12,3]	LPS 5	anthropogenic_shore_area	0.043	0.036	0.008	0.134	1.002	2100

pfit[12,4]	LPS 5	land	0.005	0.039	0.000	0.025	1.001	140000
pfit[13,1]	LPS 6	open_water	0.798	0.062	0.675	0.887	1.002	73000
pfit[13,2]	LPS 6	vegetation_on_by_water	0.172	0.050	0.090	0.284	1.001	50000
pfit[13,3]	LPS 6	anthropogenic_shore_area	0.022	0.020	0.004	0.073	1.002	2100
pfit[13,4]	LPS 6	land	0.007	0.044	0.000	0.036	1.001	130000
pfit[14,1]	LPS 7	open_water	0.868	0.055	0.772	0.933	1.024	11000
pfit[14,2]	LPS 7	vegetation_on_by_water	0.119	0.038	0.058	0.206	1.001	15000
pfit[14,3]	LPS 7	anthropogenic_shore_area	0.006	0.007	0.001	0.022	1.002	2300
pfit[14,4]	LPS 7	land	0.007	0.046	0.000	0.034	1.001	50000

Table S5. Full GAMM Results for activity

Model summary

- Error distribution: Gaussian
- Link function: Identity
- Adjusted R^2 = 0.147
- Scale estimate = 2.7766
- *n* = 1,785

A. Parametric fixed effects (log-activity scale) - activity

			Confidence Interval (95%)	
	Estimate	Std. Error	2.5%	97.5%
(Intercept)	7.737	0.274	7.199	8.274
treatmentLPS	-0.399	0.210	-0.811	0.012
tz2adm	1.544	0.336	0.886	2.202
tz2cda	2.136	0.298	1.552	2.719
tz2cdm	1.016	0.426	0.182	1.851
tz2d1	1.165	0.310	0.557	1.773
tz2d10	0.256	0.299	-0.331	0.843
tz2d2	0.997	0.312	0.385	1.610
tz2d3	0.645	0.316	0.026	1.264
tz2d4	0.183	0.311	-0.425	0.792
tz2d5	0.357	0.306	-0.243	0.956
tz2d6	0.471	0.301	-0.120	1.062
tz2d7	0.124	0.304	-0.471	0.719
tz2d8	0.517	0.309	-0.089	1.123
tz2d9	-0.158	0.303	-0.751	0.435
tz2n1	-0.253	0.272	-0.785	0.279
tz2n10	0.311	0.306	-0.289	0.910
tz2n2	-0.047	0.299	-0.633	0.539
tz2n3	-0.035	0.303	-0.628	0.558
tz2n4	-0.022	0.303	-0.617	0.572
tz2n5	-0.255	0.307	-0.857	0.347
tz2n6	-0.266	0.304	-0.863	0.330
tz2n7	-0.898	0.306	-1.497	-0.298
tz2n8	-0.912	0.309	-1.518	-0.306
tz2n9	-0.421	0.304	-1.016	0.174
tz2nda	0.804	0.338	0.141	1.466
tz2ndm	1.067	0.328	0.425	1.710

adm - Astronomical twilight morning, cda - Civil twilight evening, cdm - Civil twilight morning, nda - Nautical twilight evening, ndm - Nautical twilight morning, n - night, d - day
Here, the 95% confidence intervals were calculated using confint().

B. Smooth terms - activity

	edf	Ref.df
s(hrs_ps):treatmentcontrol	1.00	1.000
s(hrs_ps):treatmentLPS	3.70	3.698

C. Random effects (variance components) - activity

Random_effect	SD	Variance	ICC

(Intercept)	0.352	0.124	0.043
Residual	1.666	2.777	NA

D. Correlation structure - activity

Structure	Phi
AR(1)	0.252

AR(1) structure applied within individuals to account for temporal autocorrelation.

E. Model fit statistics - activity

n_observations	n_individuals	Adjusted_R2	logLik
1785	18	0.147	-3401.790

Table S6. Full GAMM Results for speed

Model summary

- Error distribution: Gaussian
- Link function: Identity
- Adjusted $R^2 = 0.116$
- Scale estimate = 2.1084
- *n = 4,378*

A. Parametric fixed effects (log-speed scale) - speed

			Confidence Interval (95%)	
	Estimate	Std. Error	2.5%	97.5%
(Intercept)	-3.728	0.143	-4.009	-3.447
treatmentLPS	-0.222	0.096	-0.410	-0.034
tz2d2	-0.025	0.166	-0.350	0.300
tz2d3	-0.476	0.188	-0.843	-0.108
tz2d4	-0.449	0.186	-0.814	-0.084
tz2d5	-0.427	0.182	-0.784	-0.071
tz2d6	-0.377	0.182	-0.733	-0.021
tz2d7	-0.200	0.180	-0.554	0.153
tz2d8	-0.069	0.180	-0.423	0.284
tz2d9	-0.233	0.179	-0.585	0.118
tz2d10	0.075	0.180	-0.279	0.428
tz2cda	1.168	0.200	0.776	1.560
tz2nda	0.151	0.195	-0.232	0.533
tz2ada	-0.719	0.195	-1.101	-0.336
tz2n1	-0.476	0.179	-0.828	-0.125
tz2n2	-0.632	0.177	-0.979	-0.285
tz2n3	-0.450	0.177	-0.796	-0.103
tz2n4	-0.403	0.179	-0.754	-0.053
tz2n5	-0.788	0.178	-1.137	-0.439
tz2n6	-0.694	0.181	-1.049	-0.340
tz2n7	-1.042	0.177	-1.388	-0.696
tz2n8	-1.047	0.178	-1.396	-0.698
tz2n9	-0.837	0.178	-1.186	-0.487
tz2n10	-0.218	0.177	-0.564	0.129
tz2adm	0.908	0.199	0.518	1.297
tz2ndm	0.784	0.195	0.401	1.167
tz2cdm	0.200	0.177	-0.147	0.548

adm - Astronomical twilight morning, cda - Civil twilight evening, cdm - Civil twilight morning, nda - Nautical twilight evening, ndm - Nautical twilight morning, n - night, d - day
Here, the 95% confidence intervals were calculated using confint().

B. Smooth terms - speed

	edf	Ref.df
s(hrs_ps):treatmentcontrol	1.00	1
s(hrs_ps):treatmentLPS	1.00	1

C. Random effects (variance components) - speed

Random_effect	SD	Variance	ICC
(Intercept)	0.128	0.017	0.008
Residual	1.452	2.108	NA

D. Correlation structure - speed

Structure	Phi
AR(1)	0.34

AR(1) structure applied within individuals to account for temporal autocorrelation.

E. Model fit statistics - speed

n_observations	n_individuals	Adjusted_R2	logLik
4378	18	0.116294	-7582.177

Table S7. Full GAMM Results for step length (distance travelled)

Model summary

• Error distribution: Gaussian
• Link function: Identity
• Adjusted R^2 = 0.108
• Scale estimate = 2.022
• n = 3,914

A. Parametric fixed effects (log-distance scale) - distance

			Confidence Interval (95%)	
	Estimate	Std. Error	2.5%	97.5%
(Intercept)	3.377	0.148	3.087	3.667
treatmentLPS	-0.249	0.095	-0.434	-0.064
tz2d2	-0.033	0.172	-0.370	0.303
tz2d3	-0.492	0.197	-0.878	-0.106
tz2d4	-0.448	0.194	-0.829	-0.066
tz2d5	-0.432	0.190	-0.805	-0.060
tz2d6	-0.395	0.189	-0.767	-0.024
tz2d7	-0.231	0.188	-0.599	0.137
tz2d8	-0.138	0.187	-0.506	0.229
tz2d9	-0.207	0.187	-0.574	0.159
tz2d10	0.002	0.188	-0.367	0.371
tz2cda	0.951	0.210	0.539	1.362
tz2nda	0.492	0.205	0.091	0.894
tz2ada	-0.546	0.204	-0.946	-0.146
tz2n1	-0.397	0.188	-0.766	-0.027
tz2n2	-0.555	0.186	-0.919	-0.192
tz2n3	-0.441	0.186	-0.805	-0.077
tz2n4	-0.314	0.186	-0.680	0.051
tz2n5	-0.711	0.186	-1.076	-0.347
tz2n6	-0.584	0.189	-0.955	-0.212
tz2n7	-0.952	0.185	-1.314	-0.589
tz2n8	-0.895	0.187	-1.262	-0.527
tz2n9	-0.802	0.186	-1.167	-0.437
tz2n10	-0.254	0.185	-0.618	0.109
tz2adm	0.762	0.211	0.348	1.175
tz2ndm	0.964	0.205	0.561	1.366
tz2cdm	0.269	0.184	-0.092	0.629

adm - Astronomical twilight morning, cda - Civil twilight evening, cdm - Civil twilight morning, nda - Nautical twilight evening, ndm - Nautical twilight morning, n - night, d - day
Here, the 95% confidence intervals were calculated using confint().

B. Smooth terms - distance

	edf	Ref.df
s(hrs_ps):treatmentcontrol	1.00	1.000
s(hrs_ps):treatmentLPS	1.00	1.000

C. Random effects (variance components) - distance

Random_effect	SD	Variance	ICC
(Intercept)	0.115	0.013	0.007

Residual	1.422	2.022	NA

D. Correlation structure - distance

Structure	Phi
AR(1)	0.362

AR(1) structure applied within individuals to account for temporal autocorrelation.

E. Model fit statistics - distance

n_observations	n_individuals	Adjusted_R2	logLik
3914	17	0.108	-6662.330

Table S8. Full GAMM results for activity including sex as a fixed effect

Model summary

- Error distribution: Gaussian
- Link function: Identity
- Adjusted R^2 = 0.148
- Scale estimate = 2.7766
- *n* = 1,785

A. Parametric fixed effects (log-activity scale) - activity

			Confidence Interval (95%)	
	Estimate	Std. Error	2.5%	97.5%
(Intercept)	7.925	0.379	7.182	8.667
treatmentLPS	-0.404	0.207	-0.810	0.001
sexM	-0.215	0.301	-0.806	0.375
tz2adm	1.546	0.336	0.888	2.204
tz2cda	2.134	0.298	1.551	2.718
tz2cdm	1.020	0.426	0.186	1.855
tz2d1	1.166	0.310	0.558	1.774
tz2d10	0.257	0.299	-0.330	0.844
tz2d2	0.998	0.313	0.386	1.611
tz2d3	0.645	0.316	0.026	1.264
tz2d4	0.184	0.311	-0.425	0.793
tz2d5	0.357	0.306	-0.242	0.957
tz2d6	0.472	0.301	-0.119	1.063
tz2d7	0.125	0.304	-0.470	0.721
tz2d8	0.518	0.309	-0.087	1.124
tz2d9	-0.156	0.303	-0.750	0.437
tz2n1	-0.252	0.272	-0.785	0.280
tz2n10	0.312	0.306	-0.288	0.911
tz2n2	-0.046	0.299	-0.632	0.540
tz2n3	-0.035	0.303	-0.628	0.558
tz2n4	-0.023	0.304	-0.618	0.571
tz2n5	-0.255	0.307	-0.857	0.348
tz2n6	-0.265	0.304	-0.861	0.332
tz2n7	-0.896	0.306	-1.496	-0.297
tz2n8	-0.911	0.309	-1.517	-0.305
tz2n9	-0.421	0.304	-1.016	0.174
tz2nda	0.805	0.338	0.142	1.467
tz2ndm	1.068	0.328	0.426	1.710

adm - Astronomical twilight morning, cda - Civil twilight evening, cdm - Civil twilight morning, nda - Nautical twilight evening, ndm - Nautical twilight morning, n - night, d - day
Here, the 95% confidence intervals were calculated using confint().
The sex coefficient represents the difference between males and females, with females as the reference category. Because only two females were included in the analysis, this estimate should be interpreted cautiously.

B. Smooth terms - activity

	edf	Ref.df
s(hrs_ps):treatmentcontrol	1.00	1.000
s(hrs_ps):treatmentLPS	3.70	3.703

C. Random effects (variance components) - activity

Random_effect	SD	Variance	ICC
(Intercept)	0.344	0.118	0.041
Residual	1.666	2.777	NA

D. Correlation structure - activity

Structure	Phi
AR(1)	0.252

AR(1) structure applied within individuals to account for temporal autocorrelation.

E. Model fit statistics - activity

n_observations	n_individuals	Adjusted_R2	logLik
1785	0	0.148	-3401.534

Table S9. Full GAMM results for speed including sex as a fixed effect

Model summary

- Error distribution: Gaussian
- Link function: Identity
- Adjusted $R^2 = 0.122$
- Scale estimate = 2.1098
- n = 4,378

A. Parametric fixed effects (log-speed scale) - speed

			Confidence Interval (95%)	
	Estimate	Std. Error	2.5%	97.5%
(Intercept)	-3.439	0.153	-3.738	-3.139
treatmentLPS	-0.236	0.063	-0.359	-0.112
sexM	-0.318	0.086	-0.486	-0.150
tz2d2	-0.026	0.166	-0.351	0.299
tz2d3	-0.476	0.188	-0.843	-0.108
tz2d4	-0.448	0.186	-0.813	-0.082
tz2d5	-0.426	0.182	-0.782	-0.069
tz2d6	-0.375	0.182	-0.731	-0.020
tz2d7	-0.197	0.180	-0.550	0.157
tz2d8	-0.067	0.180	-0.421	0.286
tz2d9	-0.233	0.179	-0.585	0.118
tz2d10	0.076	0.181	-0.277	0.430
tz2cda	1.170	0.200	0.778	1.562
tz2nda	0.148	0.195	-0.235	0.531
tz2ada	-0.721	0.195	-1.104	-0.338
tz2n1	-0.476	0.180	-0.828	-0.124
tz2n2	-0.634	0.177	-0.981	-0.286
tz2n3	-0.453	0.177	-0.800	-0.106
tz2n4	-0.406	0.179	-0.756	-0.055
tz2n5	-0.790	0.178	-1.139	-0.440
tz2n6	-0.697	0.181	-1.051	-0.342
tz2n7	-1.048	0.177	-1.394	-0.701
tz2n8	-1.050	0.178	-1.399	-0.701
tz2n9	-0.838	0.178	-1.188	-0.488
tz2n10	-0.221	0.177	-0.567	0.126
tz2adm	0.906	0.199	0.517	1.296
tz2ndm	0.782	0.195	0.399	1.165
tz2cdm	0.199	0.177	-0.149	0.547

adm - Astronomical twilight morning, cda - Civil twilight evening, cdm - Civil twilight morning, nda - Nautical twilight evening, ndm - Nautical twilight morning, n - night, d - day
Here, the 95% confidence intervals were calculated using confint().
The sex coefficient represents the difference between males and females, with females as the reference category. Because only two females were included in the analysis, this estimate should be interpreted cautiously.

B. Smooth terms - speed

	edf	Ref.df
s(hrs_ps):treatmentcontrol	1.00	1
s(hrs_ps):treatmentLPS	1.00	1

C. Random effects (variance components) - speed

Random_effect	SD	Variance	ICC
(Intercept)	0.005	~0.000	<0.001
Residual	1.453	2.110	NA

D. Correlation structure - speed

Structure	Phi
AR(1)	0.34

AR(1) structure applied within individuals to account for temporal autocorrelation.

E. Model fit statistics - speed

n_observations	n_individuals	Adjusted_R2	logLik
4378	18	0.1217964	-7577.614

Table S10. Full GAMM Results for step length (distance travelled) including sex as a fixed effect

Model summary

- Error distribution: Gaussian
- Link function: Identity
- Adjusted $R^2 = 0.113$
- Scale estimate = 2.022
- n = 3,914

A. Parametric fixed effects (log-distance scale) - distance

			Confidence Interval (95%)	
	Estimate	Std. Error	2.5%	97.5%
(Intercept)	3.646	0.160	3.332	3.960
treatmentLPS	-0.257	0.067	-0.388	-0.126
sexM	-0.310	0.092	-0.491	-0.130
tz2d2	-0.032	0.172	-0.369	0.304
tz2d3	-0.488	0.197	-0.874	-0.102
tz2d4	-0.441	0.194	-0.822	-0.060
tz2d5	-0.424	0.190	-0.796	-0.051
tz2d6	-0.388	0.189	-0.759	-0.016
tz2d7	-0.223	0.188	-0.591	0.145
tz2d8	-0.132	0.187	-0.499	0.235
tz2d9	-0.202	0.187	-0.569	0.164
tz2d10	0.008	0.188	-0.361	0.376
tz2cda	0.958	0.210	0.547	1.370
tz2nda	0.496	0.205	0.094	0.898
tz2ada	-0.540	0.204	-0.940	-0.140
tz2n1	-0.390	0.188	-0.760	-0.021
tz2n2	-0.553	0.186	-0.917	-0.190
tz2n3	-0.439	0.186	-0.803	-0.075
tz2n4	-0.313	0.186	-0.678	0.052
tz2n5	-0.710	0.186	-1.075	-0.346
tz2n6	-0.583	0.189	-0.954	-0.212
tz2n7	-0.955	0.185	-1.317	-0.592
tz2n8	-0.895	0.187	-1.262	-0.527
tz2n9	-0.801	0.186	-1.166	-0.437
tz2n10	-0.256	0.185	-0.620	0.107
tz2adm	0.760	0.211	0.346	1.174
tz2ndm	0.966	0.205	0.563	1.368
tz2cdm	0.270	0.184	-0.090	0.631

adm - Astronomical twilight morning, cda - Civil twilight evening, cdm - Civil twilight morning, nda - Nautical twilight evening, ndm - Nautical twilight morning, n - night, d - day
Here, the 95% confidence intervals were calculated using confint().
The sex coefficient represents the difference between males and females, with females as the reference category. Because only two females were included in the analysis, this estimate should be interpreted cautiously.

B. Smooth terms - distance

	edf	Ref.df	
s(hrs_ps):treatmentcontrol	1.00		1.000
s(hrs_ps):treatmentLPS	1.00		1.000

C. Random effects (variance components) - distance

Random_effect	SD	Variance	ICC
(Intercept)	0.001	<0.001	<0.001
Residual	1.422	2.022	NA

D. Correlation structure - distance

Structure	Phi
AR(1)	0.362

AR(1) structure applied within individuals to account for temporal autocorrelation.

E. Model fit statistics - distance

n_observations	n_individuals	Adjusted_R2	logLik
3914	17	0.113	-6658.178

Table S11. The posterior probability (certainty) of the hypothesis that the mean proportional use of a habitat type is smaller in the control group than in the treatment group from the first until the seventh days post stimulation (dps). Results from the multinomial model when using the land cover map from R.T.K. (results shown in manuscript).

habitat class / days post stimulation (dps)	1 dps	2 dps	3 dps	4 dps	5 dps	6 dps	7 dps
open water	0.024	0.010	0.152	0.850	0.989	0.991	0.998
(semi)natural vegetation close to or on water	0.976	0.959	0.771	0.144	0.017	0.013	0.134
anthropogenic shore area	0.675	0.843	0.787	0.663	0.863	0.700	0.003
land/farmland	0.222	0.863	0.575	0.246	0.035	0.066	0.020

Table S12. The posterior probability (certainty) of the hypothesis that the mean proportional use of a habitat type is smaller in the control group than in the treatment group from the first until the seventh days post stimulation (dps). Results from the multinomial model when using the land cover map from E.J. (results shown for comparison to those in main manuscript).

habitat class / days post stimulation (dps)	1 dps	2 dps	3 dps	4 dps	5 dps	6 dps	7 dps
open water	0.031	0.011	0.188	0.850	0.993	0.995	0.998
(semi)natural vegetation close to or on water	0.969	0.951	0.728	0.131	0.011	0.009	0.097
anthropogenic shore area	0.457	0.851	0.784	0.672	0.869	0.792	0.003
land/farmland	0.222	0.866	0.583	0.297	0.052	0.056	0.016

Supplementary text

Supplementary Text S1. Avian influenza screening

To evaluate if any of the mallards included in our experiment were already fighting an infection, we screened all individuals for avian influenza virus. For this purpose, we collected oral and cloacal swabs at the time of capture. We placed the swabs in Sigma-Virocult® virus transport medium and stored them at -80°C within 1 to 2 h after collection. We extracted RNA from the swabs as described previously[1]. Briefly, RNA was isolated using Tri Reagent BD (Sigma) supplemented with acetic acid. We then added the aqueous phase from the phase separation step in the Tri Reagent manual to a new tube, and processed the samples as described in step 4 (Load and Bind) and onwards in the peqGOLD Blood RNA Kit manual. We used the DNase I Digest Kit from peqGOLD to remove contaminating DNA.

The samples were then screened for avian influenza virus by the National Reference Laboratory for Avian Influenza (AI) in Germany, at the Institute of Diagnostic Virology (IVD) at the Friedrich-Loeffler-Institut (https://www.fli.de/en/institutes/institute-of-diagnostic-virology-ivd/reference-laboratories/woah-fao-and-nrl-for-ai/). All individuals tested negative for AI infection.

1 Jax E et al. 2021 Health monitoring in birds using bio-loggers and whole blood transcriptomics. Sci. Rep. 11, 10815. (doi:10.1038/s41598-021-90212-8)