Appendix S1

Context-dependent dispersal directionality in a headwater stream salamander

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Movement Ecology

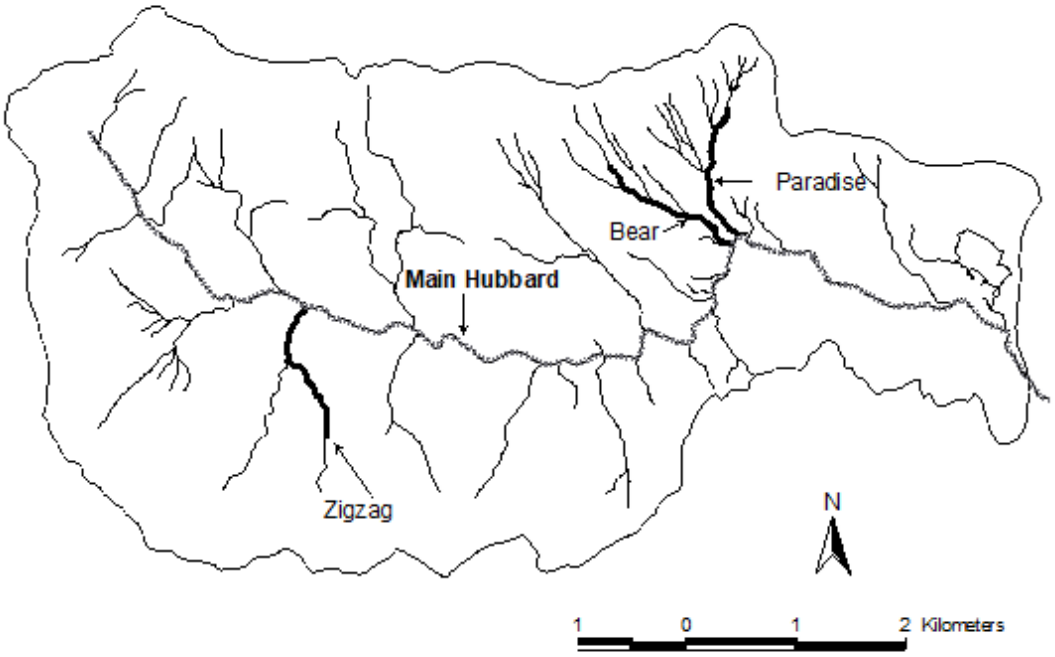

Figure S1. A map of the three study streams in the Hubbard Brook Experimental Forest (New Hampshire, USA). All three streams flow into the main Hubbard Brook.

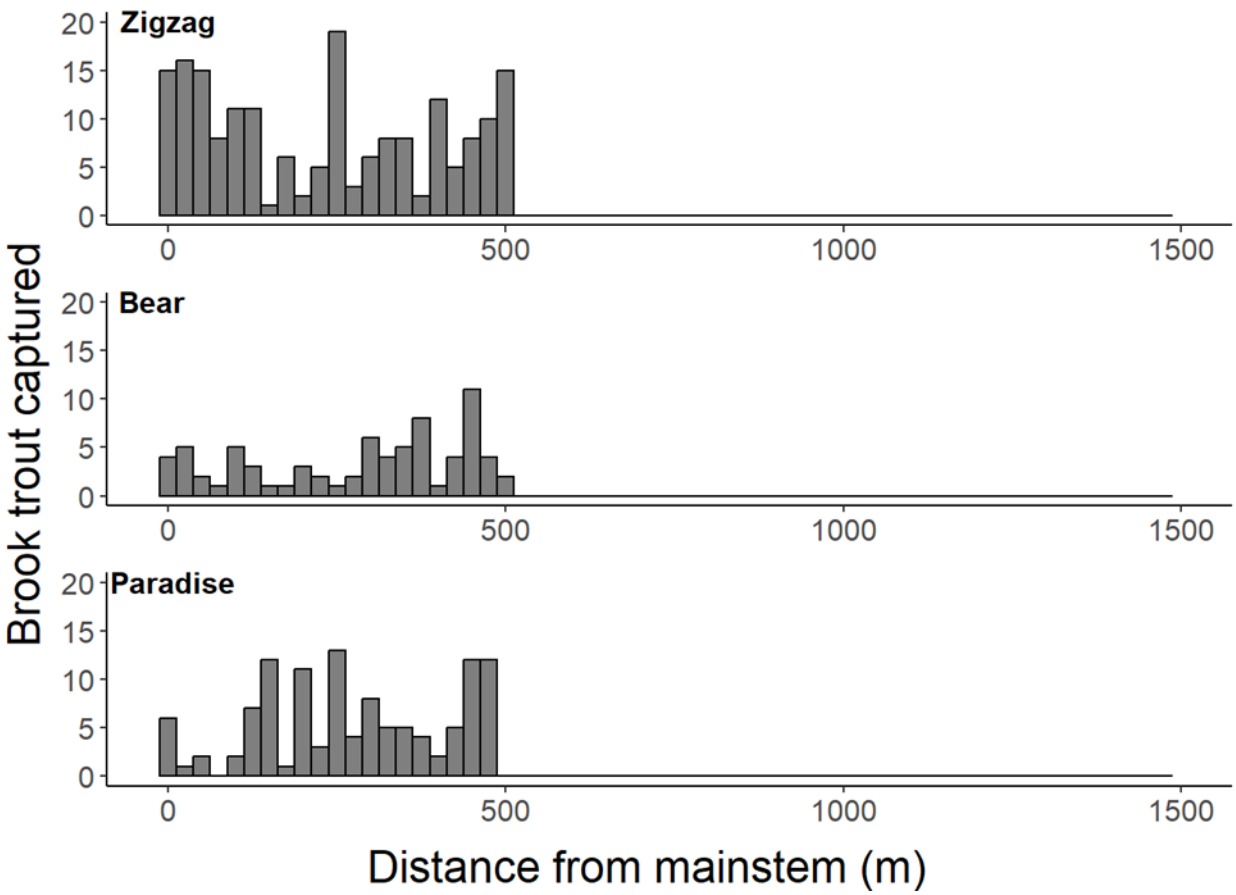

Figure S2. Histogram showing the spatial distribution of brook trout (*Salvelinus fontinalis*) in three streams in the Hubbard Brook Experimental Forest (New Hampshire, USA). Fish were captured using non-baited minnow traps placed every 25m along the stream. Traps were checked once per week from mid-June – mid-August from 2022-24 and twice per month in 2025. Traps were allowed to soak for approximately 48 hours prior to each survey. Captured fish were marked via a combination adipose fin clip and elastomer tag, and only unique individuals are shown here.

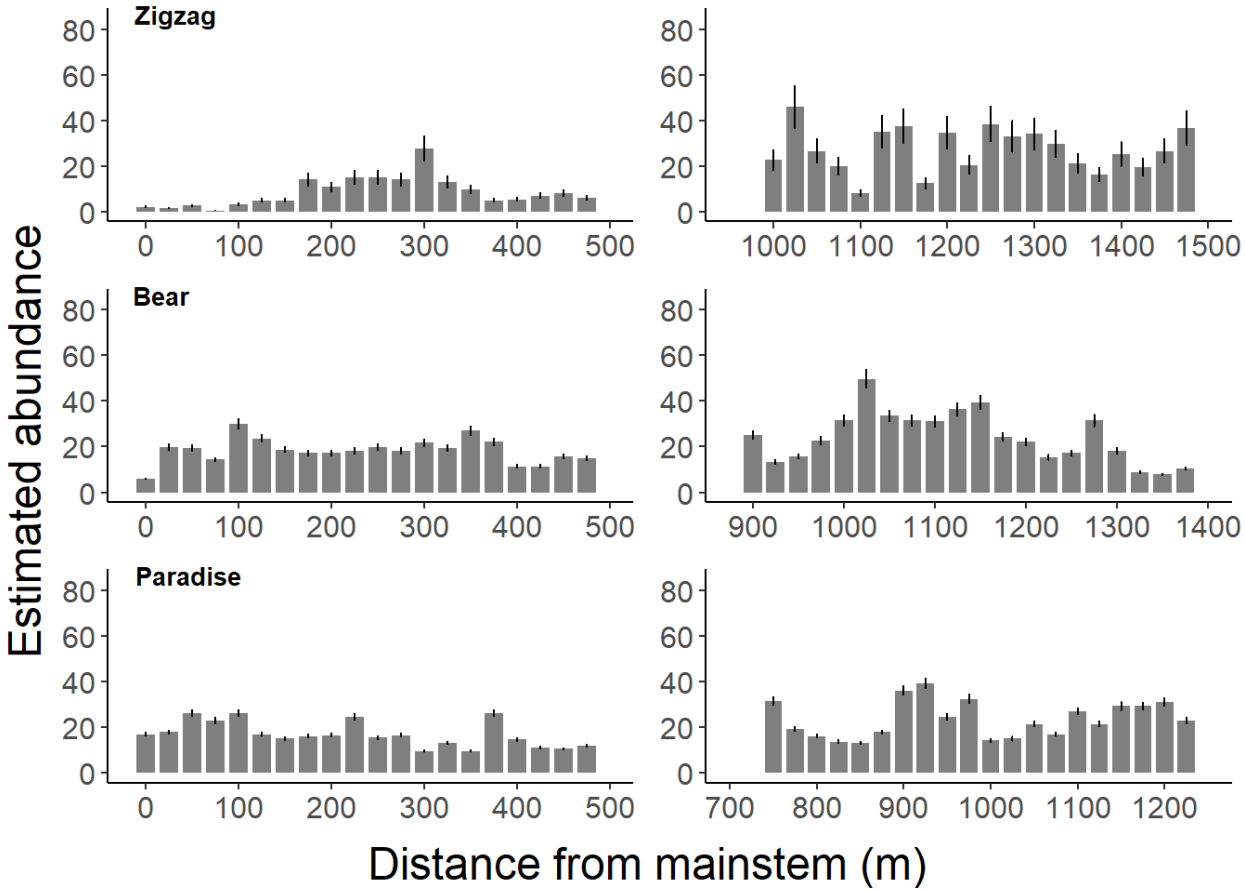

Figure S3. Bar graph showing estimated abundances of *Gyrinophilus porphyriticus* as a function of their distance from the mainstem confluence. Each bar represents 25m of continuous stream channel length. Mark-recapture surveys were conducted in three streams in the Hubbard Brook Experimental Forest (New Hampshire, USA) from 2015-2025. Surveys took place in 500m long reaches. Downstream reaches are on the left, upstream reaches on the right. Distance between reaches is 500m in Zigzag Brook, 400m in Bear Brook, and 250m in Paradise Brook. Lines indicate 95% confidence intervals.

TABLE S1. Comparison of candidate models used to estimate conspecific density and yearly apparent survival probabilities for *G. porphyriticus* in each of three study streams (Bear, Paradise, and Zigzag Brooks, respectively). Capture-mark-recapture data was collected from 2012-2025. Models were ranked by second-order Akaike's information criterion values (AIC_c), with the smallest AIC_c value and highest Akaike weight indicating the top model. AIC weights are not shown to reduce visual clutter, but the largest AIC weight across all non-highlighted (bold) models was $3.75 * 10^{-8}$.

Model	ΔAIC_{Bear}	$\Delta AIC_{Paradise}$	ΔAIC_{Zigzag}
Φ(time) p(.) γ(.) N(stage)	**0.00 ***	35.2	>10,000
Φ(.) p(.) γ(.) N(stage)	3060.0	53.1	>10,000
Φ(time) p(.) γ(time) N(stage)	>10,000	**0.00 ***	>10,000
Φ(time) p(.) γ(stage) N(stage)	>10,000	34.2	**0.00 ***
Φ(.) p(.) γ(time) N(stage)	>10,000	40.2	>10,000
Φ(.) p(.) γ(stage) N(stage)	>10,000	52.5	>10,000
Φ(time) p(.) γ(time) N(.)	>10,000	156.7	>10,000
Φ(time) p(.) γ(stage) N(.)	>10,000	185.6	>10,000
Φ(time) p(.) γ(.) N(.)	>10,000	186.9	>10,000
Φ(.) p(.) γ(time) N(.)	>10,000	194.0	>10,000
Φ(.) p(.) γ(.) N(.)	>10,000	205.6	>10,000
Φ(.) p(.) γ(stage) N(.)	>10,000	206.5	>10,000

Notes: Asterisks indicate the top model in each respective stream. Apparent survival probability (*Φ*), capture probability (*p*), recruitment probability (*γ*) and abundance (*N*) were treated as fixed (.), variable over time (*time*), or variable between life history stages (*stage*).

TABLE S2. Candidate models for assessing variation in dispersal directionality (a), along with candidate models for assessing variation in dispersal propensity (b) of *Gyrinophilus porphyriticus* in Bear, Paradise, and Zigzag Brooks based on hypothesized combinations of explanatory variables. Fish Index is the number of unique fish captured per meter of stream length. Initial Position is the distance (m) from the mainstem confluence where an individual was first captured. Wetted Width is the average wetted width of the stream, measured every 10m (weekly). Distance Moved is the difference (in meters) between an individual's capture position pre- and post-dispersal. Conspecific Density is the number of salamanders within the same 25m bin of stream channel length as the individual. Capture-mark-recapture data was collected from 2012-2025. Models were ranked by second-order Akaike's information criterion values (AIC_c), with the smallest AIC_c value and highest Akaike weight indicating the top model. Models were run separately on adult and larval salamanders.

a	b
Directionality ~ NULL	Propensity ~ NULL
Directionality ~ Stream + Initial Position	Propensity ~ Stream + Initial Position
Directionality ~ Stream + Initial Position + Distance Moved	Propensity ~ Stream + Initial Position + Fish Index + Wetted Width + Conspecific Density
Directionality ~ Stream + Initial Position + Fish Index + Wetted Width + Conspecific Density	Propensity ~ Stream + Initial Position + Fish Index + Conspecific Density
Directionality ~ Stream + Initial Position + Fish Index + Conspecific Density	Propensity ~ Stream + Fish Index
Directionality ~ Stream + Fish Index	Propensity ~ Fish Index + Wetted Width
Directionality ~ Fish Index + Wetted Width	Propensity ~ Conspecific Density
Directionality ~ Distance Moved	Propensity ~ Wetted Width + Conspecific Density
Directionality ~ Conspecific Density	Propensity ~ Initial Position + Distance Moved
Directionality ~ Wetted Width + Conspecific Density	Propensity ~ Initial Position + Fish Index + Wetted Width + Conspecific Density
Directionality ~ Initial Position + Distance Moved	Propensity ~ Initial Position + Fish Index + Conspecific Density
Directionality ~ Initial Position + Fish Index + Wetted Width + Conspecific Density	Propensity ~ Initial Position + Conspecific Density
Directionality ~ Initial Position + Fish Index + Conspecific Density	Propensity ~ Initial Position + Fish Index
Directionality ~ Initial Position + Conspecific Density	Propensity ~ Fish Index + Conspecific Density
Directionality ~ Initial Position + Fish Index	Propensity ~ Initial Position
Directionality ~ Fish Index + Conspecific Density	Propensity ~ Fish Index
Directionality ~ Initial Position	

Directionality ~ Fish Index
Directionality ~ Fish Index + Distance Moved
Directionality ~ Distance Moved + Conspecific Density
Directionality ~ Stream + Initial Position + Fish Index + Distance Moved + Wetted Width + Conspecific Density

Notes: Models listed here are not shown in order of AIC ranking. AIC values for top models can be found in the main text. Data and code to reproduce values for remaining models can be found in the Data Availability Statement.

TABLE S3. Explanatory variables included in candidate models (after checking for correlation between variables), along with a brief explanation for their inclusion.

Variable	Calculation	Reason For Inclusion
Fish Index	Unique fish captured per meter of stream length	Fish prey upon salamanders, only present in downstream reaches
Initial Position	Distance (m) upstream from the Hubbard Brook mainstem where a salamander was first captured	Spatial location of the individual, also a proxy for watershed area
Wetted Width	Average wetted width of the stream, measured every 10m (weekly)	Captures fine scale variation in hydrology
Conspecific Density	Derived from model output - number of salamanders within the same 25m bin of stream channel length as the individual	Crowding effects, interspecific competition could force relocation
Stream	Study stream the individual was captured in	Biogeochemistry differs between streams
Distance Moved	Difference (in meters) between an individual's capture position pre- and post-dispersal	Energetic differences required for upstream vs downstream movement

TABLE S4. Estimated average yearly abundances of *Gyrinophilus porphyriticus* (both adults and larvae) by stream, along with standard errors and 95% confidence intervals. Estimates come from the top model (after model selection) using the list of models shown in Table S1.

Stream	N Estimated	SE	95% CI Low	95% CI High	Capture Probability	Yearly Apparent Survival
Bear	851	36	780	922	0.19 ± 0.02	0.53 ± 0.03
Paradise	809	27	756	862	0.22 ± 0.02	0.47 ± 0.03
Zigzag	715	76	566	864	0.20 ± 0.04	0.46 ± 0.05

TABLE S5. Comparison of estimated yearly apparent survival probabilities (± 1 SE) of *Gyrinophilus porphyriticus* (both adults and larvae) in the uppermost and lowermost 10% of stream channel length (Φ_{edge}) versus the interiors of each stream (Φ_{int}).

Stream	Φ_{edge}	Φ_{int}
Bear	0.33 ± 0.08	0.55 ± 0.04
Paradise	0.42 ± 0.06	0.49 ± 0.04
Zigzag	0.25 ± 0.04	0.45 ± 0.05

TABLE S6. Comparison of estimated yearly apparent survival probabilities (± 1 SE) of *Gyrinophilus porphyriticus* (both adults and larvae) in the upstream reach of each stream ($\Phi_{upstream}$) versus the downstream reach of each stream ($\Phi_{downstream}$). Fish are only present in downstream reaches.

Stream	$\Phi_{upstream}$	$\Phi_{downstream}$
Bear	0.57 ± 0.03	0.44 ± 0.05
Paradise	0.44 ± 0.05	0.47 ± 0.05
Zigzag	0.55 ± 0.04	0.36 ± 0.16