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Appendix 1 for:

Dispersal Evolution in Currents:
spatial sorting promotes philopatry in upstream patches

The effect of changing $\lambda$ and $K$

Figure A1: Varying values of $K$ and $\lambda$ did not much affect general results obtained under baseline parameters (when $\lambda=2$, $K=50$). A positive downstream gradient in emigration probability results in all cases, and patches persist in all cases. Overall mean emigration probability decreases as $K$ is increased (from $\sim 1/2K$ to $2K$) but does not change when $\lambda$ is increased.

Adjusting the intrinsic rate of population increase $\lambda$ and the local equilibrium density or carrying capacity $K$ can often affect evolving emigration probabilities, especially in the presence of density dependence. In Fig. A1, we investigated the effects of varying these parameters on the results obtained under the baseline parameters reported in the main text ($\lambda=2$, $K=50$). Aside from an overall decrease in mean emigration rate when $K$ is increased, very little difference is seen. Positive downstream gradients are still present and the decrease in effect with increasing current strength is also apparent. Both parameters are included in the population dynamics equation used to model number of offspring in our study, introducing density dependence in the reproductive phase.
Increasing $K$ simultaneously reduces the strength of kin competition and reduced demographic stochasticity, both alleviating selection for higher emigration probability (Travis & Dytham 1998; Cadet et al. 2003).
Effect of initial emigration probability

We varied initial emigration probabilities $d$ is to test whether starting conditions affect the results. Varying initial $d$ did affect the resulting emigration probabilities and did not change the resulting positive downstream gradient (Fig. A2). We can therefore be confident that initial conditions in $d$, as well as $\lambda$ and $K$ (Fig. A1) do not affect conclusions drawn on the evolutionary impacts of increasing current strengths.
Effects of boundary conditions

Figure A3: Changing boundary conditions does not affect overall resulting gradients in mean emigration probabilities, except in the edge patches. Positive downstream gradients are still observed and the relative effects of current strengths are similar to baseline results. Sharp declines at absorbing boundaries represent individuals lost to the system, affecting population sizes and therefore mean values. All parameters were kept at baseline values: $d=0.1$, $\mu=0.01$, $c=0.01$, LDD=0.

While changing boundary conditions affected mean emigration rates at the edges of the stream system, it did not affect the overall trends observed within the stream (Fig. A3). In the baseline experiment, we used reflective boundaries to simulate a closed system, where individuals are not able to “leave”. Absorbing upstream and downstream boundaries might represent a section of a stream system where no movement barrier exists for individuals, and mixed boundaries (reflective upstream, absorbing downstream) might represent a stream from source to sea, for example.

Sharp declines in mean emigration rates at the edges of the model landscape at absorbing boundaries (Fig. A3) represent loss of more dispersive individuals, as the key results of positive downstream gradients in emigration probabilities, and the relative effects of increasing current strength on the mean emigration probability remains, even under absorbing and mixed boundary conditions, indicating that conclusions drawn on these observations are not boundary dependent.
Genotypic Variation under different boundary conditions

In upstream patches, an overwhelming majority of genotypes have 0 values, regardless of boundary conditions (Fig. A4) which is consistent with what is found with reflective boundaries (Fig. 3). Likewise, midstream patches experience similar genotypic variation under mixed and absorbing boundaries as with reflective boundaries: wide distributions that narrow and shift towards zero as current strength increases.

It is the downstream patches where boundary conditions seem to affect genotype distributions. With absorbing boundaries, the frequency of philopatric individuals increases, presumably because individuals with non-zero genotypes are lost from the system. A high frequency of philopatric genotypes is evident under all current strengths, but is higher at intermediate
strengths, e.g. $\rho=0.6$. The shift of the genotype distribution towards zero under strong currents is less obvious when boundaries are absorbing, with highest frequency genotypes remaining comparable with weaker currents.
Proportion of philopatric genotypes

Figure A5: The proportion of individuals with genotype $d = 0$ shows a negative downstream gradient and is highly influenced by current strength $\rho$. At high current strengths, this proportion nears $1$ in the upstream patches. Results are mean proportions across 100 replicates of populations at the end of 1000 generations. All parameters were set to baseline values.

In the upstream patches, the proportion of locally recruiting individuals that exhibit an emigration probability of $0$ is highly affected by current strength (Fig. A5). This proportion is close to zero when current strength is $0.5$ and increases to almost $1$ when it is $>0.8$. The first ten patches experience this effect most strongly, while the rest of the stream levels out, though the effect of current strength is still seen slightly. This decrease is especially steep in the first few patches.
Effect of varying rates of long-distance dispersal by patch

Figure A6: Incorporating rare long-distance dispersal (LDD) alters the spatial pattern of mean emigration probability along the stream. The positive downstream gradient loses its positive slope midstream, as mean emigration rate values overlap when LDD values are >0.01. All other parameters were kept at baseline values: initial $d=0.1$, $\mu=0.01$, $c=0.01$.

Introduction of LDD events changes the spatial pattern observed in baseline experiments (Fig. A6). The positive downstream gradient in emigration probability that is maintained under all other experiments disappears in midstream patches, where the gradient starts flattening. This is likely due to the increased mixing of genotypes that increased LDD rate produces. Additionally, the mean emigration probability in upstream patches increases with increased LDD, even at high current strengths, while downstream patches have little to no observable response. This location-specific response to LDD produces the flattening of the dispersal gradient that can be seen in Fig. 5 in the main paper.
Effect of LDD on genotypic variation

Figure A7: Introduction of rare long-distance dispersal events increase genotypic variation in upstream patches at low, B) 0.006, and higher, C) 0.02 LDD probabilities, compared to when LDD is not present, A) 0. Current strength $\rho = 1$. Results shown are of populations at the end of 1000 generations and accumulated over 100 replicates. Parameters other than LDD probability were set to baseline values.

Incorporation of any long-distance dispersal increases the genotypic variation in upstream patches under all current strengths >0.5 (Fig. A7). The genotype distribution of the upstream patches with no LDD is very narrow, with only a few individuals having nonzero genotypes. However, when even a low LDD probability is included, such as 0.006, this genotypic variation increases. Though still in low numbers, this accounts for the increase in mean emigration rate in upstream patches seen in Figure 5 in the main paper. Similarly, the genotypic variation in midstream patches also increases, bringing the highest emigration probability from just under 0.4 to 0.58 when LDD=0.02. This reflects the substantial increase in mean emigration probability seen in Figure 5 in the main paper.
**Effect of current on Population Size**

![Figure A8: Population sizes at the end of 1000 generations for 10 replicates using baseline parameters. Population sizes do not vary with current strength and there is no downstream gradient. Note that the sharp increase at patch 40 is due to reflective boundary conditions.](image)

While there is noise around the mean population size per patch, there is no discernible spatial pattern along the stream, regardless of current strength (Fig. A8). The positive downstream gradient in mean emigration rate seen in Fig. 2 of the main paper can therefore be considered to be independent of population size. The sharp increase at Patch 40 reflects the increase in mean emigration rate in that location and is due to reflective boundary conditions.
Figure A9: Genotypes originating from mutations in upstream patches travel much further downstream under high current strengths. Originating patch, where the mutation occurred, is shown on the x-axis, while the destination patch, where the genotype ended up at the end of 1000 generations, is shown on the y-axis. Warmer colours indicate higher frequency of exchange between each pair of patches under current strengths 0.6, 0.8, and 1. All parameters were set at baseline values.

The possible origins of genotypes reaching a patch is directly affected by current strength as genotypes travel further under stronger currents (Fig. A9). This means that, under stronger currents, genotypes with a non-zero but lower value for emigration probability can reach further downstream faster, overall reducing the accumulation of mutations for increased emigration and thus the population mean genotype. Note also that mutations originating in upstream patches are more likely to persist, potentially due to simpler competitive landscapes (lower diversity of immigrating genotypes there).