

Research



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Collective navigation can facilitate passage through human-made barriers by homeward migrating Pacific salmon

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The mass migration of animals is one of the great wonders of the natural world. Although there are multiple benefits for individuals migrating in groups, an increasingly recognized benefit is collective navigation, whereby social interactions improve animals' ability to find their way. Despite substantial evidence from theory and laboratory-based experiments, empirical evidence of collective navigation in nature remains sparse. Here we used a unique large-scale radiotelemetry dataset to analyse the movements of adult Pacific salmon (*Oncorhynchus* sp.) in the Columbia River Basin, USA. These salmon face substantial migratory challenges approaching, entering and transiting fishways at multiple large-scale hydroelectric mainstem dams. We assess the potential role of collective navigation in overcoming these challenges and show that Chinook salmon (*O. tshawytscha*), but not sockeye salmon (*O. nerka*) locate fishways faster and pass in fewer attempts at higher densities, consistent with collective navigation. The magnitude of the density effects were comparable to major established drivers such as water temperature, and model simulations predicted that major fluctuations in population density can have substantial impacts on key quantities including mean passage time and fraction of fish with very long passage times. The magnitude of these effects indicates the importance of incorporating conspecific density and social dynamics into models of the migration process. Density effects on both ability to locate fishways and number of passage attempts have the potential to enrich our understanding of migratory energetics and success of migrating anadromous salmonids. More broadly, our work reveals a potential role of collective navigation, in at least one species, to mitigate the effects of anthropogenic barriers to animals on the move.

1. Introduction

Long-distance migration is an iconic and threatened behaviour [1]. Migratory species navigate with incredible precision to and from highly spatially restricted locations [2]. To solve these challenging navigational problems, species use mechanisms ranging from an innate sun compass [3] and magnetic maps [4] to learned olfactory cues [5,6]. However, long-distance migrations are threatened by human influence [7]. Fences, highways and other developments block terrestrial migration pathways [8], light pollution interferes with aerial migrations [9] and dams and de-watering impede passage both upstream and downstream (e.g. Norrgård *et al.* [10]). In light of these impacts, it is essential to understand the mechanisms of navigation in order to predict and mitigate human impacts on migratory populations.