Functional Ecology

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# Declining marine food levels may have mitigated the negative effects of increased cost of migration in salmon

*Chaparro Pedraza, Perla Catalina; de Roos, Andre*

Migratory fish populations have shown dramatic declines over recent decades. In the North Atlantic, 24 migratory fish species have decreased in abundance by more than 90%, including some of cultural and economic importance such as salmon.

Multiple threats have contributed to this decline, including building of dams and other structures in rivers and streams, and food decline in the ocean. The presence of dams, for instance, increases the energetic costs of migration to upstream breeding sites. Salmon cease feeding when leaving the ocean and use only their stored energy reserves during the breeding migration. Therefore, additional energy demands, like those of re-ascending a dam, reduce their energy reserves available for reproduction, resulting in low offspring production. Food decline in the ocean also has a negative impact on offspring production because fish are less able to cover their metabolic activities including reproduction. On their own, the effects of increased migration costs and food reduction in the ocean are well documented, but their cumulative effects are not well-known.

In this study, we aim at understanding the cumulative effects of these two threats using a mathematical model that captures how fish acquire and utilize energy throughout their life cycle. This model reveals that food decline in the ocean can mitigate rather than exacerbate the negative effect of elevated migration costs due to the presence of dams and other structures in rivers. This is because fish growing in the ocean under higher food



abundance reach a larger body size but are leaner. As a consequence of their leaner condition, they spend most of their energy reserves to transport their large and heavy body when migration costs are high, and little is left for reproduction.

Our results show that multiple threats can interact in very unexpected ways, resulting in counterintuitive outcomes. Since human activities are increasing the variety of threats concurrently affecting organisms and their environment, it is an urgent matter to understand how these threats interact.