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ARTICLE

Fishway passage bottleneck identification and prioritization: a case study of Pacific lamprey at Bonneville Dam

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Abstract: Fishways designed for salmonids often restrict passage by non-salmonids, and effective tools are needed both to identify passage problems for nontarget species and to inform remediation planning. In this case study, we used migration histories from 2170 radio-tagged adult Pacific lamprey (*Entosphenus tridentatus*) to identify locations of poor passage (bottlenecks) at a large, multifishway dam. Over 10 years, 49% of tagged lamprey that entered fishways failed to pass the dam. Models accounting for repeated attempts by individual lamprey indicated successful passage strongly depended on attempted passage route. Success also varied with time of fishway entry, water temperature, and lamprey body size. Most failed passage attempts terminated in lower fishway segments, but extensive seasonal shifts in bottleneck locations were detected. Ranking metrics helped prioritize bottlenecks and identified sites where structural or operational modifications should improve lamprey passage. Our integration of spatially intensive monitoring with novel analytical techniques was critical to understanding the complex relationships among fishway features, environmental variation, and lamprey behavior. The prioritization framework can be applied to a wide range of fish passage assessments.

Résumé : Les passes migratoires conçues pour les salmonidés restreignent souvent le passage d'autres poissons, et des outils efficaces sont nécessaires pour cerner les problèmes associés au passage d'espèces non visées et éclairer la planification de mesures correctives. Dans la présente étude de cas, nous avons utilisé les historiques de migration de 2170 lamproies du Pacifique (*Entosphenus tridentatus*) adultes munies de radio-émetteurs pour cerner les lieux de passage difficiles (goulots d'étranglement) à un important barrage comptant plusieurs passes. Sur une période de 10 ans, 49 % des lamproies munies d'émetteurs qui entraient dans ces passes ne réussissaient pas à remonter le barrage. Des modèles tenant compte de tentatives multiples par les mêmes lamproies ont indiqué que le succès du passage dépendait fortement de la voie de passage employée. Le taux de succès variait également selon le moment de l'entrée dans la passe, la température de l'eau et la taille du corps de la lamproie. La plupart des tentatives de passage infructueuses prenaient fin dans des sections avals des passes, mais d'importantes variations saisonnières de l'emplacement des goulots d'étranglement ont été décelées. Le classement des différents paramètres a aidé à établir la priorité des goulets et à cerner les sites où des modifications structurales ou opérationnelles devraient améliorer le passage des lamproies. L'intégration d'une surveillance spatiale fine et de nouvelles techniques analytiques s'est avérée essentielle à une meilleure compréhension des liens complexes entre les caractéristiques des passes à poissons, les variations des conditions du milieu et le comportement des lamproies. Le cadre d'établissement de la priorité peut être appliqué à un vaste éventail d'évaluations de passes à poissons. [Traduit par la Rédaction]

Introduction

River systems worldwide have been fragmented by dams and other anthropogenic obstacles that restrict fish movements (Nilsson et al. 2005). A diverse array of fishways and other passage systems has facilitated upstream fish passage at such sites (Clay 1995; Odeh 1999). Unfortunately, many were designed solely to accommodate migratory species with high social or economic value, with little consideration for nontarget species, resulting in local extirpations (Winston et al. 1991), population fragmentation (Morita and Yamamoto 2002), and reduced abundance and diversity of riverine fauna (Pringle et al. 2000). These outcomes have been propagated by the export of fishways designed in one region — typically for a single species or group of related species — to regions with entirely different fish communities (e.g., Agostinho et al. 2007; Mallen-Cooper and Brand 2007).

Weir-and-pool and vertical slot fishways designed for anadromous salmonids (*Oncorhynchus* spp. and *Salmo* spp.) and clupeids (*Clupea* spp. and *Alosa* spp.) are among the most widely used fish passage systems. Performance testing for these fishway types historically included swim speed evaluations and velocity barrier experiments using the target species (e.g., Weaver 1963; Beamish 1978). Such designs effectively pass some species with high burst swim speeds, endurance, or motivation to pass upstream (e.g., Schwalme et al. 1985; Keefer et al. 2004; Noonan et al. 2012). However, they often present substantial challenges for nontarget species with limited ability to traverse turbulent or high velocity conditions (Agostinho et al. 2007; Pratt et al. 2009; Bunt et al. 2012). Even when structures are known to limit passage for a specific group of fishes, it can be difficult to identify causal mechanisms and specific locations associated with the poor performance.

In this paper, we apply passage metrics and statistical models novel to the fish passage literature to identify fishway bottlenecks

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