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Short Note

Evaluating the sensitivity of dendritic connectivity to fish pass efficiency for the Sesan, Srepok and Sekong tributaries of the Lower Mekong

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ABSTRACT

Hydropower dam development in the Mekong River Basin is threatening both biodiversity and the output of the world's largest inland fishery. Fragmentation of the river system by dams blocking the free movement of riverine species can have a direct impact on migratory fish species, which constitute a significant portion of the basins wild fishery. Fish passes, which allow fish to bypass dams, are often proposed as potential solutions to these problems. However, there is uncertainty around the effectiveness of fish passes in the species-rich environment of the Lower Mekong, and this has real consequences for the region and its development strategies. As a first step to evaluate the effects of dams in the region, we used the Dendritic Connectivity Index (DCI) to examine the impact on connectivity by providing fish passage on as many as 105 current, under construction and planned dams on the Sesan, Srepok and Sekong tributaries of the Mekong River. Our results indicate that, at the current stage of development, overall connectivity of the river system is sensitive to the efficiency of fish passes – and with highly efficient fish passes, connectivity comparable to a natural network is possible. However, as the number of dams on each tributary increase, even highly efficient fish passes are unable to improve connectivity significantly. While this paper does not explicitly focus on the functioning and limitation of fish passes, this broader analysis clearly establishes that, if constructed, robust monitoring for the newly-designed fish pass on the Lower Sesan II dam would be critical for evaluating and informing future development strategies.

1. Introduction

River fragmentation is one of the major environmental impacts caused by dam construction and operation (Lehner et al., 2011). Fragmentation limits the movement of riverine animals, including fish, and may cause populations to become isolated and genetically fragmented, and to lose access to spawning and nursery grounds (Cheng et al., 2015). This, in turn, increases extinction risk and reduces both biodiversity and fisheries yield (Jackson and Marmulla, 2001). The impacts of fragmentation cumulate as multiple barriers are constructed on contiguous sections of rivers or streams (Shaw et al., 2016). Dams block upstream fish passage; downstream movement is compromised by the dangers inherent in passing over the dam wall or through turbines; and the reservoir can form a lentic barrier to eggs and larvae (McLaughlin et al., 2013; Pompeu et al., 2012). A variety of engineering solutions have been implemented to provide fish passage around dams, with varying levels of success (Noonan et al., 2012).

The Mekong River Basin in Southeast Asia is experiencing a boom in hydropower dam construction (Orr et al., 2012, Grumbine et al., 2012). River and stream fragmentation, and the associated impediments to fish migration, undermine both the biodiversity and the productivity of the world's largest inland fishery (Ziv et al., 2012). Fish passes have been proposed as part of mitigation measures. However, as Orr et al. (2012) summarized, only a few fish passes have been constructed in the Mekong Basin, and in cases where they have been added (such as the Pak Mun Dam), mitigation measures have been reported as largely failing. Monitoring results on fish passes from 388 dammed rivers in similar species-rich and tropical environments in South America, Gätke et al. (2014) indicate that adequate flows that mimic natural flows with varied velocities and depths are necessary for fish passes to be a successful mitigation strategy in the Lower Mekong.

The 3S River Basin (Fig. 1, top-left), comprising the Sesan, Srepok and Sekong Rivers, is the largest of the Mekong River's sub-catchments. The 3S is regionally important as it is the source of almost a quarter of the Mekong's flow (Adamson et al., 2009; Arias et al., 2014) and 15% of its suspended sediment (Koehnken, 2012), and it provides important migratory fish habitat. It is currently undergoing rapid dam development due to its high potential for hydropower. Ziv et al. (2012)

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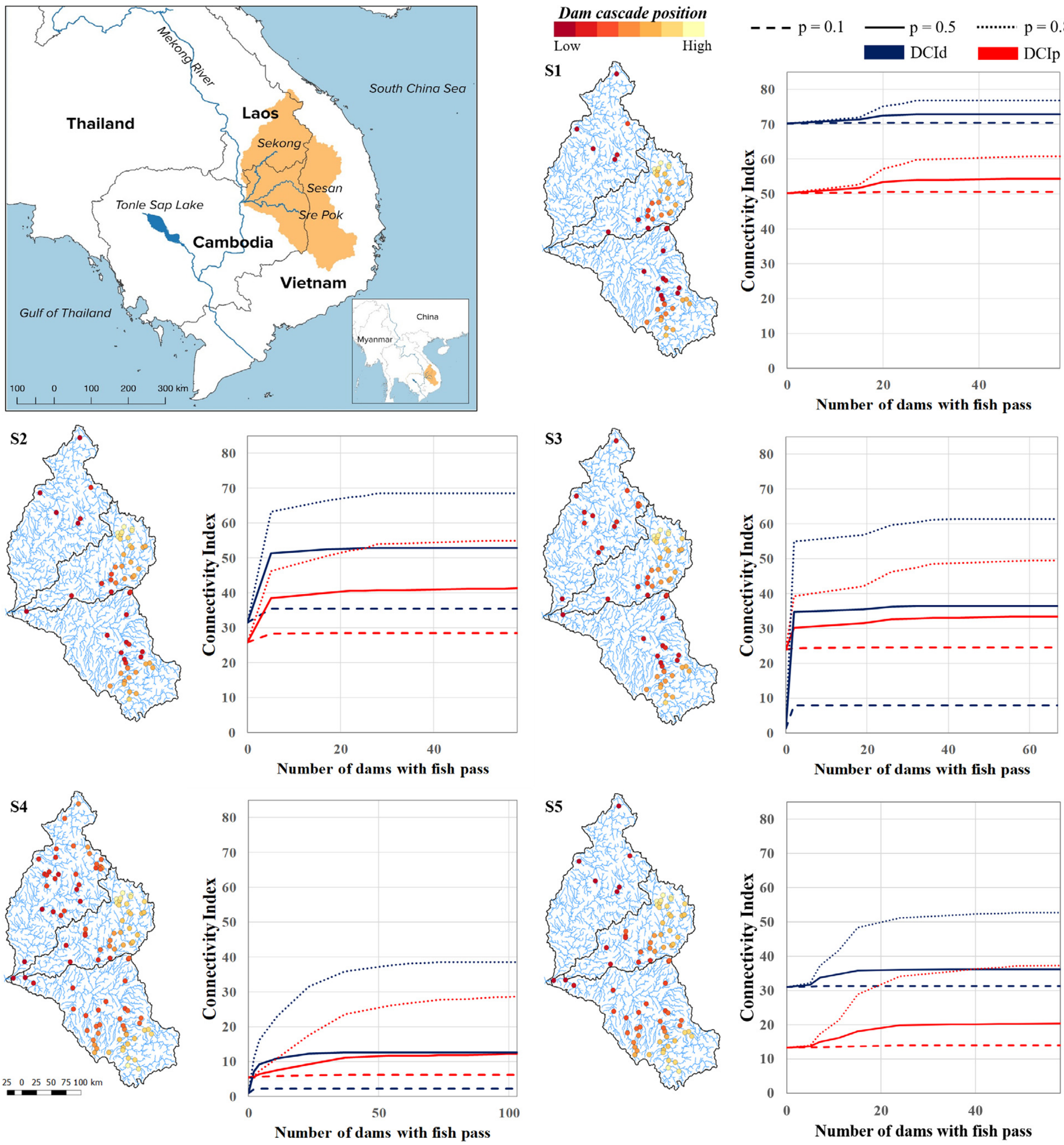

Fig. 1. (Top-left) Map of region. (S1-S5) Connectivity maps and plots for Scenarios 1 to 5, respectively. The maps show the connectivity of the tributaries to Mekong main stem. The dams are shaded red to yellow depending on position in dam cascade, corresponding to number of barriers between the dam and the outlet of the system (junction with Mekong main stem). The line graphs plot changes in connectivity as fish passes are added for dams counting from downstream to upstream along the dam cascade. Different efficiency of fish passes is captured through assigning passability values (p_m) for each pass.

projected that the construction of eight main stem dams in the 3S (without effective fish passage) would reduce the total fish catch in the Lower Mekong by 13.7%. The study attributed a significant proportion of this loss to the construction of the Lower Sesan II dam located at the junction of the Sesan and Srepok Rivers. By October 2017, construction of Lower Sesan II dam was completed. In an effort to address potential biodiversity and fish productivity impacts, in the later stages of development, a fish pass that repurposes an existing small stream to allow for a bypass path was added to the system design and is being evaluated as a possible solution to improve connectivity. Within this context, we use the Dendritic Connectivity Index (DCI) developed by Cote et al. (2009) (and described in Section 2) in combination with development scenarios for the 3S to examine the impacts of current and future dam construction on river system fragmentation. DCI allows for a broad, systems-wide overview of fragmentation by considering how providing fish passage of varying efficiencies across the basin may or may not improve connectivity and potentially benefit fish migration. Due to the straightforward application of the DCI, it has been used on multiple river systems to study the impact of barriers on fish habitat fragmentation (e.g., Don River Catchment UK, Shaw et al., 2016; North American Great Plain River system, Perkin et al., 2015; etc.), including at the global scale (Grill et al., 2015). While the system-wide nature of the indicator forces assumptions about the operation of individual dams and fish passes, we believe such analysis is an important step in