Impacts of dam removal and climate change on abundance of the Formosan landlocked salmon

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The Wuling basin in central Taiwan is the last refuge of the critically endangered Formosan landlocked salmon Oncorhynchus formosanus, but the habitat has been degraded by human interference, including agricultural practices and dam construction. Four check dams were removed in Kaoshan Stream between 1999-2001 to help restore the natural habitat, and we construct an age-structured stochastic simulation model to quantify the effect of this dam removal on salmon abundance. Typhoons are an important factor in the population dynamics, and the presence of dams may augment the mortality associated with typhoons. We define an annual typhoon score that measures the impact of typhoons on salmon survival. We found that habitat restoration resulting from dam removal is a more significant factor than the creation of upstream passage in increasing survival and that juveniles receive the largest benefit. The model predicts that the salmon in Kaoshan Stream would have disappeared by 2007 if the dams had not been removed, indicating that dam removal was effective in increasing abundance. The model projects that after dam removal, the salmon population will stabilize just below 400 by 2018, which indicates growth from the most recent observed value of 262 in 2014. We then modify the forecasted typhoon scores to include anticipated increases in typhoon intensity associated with climate change. All of these scenarios result in a downward rather than stable trend in abundance, with larger increases in the typhoon score associated with faster rates of decline in the population. However, the population remains above 100 over the next 20 years even in scenarios with high typhoon scores. The model suggests that dam removal reversed the salmon population decline, but the anticipated increase in rain intensity associated with climate change poses a future threat to the salmon.