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Original research article

Estimating the size of the spawning population and evaluating environmental controls on migration for a critically endangered Asian salmonid, Sakhalin taimen

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ABSTRACT

Sakhalin taimen *Parahucho perryi*, an east Asian fish noted to be one of the largest salmonids in the world, is threatened throughout its range in northern Japan and neighboring Russian Federation. We report here on the first effort to enumerate and characterize the spawning run of a river population. We applied sonar and video methods in a tributary of the Sarufutsu River in Hokkaido, Japan, and evaluated environmental controls on migration. Over two years we estimated the tributary population to range from 335 to 425. We found passage rate by our site to increase with temperature and decrease with river discharge, and migratory cues were reinforced by strong diel fluctuations in environmental conditions. Finally, we report evidence of males arriving early to the spawning grounds in this species. Given our results and data on the recreational fishery, we conclude that a substantial number of individuals in the population are affected by angling, underscoring the need to establish fishing regulations. Further, our study indicates passage success can vary over the migration period, and efforts at modifying or removing impediments, and devoting more research to factors controlling passage, could ultimately improve the status of this species.

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1. Introduction

The precarious status of species in the genus *Hucho* and *Parahucho*, recognized as the largest salmonid fishes in the world, has received little attention (Holčik et al., 1988; Rand, 2013). The five extant species have a broad distribution in the arctic and temperate rivers of Eurasia. Recent status assessments have concluded that all species are either threatened or Data Deficient based on IUCN extinction risk criteria (Rand, 2013). While there are some noted exceptions of innovative, successful field efforts aimed at understanding status of the species (e.g. Fukushima, 2001; Jensen et al., 2009), there are still few examples of field programs to produce reliable status and trend data to help guide ongoing and future conservation programs.

In many respects fisheries science has lagged behind other natural resource fields given the difficulty of estimating population sizes in aquatic ecosystems. A quote from John Shepherd, introduced into the literature by Hilborn (2002), succinctly conveys the core problem: "counting fish is like counting trees-except they are invisible and they keep moving". However, great strides have been made in recent years in our ability to estimate the population size and characteristics of

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salmonids during their spawning run. It has now become routine to use sonar technology to produce reliable population data on which to base fishery management decisions. Many fishery agencies now are applying this sonar technology. The development of multi-beam sonar systems in particular has substantially improved data reliability and expanded our ability to describe characteristics of river migrants, including accurate estimates of fish sizes (e.g. Holmes et al., 2006; Maxwell, 2007; Burwen et al., 2010). These sonar systems now provide high resolution images and produce reliable estimates of fish passage in a variety of river systems in North America. With the deployment of multiple systems, it is now possible to monitor passage in large river systems (e.g. Copper River in Alaska, Fraser River in British Columbia). While this technology is now being applied in many rivers to provide data for managers on major commercial and sport fisheries (for a recent example, see Miller et al., 2013), we see new application opportunities in the use of this technology on threatened and endangered salmonid populations.

While there have been many studies on migration dynamics and factors affecting passage by natural and artificial barriers for Pacific and Atlantic salmon (e.g. Hinch and Rand, 1998; Thorstad et al., 2008), very few studies have been undertaken on other diadromous species (Roscoe and Hinch, 2010). In recent decades, for example, it has been discovered that fish ladders on dams designed for Pacific salmon are not suitable for native Pacific lamprey given important differences in swimming performance (Moser and Mesa, 2009). Work by engineers and biologists has emphasized the need to understand particular requirements of effective passage for different species, and how certain factors, like discharge and temperature, may play an important role (Roscoe and Hinch, 2010). Taimen may experience unique challenges passing river impediments, given their unique body shape (having a relatively high length to height ratio compared to other salmonids, Kawanabe and Mizuno, 1989) and large maximum sizes. One can imagine the difficulty, for example, of a 2 m long adult taimen navigating through a constricted fishway. It is important to describe these species-specific differences as a step toward addressing passage problems, but we are not aware of any directed studies of migration or passage dynamics for species in the genera *Hucho* and *Parahucho*.

Here we describe a simple monitoring effort, based on these well-established protocols to estimate the size of the spawning run of a threatened population of Sakhalin taimen (*Parahucho perryi*) in Hokkaido, Japan. Through an integrated monitoring effort, we estimated passage of taimen by a fixed point in the river and evaluated temporal patterns and environmental controls on fish passage and migration. At the end of the paper, we describe implications of our research on conserving this highly threatened species.

2. Material and methods

2.1. Description of the river, salmonid populations and study site

The Sarufutsu River is located in the Soya Region in northern Hokkaido Island, Japan, and flows into La Pérouse Strait, a body of water separating Sakhalin, Russian Federation and Hokkaido, Japan in the Northwestern Pacific Ocean (Fig. 1). The size of the watershed is 361 km^2. The study area has a cool-temperate climate with heavy snowfall in winter. The region receives an annual average of over 1100 mm of precipitation, with 42% in the form of snow. The upper watershed is under forest cover, and the predominant tree species are acer (Acer mono), birch (*Betula ermanii*), oak (*Quercus crispula*), tilia (*Tilia japonica*) and fir (*Abies sacharinensis*). The forest understory is dominated by Sasa dwarf bamboo (*Sasa senanensis*).

The river supports a number of wild salmonid populations, including white spotted char (*Salvelinus leucomaenis*), masu salmon (*Oncorhynchus masou*), pink salmon (*O. gorbuscha*), and chum salmon (*O. keta*). The river may support the most abundant population of Sakhalin taimen (*Parahucho perryi*) throughout its range in Japan. This species has become highly threatened as a result of overfishing, habitat loss and extensive agricultural development (Fukushima et al., 2011). Our study site is located in the Karibetsu River, a large tributary draining an area of 83 km^2, representing 23% of the entire Sarufutsu watershed. The river is recognized as an important spawning river for Sakhalin taimen.

2.2. Monitoring adult taimen passage and study site conditions

We monitored passage of taimen at a low, concrete weir on the Karibetsu River during the springs of 2013 and 2014 (Figs. 1 and 2). The weir is located 2–3 km downstream of most of the spawning grounds in this tributary system (Fukushima, 2001). We used multi-beam sonar imaging systems (DIDSON, or Dual Frequency Identification Sonar in 2013, and ARIS 3000, or Adaptive Resolution Imaging Sonar in 2014, www.soundmetrics.com) and a CCD video camera to monitor passage. The imaging system DIDSON (set at high resolution, 1.8 MHz) uses 96 sound beams that are focused by a lens to produce video-quality images of underwater targets (Moursund et al., 2003). The newer ARIS system is based on the same technology, but can operate at a higher frequency (3.0 MHz) and resolution, utilizing a total of 128 beams. The units were supported on a metal frame and the beam was oriented across the channel, perpendicular to the river flow, just upstream of the final, upstream weir step (Fig. 2). This position was chosen to ensure fish ascending the weir would pass through the beam on their migration to the spawning grounds, with low probability of passing back downstream. The beam geometry was evaluated using a wood model of the fish fastened to a 3 m long pole. This protocol was carried out at the beginning of the monitoring period each year, and after any adjustments were made to the position of the imaging sonar to assure all taimen

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