Effects of habitat fragmentation by damming on the persistence of a stream-dwelling char
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Introduction

Throughout the world, rivers are increasingly fragmented by damming. In Japan, 86% of rivers have impassable artificial barriers. Especially, Japanese mountain streams were highly fragmented by dams installed to control erosion (Fig. 1). The Japanese Ministry of Construction (1999) reported that a total of 53,028 dams were built on Japanese streams to control erosion. As Japanese land area is 387,000 km², an erosion control dam exist per 7.2 km² land area!

Dams fragmented fish populations in stream. Habitat fragmentation has a harmful influence on population persistence. Ecologists have long believed that small populations face higher risk of extinction through demographic, environmental and genetic stochasticity. We postulated that dammed-off populations having a small habitat size tend to disappear more quickly than those having a large habitat size (Fig. 2).

Methods

Study fish

White-spotted char, a salmonid fish, is commonly distributed Japanese mountain streams (Fig. 3). The life cycle of this species is highly variable. Some fish descend to the sea and return to their natal stream to reproduce as a large “migrant form”, while other fish remain in their natal stream and reproduce as a small “resident form”. Currently, many populations are fragmented by dams installed to control erosion, and extant char populations above dams are sustained by resident forms only.

Life history traits of resident char:

<table>
<thead>
<tr>
<th>Trait</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Age at maturity</td>
<td>3 years</td>
</tr>
<tr>
<td>Size at maturity</td>
<td>15−25 cm</td>
</tr>
<tr>
<td>Longevity</td>
<td>6 years</td>
</tr>
<tr>
<td>Fecundity</td>
<td>100−400</td>
</tr>
</tbody>
</table>

Field observations

We established the presence or absence of white-spotted char in areas above 52 dams by intensive electrofishing and snorkeling (Fig. 4). As white-spotted char inhabits all undammed upper reaches of the surveyed system, white-spotted char had the opportunity to establish populations in all of the dammed-off sites. As predictors of white-spotted char occurrence, five explanatory variables were measured: (1) isolation period (determined from the year of the dam construction); (2) watershed area above the dam; (3) gradient; (4) altitude; (5) distance from sea.

Fig. 2. The population structure of salmonid fishes fit the characteristics of a metapopulation. Before damming, dammed-off habitats are interconnected by way of the sea. In small dammed-off populations, demographic, environmental, and genetic stochasticity would promote extinction. Are fish population doomed once they are dammed?

Results

The white-spotted char were absent in 17 dammed-off sites and were present in 35 dammed-off sites, even though the char abounded in all 52 streams below the dams. Among five habitat characteristics (isolation period, watershed area, gradient, altitude, distance from sea) examined, stepwise logistic regression analysis identified three variables (watershed area above the dam, isolation period, and gradient) as the best predictors of white-spotted char occurrence. The occurrence of white-spotted char increased with increasing watershed area, with decreasing isolation period, and with increasing gradient (Fig. 4). Using the logistic model identified from stepwise procedure, we predicted the relationships between the probability of occurrence and watershed area of varied isolation period (Fig. 5). The effect of watershed area on the occurrence of char is most pronounced in small habitats, and the probability of occurrence decreases dramatically with increasing isolation period, especially in habitats less than 1 km².

Fig. 4. Presence (blue circles) and absence (red circles) of white-spotted char in 52 dammed-off sites in relation to (a) isolation period and watershed area, and (b) gradient and watershed area. Dashed lines represent 50% probability of occurrence obtained from logistic regression analyses.

Fig. 5. Relationships between watershed area and probability of white-spotted char occurrence in dammed-off sites with different isolation periods (3, 10, 20, 30, 40, 50 years). These curves were predicted from the logistic regression model.

Fig. 1. A typical dam to control erosion.

Fig. 3. White-spotted char Salvelinus leucomaenis (Pallas)

Fig. 4. Map of the study area indicating the location of the 52 surveyed dams.