<RESEARCH REPORT>

Distribution of amphidromous sculpin, *Cottus reini*, in relation to the presence of artificial structures in rivers around Lake Biwa

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Abstract: The Japanese sculpin, *Cottus reini*, is an amphidromous, bottom-dwelling freshwater fish. However, compared with other sculpins, little information exists on its distribution in rivers. In river habitats, artificial structures exist that are designed to control floods, but these may also exert a serious influence on fish migration. The objectives of this study were to determine the distribution pattern of *C. reini* in rivers and to evaluate the impact of artificial structures on this pattern. The investigations were conducted at 22 sites located in three tributary rivers of Lake Biwa. Multivariate analyses revealed that the cumulative height of weirs was a better predictor of the distribution of the species compared with other factors, and that weirs have a negative impact on the presence of the species. In contrast, previous research showed that *Cottus nosawae*, which has low mobility, is considered to be insusceptible to movement weirs. Therefore our result suggests that artificial structures prevent movements of *C. reini*.

Key Words: weir, migration, river, sculpin, Lake Biwa

INTRODUCTION

The life history of amphidromous fishes is as follows: larvae migrate downstream to the sea soon after hatching, which is followed by early feeding and growth in the sea, and then upstream juvenile migration from the sea back into freshwater for further somatic growth, sexual maturation and reproduction (McDowall, 1992, 1997). The Japanese sculpin, *Cottus reini*, is an amphidromous bottom-dwelling freshwater fish that migrates between Lake Biwa and its tributaries (Goto et al., 1989; Munehara et al., 2011). However, compared with other sculpins, there is a paucity of information on the distribution and migration pattern of *C. reini*.

Many artificial structures have been built in rivers to control flooding. As weirs are known to drastically influence fish movement (Moyle et al., 1990; Nicola et al., 1996), it is widely recognized to take into account of the height of weirs to secure the migration of many fishes. Jurg et al. (1998) reported that the bullhead (*Cottus gobio*) is a useful indicator species to evaluate the longitudinal connectivity of a river if interrupted by obstruction. The objective of this study was to evaluate how artificial structures affect the distribution of *C. reini* in rivers.

1. METHODS

We examined the distribution pattern of *C. reini* in three rivers around Lake Biwa (Fig. 1). The study area was a 15.4 km length in the Ado River, 3.7 km in the Kamo River and 4.2 km in the Wani River from the river mouth. In these study areas, artificial weirs were constructed to control river flow: 1, 2, and 6 artificial weirs in the Ado, Kamo and Wani rivers, respectively (Fig. 2). Study sites of about 400 m² were set in riffles at a total of 22 sites in three rivers (8, 5 and 9 sites in Ado, Kamo and Wani rivers, respectively). *C. reini* was captured using three hand nets (35 × 25 cm frame) for 30 minutes at each site once every 2 months during March-November 2010 (3 sampling procedures for each site).

At each study site, we measured the altitude above sea level using FG-535 (Empex Instruments) and the height of weirs if present (Fig. 3). At artificial weirs with fish ways we measured the height of fish ways one by one. The altitude of Lake Biwa above the tide level in Osaka Bay was 86m (see Fig. 4).

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We compared the presence/absence of C. reinii at the study sites with distance from the river mouth (m), altitude (m) and the cumulative height of weirs (cm). To examine relationships between presence or absence of C. reinii and these three environmental factors, we used a generalized linear mixed model (GLMM: glmmML function in the glmmML package of R) with a binomial error structure (logit link function). A GLMM can be applied to non-normal data in which random effects are present (Bolker et al., 2008). In the analysis we included altitude above sea level, distance from river mouth and cumulative height of weirs as fixed effects, and identification codes of each study site as a random effect. We used a stepwise procedure to determine the most parsimonious and accurate combination of explanatory factors (i.e. the fixed effect) using the Akaike Information Criterion (stepAIC function in the MASS library). All analyses were performed using R 2.9.0 software (R Development Core Team, 2008).

Fig. 1 Map of three studied rivers flowing into Lake Biwa. The number of artificial weirs in each river is given in parenthesis.

Fig. 2 Typical artificial weirs in the study areas (a), (b) Wani River, 2.3 km from river mouth, and (c) Kamo River, 3.4 km from river mouth.
The distribution pattern of *C. reinii* in the studied rivers is shown in Fig. 4.

The distance from the river mouth at the uppermost point of *C. reinii* distribution was shorter in the Wani and Kamo rivers compared with the Ado River.

Three factors, i.e., distance from river mouth, altitude above sea level and cumulative height of weirs, showed no significant effect on presence/absence of the species when data of the three rivers were combined (Fig. 5, Mann-Whitney U-test, *p* > 0.05). In contrast, result from the selected model showed that the altitude and cumulative height of weirs positively and negatively influenced the presence of the species, respectively (Table 1). The 95% confidence intervals of the estimates included 0 for altitude (Table 1); therefore only the cumulative height of weirs showed a significant effect on *C. reinii* distribution.

![Fig. 3 Sectional image of a typical artificial structure measured in this study.](image)

2.RESULTS

![Fig. 4 Distribution of Cottus reinii in the Ado, Kamo and Wani rivers. Solid and open symbols represent the sites where the fish were captured and not captured respectively. Crossbars represent artificial constructions such as weirs.](image)
Table 1 Results of model selected by generalized linear mixed model (GLMM)
(residual deviance: 17.29 on 17 degrees of freedom AIC: 25.29)

<table>
<thead>
<tr>
<th></th>
<th>estimate</th>
<th>s.e.</th>
<th>Wald statistic (χ²)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>-40.404</td>
<td>26.152</td>
<td>-1.545</td>
<td>0.1220</td>
</tr>
<tr>
<td>Altitude above sea level (m)</td>
<td>0.540</td>
<td>0.276</td>
<td>1.957</td>
<td>0.0504</td>
</tr>
<tr>
<td>Cumulative height of weirs (cm)</td>
<td>-0.042</td>
<td>0.013</td>
<td>-3.274</td>
<td>0.0011</td>
</tr>
</tbody>
</table>

Fig. 5 Frequency of presence and absence of *Cottus reinii* in relation to (a) altitude above sea level, (b) distance of river mouth, and (c) cumulative height of barriers (c).

3. DISCUSSION

Our results suggest that the uppermost limit of distribution of amphidromous *C. reinii* was restricted only by the cumulative height of weirs, and not by distance from the river mouth or altitude above sea level. A congeneric species, *C. nozawae*, which is distributed in the middle and upper reaches of rivers in Hokkaido Island and the northeastern part of Honshu Island, spends its whole life within a restricted area consisted of several ripples and pools (Goto. 1975, 1980, 1998). Nakano *et al.* (1995) reported that there was small impact on *C. nozawae* by artificial structure,
because the species is non-migratory. Therefore, the impact of the artificial structures on the movement of *C. nozawae* was negligible (Watanabe *et al*, 2001). However, our results show that the cumulative height of weirs has a significant influence on *C. reinii* distribution. This result indicates that artificial constructions in rivers might prevent the migration of the species.

Similarly, Porto *et al* (1999) demonstrated that low barriers (0.45 and 0.75m in height) could restrict the upstream migration of two fishes (mottled sculpin, *Cottus bairdi*, and longnose dace, *Rhinichthys cataractae*) in tributary streams on the Canadian side of Lake Ontario. Thus, artificial structures can clearly prevent fishes from moving in the upstream direction.

This may be particularly true for benthic fish without sucker such as *C. reinii*, which has a low ability to climb the steep gradients, as benthic fish are thought to be susceptible to the height of weirs.

We consider that our finding, that artificial structures cause negative effects on the migration of *C. reinii*, can make an important contribution to the conservation of this species.

Further studies are necessary to clarify ideal artificial structures other than its height to guarantee fish movement.

CONCLUSIONS

*C. reinii* migrates between Lake Biwa and its tributaries during its life cycle. Our results show that only the cumulative height of weirs showed a significant negative association with the distribution of the species. Artificial structures are commonly constructed in rivers for flood control and irrigation, and prevent the migration of fish. Hence, the improvement of artificial structures will be necessary to guarantee the mobility of small amphidromous species.

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REFERENCES


Japanese.