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Management and Ecological Note

Re-establishment of the North Sea houting in the River Rhine

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The anadromous fish species North Sea houting, *Coregonus oxyrinchus* (L.), became extinct in the River Rhine (Kranenbarg *et al.* 2002) and many other rivers draining to the North Sea in the 1940s (Lelek 1987). The cause was believed to be a combination of overfishing, poor water quality, habitat loss and fragmentation and barriers hampering upstream migrations (De Groot & Nijssen 1997). Since the 1980s, water quality in the River Rhine has greatly improved, many migration barriers were facilitated with fishways (De Leeuw *et al.* 2005) and no commercial fisheries on houting existed after its extinction. Thus, a large part of the possible causes for extinction were mitigated. Given the small size and isolation from the only remaining houting population in Denmark, it was decided to reintroduce houting in the German section of the River Rhine (cf. Hodder & Bullock 1997). Descendants of the last known reproducing population of houting from the Danish River Vidå (Hansen *et al.* 2006) were the donor population for the Rhine re-introduction programme that started in 1996. Approximately 1.9 million juvenile houting were stocked at two locations in the Lower Rhine, up to 2005. After stocking, the fish drifted/migrated downstream towards the Rhine delta (Borcherding *et al.* 2006). At present, two of the three North Sea outlets of the River Rhine are closed by dams with discharge sluices (De Leeuw *et al.* 2005). Increasing catches of adult houting in Lake IJsselmeer, one of the two closed off former estuaries of the River Rhine (De Leeuw *et al.* 2005), raised the question whether these fish originated from stocking or natural reproduction. Therefore, a mark–recapture experiment was conducted in 2006, in which all houting embryos were stained with Alizarin (Eckmann 2003) before being stocked into the Lower Rhine. Otolith analysis of young-of-the-year (YOY) houting caught in the lower sections of the River Rhine should then allow identification of their origin, i.e. from stocking or from natural reproduction.

Mature houting were caught in the River Treene in northern Germany (November/December 2005). Egg

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fertilisation was carried out at a hatchery at Lake Kellersee, where eggs were incubated in zoug-jars (50 L) using lake water, each containing approximately 1 million houting eggs. One of these zoug-jars was connected to a recirculation system set up in February 2006. The labelling solution, made up of 1 g L^{-1} Tris-buffer and 1 g L^{-1} Alizarin Red S monohydrate (Sigma-Aldrich, Taufkirchen, Germany) dissolved in de-ionised water (temperature 1–5 °C), was added to the recirculation system, but with the zoug-jar isolated. When the pH stabilised (adjusted to 8–8.5 with HCl 25%, Eckmann *et al.* 2007), the zoug-jar was re-incorporated in the recirculation system for 24 h.

After hatching in mid April, houting larvae were reared in net cages in Lake Kellersee. Mortality of larvae stained with alizarin did not differ from control batches. Larvae grew about 25–35 mm total length (L_T) until mid May, when 400 000 marked juvenile houting were stocked into the Lower Rhine and the River Lippe (Borcherding *et al.* 2006).

The success of the alizarin marking was evaluated against a control batch of marked houting that was retained until June; these grew up to about 60 mm L_T. Young-of-the-year houting were caught either in Lake IJsselmeer near the Afsluitdijk (catch date – 21 June to 25 July 2006; L_T: 62–120 mm; in the fyke net monitoring programme – Zeldzame vissen in het IJsselmeergebied; ter Hofstede & van Willingen 2001), or with an anchored stow net in the lower River Rhine near the city of Rees (Rhine-km 843, catch date – August to October 2006; L_T: 97–140 mm).

Otoliths were embedded in epoxy resin and ground to the midplane, so that the otolith primordia were exposed at the surface. The otoliths were polished with aluminium oxide and then checked for alizarin marks with an epifluorescent microscope (546 nm excitation wavelength) (Eckmann 2003). The otoliths of 23 individuals of the control group all had a clear alizarin mark at the nucleus, confirming 100% labelling success, which is in accordance with Eckmann *et al.* (2007).

From 55 YOY houting caught in the summer 2006 in Lake IJsselmeer, two individuals (3.6%) had an alizarin mark at the centre of their otoliths (catch date – 22 July 2006; L_T: 113 mm; catch date – 24 July 2006; L_T: 94 mm). None of the four individuals caught in the Lower Rhine had an alizarin mark. These results suggest that the majority of YOY houting in 2006 originated from natural reproduction, indicating the presence of a self-sustaining population. Thus, the re-introduction programme of North Sea houting in the Rhine system can be considered a success, according to the definition of IUCN (1998), and further stocking appears to be unnecessary (Seddon 1999; Fischer & Lindenmayer 2000).

Other studies on the migration of houting further support re-establishment and show that this species uses the whole Lower Rhine, the Rhine delta and marine habitats as feeding grounds (Winter *et al.* 2008). Scale transects of Sr^{88}:Ca^{44} ratios found only ≈10% of adult houting caught in Lake IJsselmeer in 2002 reached the sea as small juveniles, while the majority either lived exclusively in fresh water (72%) or migrated to the marine environment later in life (18%) (Borcherding *et al.* 2008). These results are in accordance with suggestions of Kranenbarg *et al.* (2002) that at present the riverine and estuarine waters in the Netherlands function as an important feeding habitat for the species.

These results provide evidence that houting has successfully re-established in the River Rhine. Although the present situation, with dams separating Lake IJsselmeer from the Wadden Sea and Haringvliet from the North Sea, still considerably deviates from the historical situation with open estuaries, houting appears to have suitable habitats available to re-establish. However, the low number of juveniles directly migrating to sea (Borcherding *et al.* 2008) suggest that connectivity and saline gradients at the dams should be restored (Kranenbarg *et al.* 2002), as the populations should be free-ranging in the wild (IUCN 1998).

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