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EXTENDED ABSTRACT

Measures against invasive fish, rotenone as an effective tool for ecological restoration

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Invasive fish species often pose a threat to indigenous species and is a worldwide problem. Invasive fish species have a great potential to alter the ecosystem when introduced to new locations. The outcome of not taking any measures against these invaders might be loss of indigenous species and a permanently altered ecosystem in the affected rivers and lakes.

There are many methods for removing unwanted fish, like electro-fishing, netting, and fish traps, but few of these mechanical measures have proven effective in the long run if a complete eradication is wanted. Chemical measures have been the favoured practice in fish eradication attempts. The piscicide rotenone has been used for fish control and eradication for more than 70 years. Rotenone is a natural product isolated from roots of tropical plants in the pea family Leguminosae, and it is highly toxic to fish. CFT Legumine, containing rotenone, is under assessment in the EUs Biocidal Product Regulation, and is the only legal piscicide in the EU. Norway is Europe's largest user of CFT Legumine in eradication efforts. The Norwegian Environment Agency gives permissions for the use of rotenone after assessing eradication applications.

The Norwegian Veterinary Institute has administered and performed several rotenone treatments against invasive fish and fish parasites every year for the last 10 years. Species that have been introduced outside their native range, and successfully eradicated, include the domestic invasive minnow (*Phoxinus phoxinus*), roach (*Rutilus rutilus*), pike (*Esox lucius*) and common whitefish (*Coregonus lavaretus*), and the exotic invasive rainbow trout (*Oncorhynchus mykiss*), lake trout (*Salvelinus namaycush*) and the salmon fish fluke

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Gyrodactylus salaris. The volumes of treated lakes have been from approximately 3,000 to 600,000 m^3, with a maximum of 216 million m^3. Treated rivers have varied widely in discharge, topography, and treated distance, with maximums of 42 km length and discharge of 200 m^3/s. Trained personnel conduct treatments. The description of method used in rotenone treatments can be found in Sandodden et al. (2018).

All treatments against invasive fish species in Norway the last 10 years have so far been successful in removing the introduced species. One example is the treatment of seven lakes in Trondheim municipality in Sør-Trøndelag County. Roach was an invasive species to the region, and the main reasons for eradication were a concern for the roach to adversely affect potable water quality if spread further to the nearby lake for drinking water supply. In addition, there was a goal to eradicate this blacklisted species permanently from the region, and to contribute to conservation of natural fish stocks and biodiversity. Rotenone treatment was considered the only measure that could eradicate roach from these lakes. One lake was 17,000 m^3 and 10 m deep, while the six other lakes ranged from 412,000 to 615,000 m^3, with maximum depths of 10 to 17 m. In September 2016, a crew of 14 people performed a treatment. A total of 4,000 l of CFT Legumine was used, and the target concentration was 49.5 µg/l rotenone (Bardal et al. 2018).

Another example is the eradication of minnow at Hardangervidda National Park, a high altitude tree-less plateau in southwest Norway. The treatment area comprised 40 ponds and smaller lakes over an area of 2 km^2. Total water coverage was 140,000 m^2, with depths of up to 4 m and average depths of 0.5-1 m. In addition, streams and marshes were a significant part of the defined treatment area. The treatment was performed during four days in August 2013 by16 people. Target concentration was 33 µg/l rotenone and a total of 225 l of CFT Legumine was used. Barriers were built to prevent minnow from re-entering treated area (Bardal 2017).

The effect of rotenone on non-target organisms are well documented, and even if some invertebrate taxa are very sensitive, the general findings from Norway are that most taxa recolonize within a year. Areas for treatment can be divided into sectors that are more manageable by building temporary barriers. Impact on species downstream of treatment area can be mitigated by the use of potassium permanganate.

Early detection and action against the invasive species is favourable. It is beneficial to have an action plan or program for eradication/control, a clear pathway for application and permissions, and a skilled experienced group to execute the ecological restorations. Norway and England both have dedicated groups because of their eradication programmes against, respectively, salmon fish fluke and topmouth gudgeon (*Pseudorasbora parva*).

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