Published on paper: 1989. Published online: 2024-10-20.
ISSN 1502-4873 (paper). ISSN 1891-5396 (electronic).
doi: https://doi.org/10.5324/fn.v10i0.6076.

Extermination of *Gyrodactylus salaris* — infected Atlantic salmon *Salmo salar* by rotenone treatment in the river Vikja, Western Norway

BJØRN OVE JOHNSEN, ARNE JOHAN JENSEN AND BJØRN SIVERTSEN

Johnsen, B. O., Jensen, A. J. & Sivertsen, B., 1989. Extermination of *Gyrodactylus salaris* — infected Atlantic salmon *Salmo salar* L. by rotenone treatment in the river Vikja, Western Norway. *Fauna norv. Ser. A 10:* 39—43.

Infections by *Gyrodactylus salaris* of Atlantic salmon in the river Vikja were discovered in 1981. To prevent further spreading of the parasite to neighbouring rivers in the Sognefiord area, the river was treated with rotenone in November 1981 and in May 1982 in order to exterminate the salmon population and consequently the parasite. Eggs of Atlantic salmon and Brown trout deposited in the gravel survived the rotenone treatment. Annual investigations of the river indicate a build-up of the Atlantic salmon population after 1982. In 1986 and 87 four yearclasses of young Atlantic salmon were present. No *G. salaris* have been found after 1981. Rotenone treatment seems to be a useful method for exterminating *G. salaris* from river populations of Atlantic salmon.

B. O. Johnsen and A. J. Jensen: Norwegian Institute for Nature Research, Tungasletta 2, N-7004 Trondheim, Norway.
B. Sivertsen: Sogn og Fjordane College, P.O. Box 39, N-5801 Sogndal, Norway.

INTRODUCTION

Mass infections by the parasitic flatworm *Gyrodactylus salaris* Malmberg, 1957 in populations of Atlantic salmon, *Salmo salar* L., parr from natural waters were in Norway first observed in the river Lakselva, Misvær (Johnsen 1978). Infections of Atlantic salmon by *G. salaris* were also reported by Heggberget and Johnsen (1982) and Johnsen and Jensen (1986, 1988). By the end of 1988, *G. salaris* had been reported from 32 Norwegian rivers and approximately 35 hatcheries scattered throughout the country (T.A.Mo, The National Veterinarian Institute, pers. comm.). The distribution of *G. salaris* in Norwegian rivers is associated with stocking of fish from infected salmon hatcheries. When the parasite has come to a river, it may spread to neighbouring rivers when infected fish migrate through brackish water. *G. salaris* is most probably a recent introduction to Norwegian rivers, and populations of salmon parr have been drastically reduced in infected rivers (Johnsen and Jensen 1986).

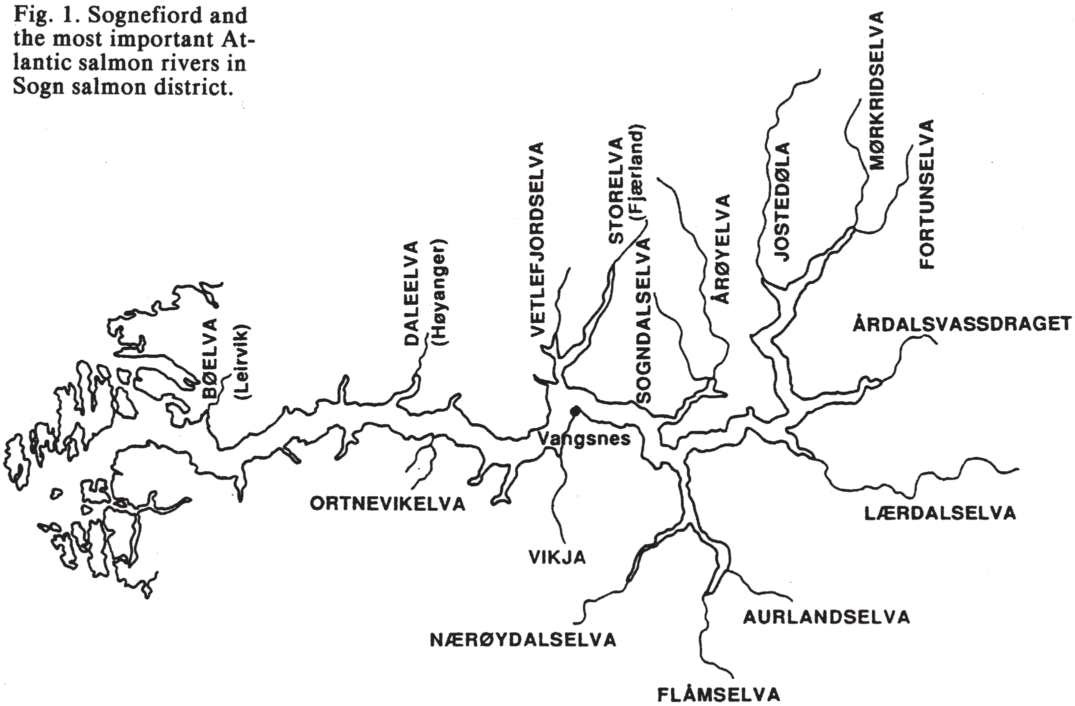
G. salaris was discovered on Atlantic salmon parr in the river Vikja in November 1981. The density of salmon parr was extremely low (<1/100 m²), and the salmon parr were heavily infected by the parasite (Gyrodactylusprosjektet 1982). Most probably, the parasite was introduced to the river in 1975 when 2300 anadromous Brown trout smolts from an infected hatchery were released in the river Vikja (Gyrodactylusprosjektet 1982).

In an attempt to prevent further spreading of the parasite to neighbouring rivers, the fish populations in the river Vikja were treated with rotenone in November 1981 and May 1982. Following the treatment, investigations of the salmon and trout parr populations have been carried out each year to determine whether the treatments had been successful. This paper describes the results of these investigations.

Description of the river and the fiord area

The river Vikja is situated in the county of Sogn og Fjordane in western Norway (61° 5'N, 6°35'E) (Fig. 1). The total catchment area is 124 km². The river is regulated for production of hydroelectricity. Atlantic salmon and anadromous Brown trout ascend 2 km of the river, as far as the outlet from Hove power plant. The damages caused by water

Fig. 1. Sognefiord and the most important Atlantic salmon rivers in Sogn salmon district.



regulation are compensated for by stocking 12000 Atlantic salmon smolts and 4000 smolts of anadromous Brown trout annually.

The river Vikja empties into Sognefiord, which is the longest fiord in Norway. Sognefiord drains several important salmon rivers of which Lærdalselva, Årøyelva and Aurlandselva are best known. Fig. 1 shows all of the salmon rivers in the Sogn salmon district which were included in the river fishing statistics in 1986 (Anon. 1987). The two nearest neighbouring rivers, Ortnevikelva and Vetlefjordselva, are situated 24 and 25 km from the river Vikja, respectively. Because of the large amounts of fresh water supplies to Sognefiord, water in the surface layer is rather brackish during the summer. At Vangsnes near the river Vikja (Fig. 1) salinity was measured at 7 $^{0}/_{00}$ at 0 m in July 1934. The salinity decreased further toward the inner part of the fiord (Helland-Hansen & Lie 1944). In an average year the salinity at Vangsnes is less than 12 $^{0}/_{00}$ in the surface layer in the period from June to September. In an average year in July and August, the salinity in the surface is less than 6 $^{0}/_{00}$ (Hermansen 1974).

MATERIAL AND METHODS

The rotenone treatment was carried out by fishery scientist Øivind Vasshaug on November 17th 1981, and repeated on May 5th 1982. Rotenone (Pro-nox-fish) was added at the inlet of Hove power plant, and supplied at several other locations downstream. The water discharge through the power plant was manipulated to give a maximum effect of the rotenone treatment. During treatment, the volume of flow was increased slightly to ensure that the rotenone solution penetrated throughout the entire river bed. Backwaters and small ponds were treated with a rotenone solution that was spread from an extinguisher pump. All tributaries where fish could ascend were also treated with rotenone, as well as one neighbouring stream (Hopra).

Samples of Atlantic salmon and Brown trout were collected by electrofishing 270—950 m^2 in the river during late autumn each year between 1983 and 1987. In 1988 the river was not investigated because of the large flow. All specimens were preserved in formaldehyde (1983—1984) or alcohol (1985—1987). In the laboratory the skin and fins of all fish were carefully examined for

Table 1. Number of fish caught (n), mean size in mm (L) and standard deviation of length (SD) of different ageclasses of Atlantic salmon and Brown trout from the River Vikja in the period 1983—1987.

		0+			1+			2+			3+			4+		
Date	Area m2	n	L	SD	n	L	SD	n	L	SD	n	L	SD	n	L	SD
Atlantic salmon																
830912	700	14	29.1	3.5	24	64.3	5.3	0	-	-	0	-	-	0	-	-
831207	900	8	32.5	4.3	31	65.9	5.5	0	-	-	0	-	-	0	-	-
840925	600	7	33.9	4.1	3	59.3	1.5	35	96.0	8.2	0	-	-	0	-	-
851113	950	34	35.8	3.6	22	74.5	13.0	0	-	-	14	131.5	9.4	0	-	-
861126	270	1	42.0	-	13	71.1	9.0	10	111.5	8.4	0	-	-	1	139.0	-
871007	650	4	33.3	1.0	10	67.1	5.8	28	97.6	7.6	23	127.0	11.5	0	-	-
Brown trout																
830912	700	4	40.8	2.2	117	87.9	17.6	0	-	-	0	-	-	0	-	-
831207	900	0	-	-	274	93.2	20.8	0	-	-	2	150.0	28.3	0	-	-
840925	600	0	-	-	10	71.5	6.0	100	109.1	14.8	1	148.0	-	0	-	-
851113	950	6	47.7	3.4	9	83.2	7.9	7	105.6	10.4	19	131.7	9.3	0	-	-
861126	270	3	47.7	2.9	2	86.0	0.0	2	127.0	12.7	1	143.0	-	0	-	-
871007	650	4	45.5	1.9	7	81.1	10.9	3	117.7	3.1	0	-	-	0	-	-

Gyrodactylus. Fish scales were read to determine age. A total of 282 Atlantic salmon and 571 Brown trout were investigated (Table 1).

A varying number of hatchery fish were found among the wild fish in the river each year. Atlantic salmon and Brown trout smolts are released every year in the river, and some do not migrate to the sea. These fish could be distinguished from the wild fish because of the wear and tear of their fins, and they were excluded from the material.

RESULTS

Gyrodactylus salaris was discovered on Atlantic salmon parr collected in the river in November 1981. At that time the density of salmon parr was low (<1/100 m^2) and salmon parr were heavily infected with parasites (Gyrodactylus-prosjektet 1982).

In association with the rotenone treatment on November 17th 1981, the river was electrofished in an attempt to find infected salmon parr. After considerable effort only one salmon parr was caught (Gyrodactylusprosjektet 1982).

During the rotenone treatment in November 1981, a total of 77 adult Atlantic salmon and a considerable number of anadromous Brown trout were found dead. The young fish which were found dead after the rotenone treatment were almost exclusively Brown trout. Only a few Atlantic salmon (0+) were found. The day after the treatment no live fish were found in the river.

The rotenone treatment was repeated in May 1982. Before the treatment electrofishing was carried out, and a few Brown trout parr were found in the river above the inlet dam to Hove power plant. These fish had probably migrated downstream from the upper parts of the watercourse. Before the rotenone treatment a 100 m^2 area below the outlet from the power plant at Hove bridge was electrofished. No fish were found. After the treatment 6—7 specimens of anadromous Brown trout (size 30—35 cm) were found in this part of the river. They had probably ascended the river after the treatment in November 1981.

Electrofishing in October 1982 showed that eggs which were buried in the gravel during the rotenone treatments had survived, and 31 Atlantic salmon and 80 Brown trout were found. All specimens of Atlantic salmon were less than 6 cm. The Brown trout which were found were 5—9 cm in length. Scale analysis showed that all specimens were of age 0+ (Vasshaug 1983). In 1983 only 0+ and 1+ age classes of both species were recorded, and a particularly large number of 1+ Brown trout were found (Table 1). In 1984 three year-classes of Atlantic salmon were present, and in 1986 and 87 four year-classes of Atlantic salmon were present (Table 1). Two three-year old Brown trout found in 1983, and one three-year old Brown trout found in 1984, had probably migrated from the upper parts of the river (Table 1).

No *Gyrodactylus* have been found after the rotenone treatment.

DISCUSSION

Rotenone is moderately poisonous to birds and mammals, but extremely toxic to fish and some insects (Fukami et al. 1969). It has been widely used in practical fish management for several decades. The very high sensitivity of rotenone to fish is caused by the very effective absorption of rotenone through the gills of the fish (Øberg 1965). There is a general connection between a fish species' demand for oxygen and its sensitivity to rotenone. Higher oxygen demands result in higher sensitivity to rotenone. Salmonids have proven to be among the most sensitive species investigated (Burdick et al. 1955, Marking & Bills 1976).

Gyrodactylus is a parasite which is totally dependent on its host. If it falls off or if the host dies, the parasite will also die unless it finds a new host within a short period of time (Malmberg 1957).

Rotenone treatment experiments carried out in the river Vikja showed that rotenone treatment effectively killed the fish populations in this small river. No live fish were found in the river immediately following the two treatments, and the first autumn after the treatments only 0+ fish of Atlantic salmon and Brown trout were found.

Prior to the rotenone treatment only a few Atlantic salmon parr were found in the river, and they were heavily infected with *G. salaris.* After the treatment a rebuilding of the Atlantic salmon population has taken place. Since 1986, four year-classes of Atlantic salmon parr have been found in the river. No *G. salaris* has been found following the rotenone treatments. These results indicate that rotenone treatment was a useful method for exterminating *Gyrodactylus salaris* from the river Vikja. When the host was wiped out, the parasite also disappeared.

There seems to be an important connection between the occurrence of *G. salaris* in Norwegian rivers and deliveries of fish for river stocking from infected hatcheries. In all but three regions such deliveries have been made to at least one river. The rivers within each region are situated so close to each other that the occurrence of *G. salaris* in neighbouring rivers may be explained as the result of spreading with fish through brackish water in the fiord area (Johnsen and Jensen 1986). Anadromous Brown trout and Rainbow trout may contribute significantly to the spread of *Gyrodactylus* in addition to Atlantic salmon adults and smolts. Recent investigations indicate that the Rainbow trout can be a significant transport host for a number of *Gyrodactylus* species which are dangerous or harmless to salmonids in fish farms and/or natural waters (Malmberg & Malmberg 1987). The salinity of the surface water of the Sognefiord may be very low during long periods in the summer (Hermansen 1974). Rotenone treatment of the river Vikja put a stop to potential spreading of *G. salaris* to a number of important salmon rivers in the Sognefiord area, thereby hindering a possible disaster for the salmon fishery in this region.

This investigation has shown that rotenone treatment can be an effective way of removing *G. salaris* from a watercourse. A vital condition for the success in the river Vikja was the small size of the river and the fact that the volume of flow could be easily controlled. However it is important to note that this success was achieved at a time when we knew very little about rotenone treatments of rivers in Norway. In later years techniques for effective rotenone treatment have been improved, and four more rivers (Korsbrekkelva in 1987, Skibotnelva, Aureelva and Vikelva in 1988) have been treated with rotenone in an attempt to exterminate the parasite.

ACKNOWLEDGEMENTS

Fishery scientist Øivind Vasshaug deserves considerable credit for his willingness to treat the river Vikja with rotenone as soon as *G. salaris* was discovered. We thank Amy Lightfoot for improving the English of this article.

REFERENCES

Anon. 1987. Norwegian Official Statistics B 720. *Salmon and sea trout fisheries 1986.* Central Bureau of Statistics of Norway, Oslo.

Burdick, G. E., Dean, H. J. & E. J. Harris 1955. Toxicity of emulsifiable rotenone to various species of fish. *New York Fish Game J. 2,* 36—67.

Fukami, J. I., I. Yamoto & J. E. Casida 1967. Metabolism of rotenone in vitro by tissue homogenates from mammals and insects. *Science 155,* 713—716.

Gyrodactylusprosjektet 1982. *Rapport fra Gyrodactylusutvalget over virksomheten i 1981 og program for virksomheten i 1982.* 43 pp.

Heggberget, T. G. and B. O. Johnsen 1982. Infestations by *Gyrodactylus* sp. of Atlantic salmon *Salmo salar* L. in Norwegian rivers. *J. Fish Biol. 21,* 15—26.

Helland-Hansen, B. and S. Lie 1944. Fysisk havforskning i Sognefjorden. *Naturen (1944),* 303—316.

Hermansen, H. O. 1974. *Sognefjordens hydrografi og vannutveksling.* Hovedfagsoppgave i fysisk Oceanografi, Geofysisk institutt, Avd. A, Universitetet i Bergen.

Johnsen, B. O. 1978. The effect of an attack by the parasite *Gyrodactylus salaris* on the population of salmon parr in the river Lakselva, Misvær in Northern Norway. *Astarte 11,* 7—9.

Johnsen, B. O. and A. J. Jensen. 1986. Infestations of Atlantic salmon, *Salmo salar,* by *Gyrodactylus salaris,* in Norwegian rivers. *J. Fish Biol. 29,* 233—241.

Johnsen, B. O. and A. J. Jensen. 1988. Introduction and establishment of *Gyrodactylus salaris* Malmberg, 1957, on Atlantic salmon, *Salmo salar* L., fry and parr in the river Vefsna, northern Norway. *J. Fish Disease 11,* 35—45.

Malmberg, G. 1957. Om förekomsten av *Gyrodactylus* på svenska fiskar. *Södra Svenska Fiskerifor. Aarskr.,* 76 pp.

Malmberg, G. & M. Malmberg 1987. *Gyrodactylus* in salmon and Rainbow trout farms. Pp 199—204 in A. Stenmark & G. Malmberg (eds) *Parasites and diseases in natural waters and aquaculture in Nordic countries.* Proc. Zoo-Tax-Symposium, Stockholm, 2—4 December 1986.

Marking, L. L. & T. D. Bills 1976. Toxicity of rotenone to fish in stadardized laboratory tests. *U. S. Fish Wildl. Serv., Invest. Fish Control 72,* 1—11.

Øberg, K. E. 1965. On the principal way of attack of rotenone in fish. *Arkiv Zool. 18,* 217—220.

Vasshaug, Ø. 1983. Gyrodactylus. *Rapport fra Fylkesmannen i Hordaland,* April 1983, 5 pp.

Received: 26 June 1989.