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Mortality of Sea Trout (*Salmo trutta* L.) and Atlantic Salmon (*S. salar* L.) smolts during seaward migration through rivers and lakes in Denmark.

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ABSTRACT

In Denmark intensive stocking of sea trout and salmon have taken place. The total production of smolts (natural + stocked) in the Danish watersheds amounts to about 1,22 mio, sea trout smolts and 260,000 salmon smolts, respectively. These figures are however not adjusted for mortality during seaward migration. Mortality rates of trout- and salmon smolts during seaward migration have been estimated in two Danish lowland watersheds, using various methods. The results are based on seven different experiments, carried out from 1982 - 1996. Methods used are electro-fishing, smolt-traps, external tagging, Panjet marking and radio-telemetry. Estimated mortality rates during downstream migration was at least twice as high for stocked trout than for natural trout smolts. Estimated mortality rate for salmon smolts strains depended on their genetic origin. All results clearly indicates that very high mortalities occur when smolts must pass through a river and especially a lake on their way to the sea. The lakes considered here are shallow and turbid. Predation from pike (*Esox lucius* L.), pike-perch (*Stizostedion lucioperca* L.) and various avian predators was the main reason for the high mortalities. Based on the evidence presented here, it must be concluded that, if lakes are present, very serious problems must be expected when trying to re-establish anadromous salmonid populations in lowland rivers.

Keywords: Smolt; *Salmo trutta; Salmo salar;* mortality; predation; radio-telemetry.

Introduction

The area of inland waters in Denmark (43,000 km^2) consists of about 15,000 ha streams and about 45,000 ha lakes. The country is a moraine formation and is typically a lowland with sandy or gravelly soils.

Generally speaking, all streams and lakes are influenced by culture. Since the Middle Ages weirs at mills and industrial plants have increasingly prevented salmonid spawners from reaching the spawning grounds. The rivers and lakes have a high content of nutritive salts and, as a consequence of this, they have a high plant production and most lakes have fish faunas composed of cyprinids, while predators; pike (*Esox lucius* L.) and perch (*Perca fluviatilis* L.) occurs everywhere but especially pike are low in numbers. Pike-perch was introduced into Denmark in 1879 and is now spread to many river systems both in lakes and rivers. Water intakes for trout farms (about 500 in Denmark) have not only obstructed the migration of spawners but also the downstream migration of smolts. During their seaward migration the smolts are exposed to predation by pike, perch, pike-perch and burbot (*Lota lota* L.) in rivers and lakes.

Only less than 2% of the streams have never been physically regulated, and the remainder are more or less regulated. Interventions for agricultural improvements have been followed by increased applications of fertilizers, so that most of the streams have abundant macrophyte growth. Therefore, it is necessary to carry out weed cuttings and sometimes dredging of bottom and bank material, which reduces spawning success and production of salmonids.

But, during the last 20 years the water authorities have restaurated many streams. Thus, weed cuttings and bottom dredging have been reduced to a minimum, salmonid spawning grounds have been reestablished, and fish passes have been constructed. All together, most of the the streams have improved considerable in this period, but most of the lakes are still highly eutrophic.

Therefore, there is great demand and interest to rehabilitatate our salmonid (i.e. salmon and sea trout) stocks in Danish rivers.

The stocking of trout and salmon are carried out according to the Danish trout and salmon stocking programme (Rasmussen 1984, Rasmussen & Geertz-Hansen 1997). The material is distributed in numbers of fish adjusted according to the estimated carrying capacity of the locality, taken into account any natural trout population already present. The numbers of stocked trout fry, half- and yearlings in Table 1 are nearly the same during the years in the table, whereas the number of smolts today amounts to about 850,000 specimens and will be the same in the future. The number of stocked one-year salmon and smolts has been raised to about 300,000 and 110,000 respectively in the last years.

The present status of sea trout stocks in Denmark is given by Christensen *et al* (1993).

The present status and rehabilitation programme of salmon in Denmark is described by Geertz-Hansen & Jørgensen (1996). Of a total of 9 rivers known to have held salmon only the Skjern River still has a very little run (spawning escapement about 100-200) of large, mature fish. In the other rivers a major rehabilitation program has recently been undertaken (Geertz-Hansen & Jørgensen 1996). Due to the small size of the spawning population in the Skjern River no salmon eggs can be taken from this stock. Instead, eggs from salmon stocks from Sweden (Lagan and Ætran), Scotland (Conon), and Ireland (Corrib and Burrishoole) are being raised in a Danish hatchery (Holdensgaard, *et al.* 1996) and released mainly as one and two year smolts and one year parr in the rivers included in the rehabilitation programme. Basically the stocking procedures are the same as for trout. When half-yearlings and one-year old salmon parr are stocked in stream areas, where trout stockings take place, the latters are suspended.

The original, but unknown, annual production of sea trout smolts has been estimated to about 2,6 mio specimen, and the present (natural and derived from stocked fry, half- and yearling) to about 0,36 mio (0,18 natural and 0,18 stocked) specimen, which together with the river mouth plantings, should give an annual number of smolts from Danish rivers of about 1,22 mio specimen today.

The present annual production of natural salmon smolts is about 5,000 specimen in the Skjern River, and the present annual number of smolts (stocked half- and yearlings and smolts) to about 260,000 specimen from Danish rivers.

Most of the smolts stocked in rivers are river-mouth plantings, and these fish are considered to migrate to the sea shortly after stocking. But because local angling experience and tagging results show that most of the mature fish stop their migration having reached where they were released, some of the smolt stockings are moved further up-stream.

When calculating the total fishing yield (Markmann and Rasmussen 1984) derived from sea trout smolts, the starting numbers in the calculations have been the estimated number of smolts starting their seaward migration, i.e. there has been no allowance of reduced number actual reaching the marine because of an eventual mortality during migration.

Less than 15% of the present number of sea trout smolts comes from natural production and as such probably genetical adapted to their river system, and about 10% are F1-generation stocked fish, the remainder 75% are domesticated fish, held in hatcheries for several generations, where they have been selected for other traits than in nature, and therefore not genetical adapted to their river system when stocked. It is therefore supposed that they could have difficulties during their seaward migration through rivers and lakes.

Nearly 100% of the present number of salmon smolts are F1-generation stocked fish coming from non-native river systems, and they are therefore not genetical adapted to their river system.

Several research activities to get ideas and estimates of the performance of smolts of sea trout and salmon, have been initiated in several river systems in Jutland and Funen. In seven of the examined rivers a salmon rehabilitation programme has been initiated (Geertz-Hansen & Jørgensen 1996). In all the other rivers routine trout stockings have taken place for many years.

This paper gives some preliminary results from research activities in the period 1982-83 and 1992-96, using data from the Bygholm River and the Gudenå River about the problems with survival of seaward migrating sea trout and salmon smolts through rivers and lakes, combining data from trapping, external tagging, panjet-marking and radio telemetry. Further results will be published in the future.

Material and Methods

Bygholm River (Fig.1) is from spring to outlet into a brackish fiord about 34 km. Mean annual discharged 1,6 m^3/sec.
About 3 km from outlet an artificial shallow lake (about 53 ha) was established in 1917. In the river 0.5.-0.75 pike larger than 30 cm per 100 m river stretch are present. In the lake pike and pike-perch larger than 30 cm are present, 7.2 per ha and 6.6 per ha, respectively. The annual potential sea trout smolt production was estimated to about 2,400 specimen.

Marking and tagging:
In 1992 a total of 3,900 panjet-marked domesticated one-year old (19.7 cm) trout smolts were released on five different places up-stream the lake. 23 of the same size were tagged with radio transmitters (FSM-2, Lotek Inc.) and released at two different sites in the river. At the outlet of the lake a fyke-net trap caught all seaward migrating natural and stocked trout. Electrofishing in the river and lake, examination of the stomach contents of pike and pike-perch in river and lake, estimation of food consumption divided into different food items and tracking (RX 89 10HE reciever, Televilt) of radio-tagged smolts, made it possible to "make a budget" of the fate of natural and stocked sea trout smolts, (Koed 1993, Larsen & Carl 1994).

Gudenå River (Fig. 2) is from spring to outlet into a brackish fiord about 158 km. Mean annual discharge 29 m^3/sec.
In 1922 about 41 km from the spring a hydro-power station was build at Vestbirk creating a 3.7 km long and shallow lake (about 44 ha).

On the distance from Lake Vestbirk to Lake Tange (about 69 km) the Gudenå River goes through a nearly 40 km long stretch mostly with a combination of lakes and river stretches ('the lake system') and the rest (about 29 km) with river.

In 1920 a hydro-power station was build about 110 km from spring and 36 km upstream the tidal limit, creating the 584 ha Lake Tange (Fig. 2). Lake Tange is 12 km long and shallow with maximum depths of 7-8 meters.

All spawning areas of the, now extinct, native salmon stock, as well as important spawning and rearing areas for migratory trout, were situated above the Tange power station. It is crucial for the creation of a new self-reproducing salmon stock, and for the enhancement of migratory trout stocks, that smolts from upstream spawning and rearing sites can traverse the lake systems and reach the sea.
Pike, pike-perch and burbot are present everywhere in the river system.

The annual potential sea trout smolt production from the spring to Lake Vestbirk was estimated to about 4,492 specimen. The production from here to Resenbro was about 9,021 specimen and from Resenbro to the Tange power-station about 7,945 specimen, so that the total annual estimated sea trout smolt production from the spring to the Tange power-station is about 21,458 specimen annually.

Marking and tagging:

(A) In spring 1993 a total of 3,142 panjet-marked domesticated one-year old (17.8 cm) trout smolts and

(B) 2,369 panjet-marked one-year old (14.8-16.9 cm) smolt from four non-native strains (Ætran, Conon, Corrib and Burrishoole) were released on six different positions up-stream Lake Vestbirk. Two traps at Vestbirk enabled to catch all seaward migrating trout and salmon smolts.

(C) In spring 1994 a total of 13,109 panjet-marked one-year old smolt from the Corrib strain were released at four different localities from Kloster Mill (below Vestbirk) to Kongensbro (just above Lake Tange). Two traps at Tange power-station enabled to catch all downmigrating trout and salmon smolts.

(D) In spring 1996 a fyke net trap at Kongensbro (Jepsen & Aarestrup, in prep) enabled us to estimate that about 188 of F1-generation sea trout (13.9 cm), marked and released at stretches upstream the trap, entered Lake Tange. About 190 domesticated marked and released sea trout (17.2 cm) entered the lake. 2 fyke net traps below Tange power station was used to estimate passage through the lake. Estimations of the total smoltrun was made according to Ricker (1975).

(E) In spring 1982 and 83 a total of 6,000 Carlin-tagged F1-generation Swedish Mørrum sea trout strain (20.6 and 20.8cm) were released at three places: Kongensbro, just below Tange power-station and just above the outlet to the fiord. Based on recaptures and the results from Berg (1988), the mortalities through the lake, the power station and in the river from the power station to the fiord can be estimated.

Telemetry:

(F) In May 1996, 24 wild trout smolt (18.0 cm), 25 salmon smolt of Burrishoole strain and 25 salmon smolt of Ætran strain, were implanted with radio-transmitters. All 50 salmon were 1-year hatchery-reared smolt (16.7 cm). The trouts were caught in the river in the fyke-net trap at Kongensbro.

The transmitters used were ATS internal smolt transmitters, Model 377 and Model 384, weighing 1.4 and 1.7 gram, respectively. The transmitters had an expected operation time of at least 20 and 35 days. Each transmitter had a unique combination of frequency/pulserate, making each tagged fish individually recognizable.

The implantation into the salmon smolts was done at the hatchery. The transmitter was inserted into the body cavity through a mid-ventral 8-10 mm incision, anterior to the pelvic girdle. The antenna was run through a hole from the body cavity, pierced with a blunt needle. The incision was closed with 2 or 3 seperate sutures. The duration of the operation was between 1 and 2 minutes.

Upon recovery (24 hours) after the implantation, the smolts were all transferred to Gudenå River, and released in late afternoon, a few hundred meters upstream Lake Tange.

The implantation into the trout smolts was done in a similar way at the riverbank. The smolts were kept for 24- 48 hours after implantation in a netpen in the river, and released in late afternoon, a few hundred meters upstream Lake Tange.

All released fish appeared to be in good condition and exhibited normal swimming and feeding behaviour before release.

The tagged smolts were tracked daily from boat with a mobile hand-operated reciever over a period of 3 weeks. 3 automatic listening stations (ALS) were operating for five weeks, registering passage of tagged fish (see position in Fig. 2).

When the migration behaviour of a tagged fish became "abnormal" (i.e. lack of movement, decrease in signal strenght, residence in shallow water or macrofytes), the fish was, if possible, obtained by electric fishing. Usually a pike with a transmitter in the stomach was caught. If no responce, the electric fishing was repeated 1-2 times the following days, before it was concluded, that the transmitter was lying on the bottom, assumably discharged by a predator.
If the transmitter suddenly disappeared from the area and was not later detected, it was classified as eaten by avian predators.

Results

<u>Bygholm River</u>
A total of 1,503 (62.6% of production) wild trout smolt (16.3 cm) and 836 (22.4% of stocked trout) were recaptured in the trap at the outlet.This gives for stocked trout:

instantaneous mortality Z (lake):		1.4890
"	lake pr km:	0.4024
"	river pr km:	0.0007

The mean daily migration velocity for the stocked trout was 2.81 km in the river and 0.12 km in the lake.

The proportion in survival between wild and domesticated trout was 2.79 (62.6/22.4).

The mortality through the river is caused by pike predation and is insignificant compared to the mortality through the lake (pike and pike-perch). Heron (*Ardea cinerea* L.) and cormorant (*Phalacrocorax carbo* L.) were seen in the area, but their eventual importance were not quantified.

Combining the estimated mortalities we can simulate the survival of stocked smolts (Table 2). It is clearly seen from the table, that the great reduction in numbers take place during migration through the lake and that only one fifth of the potential number of smolt actually reaches the fiord.

Gudenå River

Trout

(A) A total of 1,187 (26.4% of production) wild trout smolt (18.3 cm) and 356 (13.2% of stocked trout) were recaptured in the traps at Vestbirk. This gives for stocked trout:

instantaneous mortality Z	(lake):	1.1567
"	lake pr km:	0.3126
"	river pr km:	0.0651
"	river + lake:	2.0250

The mean daily migration velocity for the stocked trout was 1.32 km in the river and 0.14 km in the lake.

The proportion in survival between wild and domesticated trout was 2 (26.4/13.2).

(E) The recaptures give the following mortality rates:

instantaneous mortality Z Kongensbro - Tange station:	0.6775
" lake pr km:	0.0565
instantaneous mortality Z Tange station	0.0408
instantaneous mortality Z Tange station- Fiord :	1.1485
" river pr km:	0.0319

The results show that if the smolts were released at Kongenbro about 15.3% reach the fiord whereas if released below the power station about 31.7 % reach the fiord so that the survival through the lake is less than 50%. This figure should be compared with the result from experiment (D) where 15 (8%) F1 generation sea-trout and 5 (2.6%) domesticated trout passed the lake, estimated from catches in fyke net traps below the power station (Jepsen & Aarestrup, in prep).

Further, 167 and 431 panjet-marked domesticated and wild trout smolts were released at Emborg (about 50 km) upstream Kongensbro but none were recaptured in the trap at Kongensbro so it is not possible to calculate survival of trout smolts through the 'lake system'.

Salmon

(B) A total of 485 (20.5% of released) smolt were recaptured in the traps at Vestbirk. This gives for stocked salmon:

		Total	Corrib	Burrish.	Conon	Ætran
instantaneous mortality Z (lake):		1.4288	1.4890	1.8857	1.7884	0.8897
"	lake pr km:	0.4202	0.4024	0.5096	0.4834	0.2405
"	river pr km:	0.0133	0.0007	0.0279	0.0084	0.0198
"	river + lake:	1.7702	1.5072	2.5993	2.0029	1.3965

The mean daily migration velocity for the four strains were:

	Total km pr day	river km pr day	lake km pr day
Corrib	4.00	6.84	1.03
Burrishool	1.53	4.13	0.46
Conon	1.39	3.13	0.45
Ætran	2.87	4.41	0.67

There is a correlation (r_s= -0.6, p= 0.30) between mortality and migration velocity, so that the faster migration velocity, the less mortality.

(C) The recaptures gives the following:

instantaneous mortality Z Kloster Mill - Emborg:		0.6300
"	lake pr km:	0.1260
instantaneous mortality Z Emborg - Resenbro:		2.2342
"	lake pr km:	0.0657
instantaneous mortality Z Resenbro - Kongensbro:		0.0612
"	river pr km:	0.0038
instantaneous mortality Z Kongensbro - Tange power:		3.1915
"	lake pr km:	0.2660
instantaneous mortality Z Kloster Mill - Tange power:		6.1169
"	lake + river pr km:	0.0913

The total survival from Kloster Mill to the Tange power station is about 0.22%.

Combining the estimated mortalities we can simulate the survival of stocked smolts (Table3).

Trout.

It is clearly seen from Table 3, that the great reduction in numbers takes place both during migration through the river and especially the lakes. It is not possible to calculate the reduction in numbers from Kloster Mill to Resenbro through 'the lake system', but from the preliminary data given in experiment (D) it is plausible that almost every smolt die.

The total catch of trout smolts in experiment (C) was only 859 smolts. Compared to the theoretical amount of 21,458 specimen only about 4% of the total smolt production from the Gudenå River system opstream lake Tange, reach and pass the Tange power station. The majority of the missing smolts are presumably dead.

Salmon.

Clearly it is the passage through the lakes that gives the very high reduction in numbers. This means that further smolts stockings should be made below Lake Tange.

The above mentioned result naturally raised the question of the causes to this high reduction in numbers. Therefore the following experiment with radiotelemetry was initiated.

(F) Most smolt migrated downstream immediately, and after 24 hours only 18 tagged smolts remained in the release-area. The first fish got out through the outlet 3 days after release. As expected mortality-rates on passing through the lake were high. As seen in Fig 3, only 4 of 50 tagged salmon smolts (8%) and none of 24 tagged trout smolts managed to pass the lake.

Pike, that is abundant in the lake, seemed to be the major predator, consuming at least 18 (36%) of the salmon- and 8 (33%) of the trout smolts.

If only smolts with a known cause of death is considered, pike account for 64% of the salmon mortality and 50% of the trout mortality (data not shown).

10 salmon and 5 trout smolts tagged were classified as eaten by avian predators. Of these 5 (4 salmon and 1 trout) were actually tracked while in the birds, 4 in grebe (*Podiceps griseigena* L.) and 1 in heron. The rest suddenly disappeared from the area, and no signal was later recieved.

21 smolts stopped moving and did not respond to electric fishing. These fish are classified as fate unknown.

From observations of pikes actually seen but not obtained by elektrofishing, we can estimate that the smolt transmitter stayed in the pike for 3-6 days before it was discharged, either by regurgitation or through the anus. The smolt itselves seemed to be digested rapidly, and only very few of the pike-stomachs investigated contained smolt-remains. The length of pikes observed with an ingested radiotransmitter varied from 35 cm to approximately 100 cm.

Smolts were predated all over the lake, as seen in Fig. 4. For salmon it seems to be fairly constant except in the area 8-10 km from release, where none were classified as predated/ missing. For trout smolts it is also fairly constant exept 6-8 km from release were a almost 45% of the released fish dies. The major mortality in this area concentrates on the area just upstream Ans Bridge, where the lake is only 25 m wide under the bridge.

At the end of the study period (23 days after release) 2 salmon (4%) and 3 trout smolts (13%) were still alive in the lake.

Discussion

From the present results it is clear that lakes in lowland river systems impose very serious problems in the rehabilitation of salmonids. This is because the mortality-rates of the smolts passing the lakes are very high. The present results clearly suggests that 'wild trout smolts' are more (i.e. 2-3 times) capable to survive during seaward migration than reared trout smolts. But it is difficult to separate the genetic effect from the effect of growth and learning of predator avoidance. However, an indication of a possible genetic effect is seen in (D) where F1-generation sea trout smolts from the original sea trout population managed to pass lake Tange app. 3 times better than domesticated smolts. Admittingly, this is too little to base any conclusions on. For now, it seems therefore more plausible to say that one wild smolt equals at least 2-3 domesticated and reared smolt, so that their fitness might be reduced during their nursery period at the hatchery (Berg & Jørgensen 1991), but more research is needed.

The results with rehabilitation of salmon in the Gudenå River shows the same as for trout. Even if F1-generation wild salmon raised in a hatchery, is used as stocking material, the migrating smolts have very low survival, in slow flowing lowland river systems with lakes and predators as pike and pike-perch.

Delays and low passage percents of salmon smolts through lakes have been reported (Hansen *et al.* 1984). However the reasons for the losses were not further studied.

The causes of mortalities were studied using implanted radio-transmitters. The implantation of radio-transmitters in salmonids is reported to have only minor effects on mortality, growth, svimming performance and general behaviour (Mellas & Haynes 1985, McCleave & Stred 1975). In long term studies infections caused by the operation can be a problem (Lucas 1989). In Norway juvenile trout with transmitters implanted was followed for 6 months, and showed no increased mortality (Økland, unpublished). When tagging smolt, extraordinary care must be taken to minimize handling-stress, because the transition from a life in a riverine to a life in marine environment is a stressfull event, making a smolt more vulnerable than a stationary fish of same size.

The behaviour of the tagged smolt in this experiment was highly satisfactory, and convinced us that the results were not seriously affected by the adverse effect of handling and tagging the fish. Preliminary test in laboratory with sea trout smolts, showed no increased mortality (data not shown). However in the case of the wild trout smolts, which were captured in a fyke net, there is a possibility that these fish were more stressed, due to the extra handling, compared to the salmon smolts. This could result in a change in behavior, leading to a lower passage percent. In fact, this seems to be the case as results from the fyke net traps presented in (D) for wild trout smolts (14.8 cm) give a passage percent of approximately 15%, and for salmon smolts (15.6 cm) 8 % (data not shown). Comparing with passage percents in (E) the Mørrum smolts are better in passing the lake. However, the difference between the 2 experiments is probably due to the larger size of the Mørrums fish, the indirect way of calculating passage percent of the Mørrums fish, and maybe differences in the characteristics of the lake in 1982-1983 and 1996.

Smolts were eaten all over the lake, but predation seemed to be highest on 2 locations. Km 6-8, more specifically around Ans Bridge, where the lake narrows, and km 10-12, the lowest part of the lake close to the outlet. These are places where the smolts seemed to have p roblems in navigating. They got delayed, moved around and therefore probably have an increased risk of meeting a predator.

There is no doubt that pike was the most important smolt-predator in the lake, but the lake is also inhabited by other species known to predate on migrating smolts: Pike-perch, burbot and eel (*Anguilla anguilla L.*). Especially pike-perch is known from other studies to prey heavily on smolts passing eutrophic turbid lakes (Larsen & Carl 1994, Koed 1993).

Pike is the most catchable predator, because of its preference for shallow vegetated areas (Diana *et al.* 1977; Chapman & Mackay, 1984) , while pike-perch and burbot during daytime takes residence in the deepest parts of the lake (Ali *et al.*, 1977; Nagiec, 1977). If a tagged smolt is eaten by a pike-perch or Burbot, that is situated deeper than 5m, the signal will be hardly detectable on the surface, and even if detected, the pike-perch would be safe from electric fishing on that depth. In fact many smolt could have been eaten by pike-perch and burbot even though none was caught. However, information from local fishermen tells that the pike-perch population is scarce in Lake Tange. Therefore it seems likely that many of the 21 smolts whose fate is unknown were in fact also eaten by pikes.

Bird predation is often hard to quantify, because of the high mobility of the predators. The chance of actually tracking a signal to a certain bird must be very small. The assumption that the sudden and permanent loss of a signal was due to avian predation is validified by the fact that we did track birds on 5 occations. The tracked birds were heron and grebe, but also cormorant (*Phalacrocorax carbo* L.), osprey (*Pandion haliaëtus*) and various gulls were present by the lake, and might have preyed on migrating smolt. Grebe is very abundant in lake Tange. Of the 4 grebes which we did track, 2 actually later in the study period discharged the transmitter.

Tagged smolt could very easily have been eaten by one of the above mentioned predators, digested and discharged, and then classified as "fate unknown". In fact it seems safe to assume that this is actually what happened to these fish. It is however not possible to identify the predator responsible.

Rehabilitation of a fish species means that stocking of fish should be done in such a way/strategi that the stockings end up with a self-sustaining population. If not, we are talking about ranching, 'put-and-take' and so on.

In many Danish streams, the extinct sea trout population have been rehabilitated using domesticated, reared trout, which have been released as fry, half-yearlings and yearlings in brooks and smaller streams where the fish have adapted to the 'wild' and managed to migrate to the sea and to come back to their nursery areas and spawn, so that after due time the stockings have been suspended (Christensen *et al.* 1993).

The conclusion from the present results, is that if lakes are present, very serious problems must be expected when trying to rehabilitate salmonids in lowland rivers. It also shows that reared salmon smolts should be released at the lower reaches of the river, but then it is difficult to talk about rehabilitation. The proper name would be sea-ranching.

One year old salmons have been stocked in rivers going to the North Sea as part of the Danish Salmon Rehabilitation Programme. Preliminary electrofishing results have showed that spawning takes place in some of the rivers but more detailed research activities will be made in the near future. But it tells us that rehabilitation of salmonids must use stockings with fish younger that smolts and that they should be released in potential spawning and nursery areas.

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Table 1. The mean annual stockings in numbers in Denmark during the years 1987 to 1995.

Salmo trutta:	1,617,000 one month old fry
	465,000 half-yearlings
	404,000 one year old
	653,000 smolts stocked in rivers
Salmo salar:	29,000 half-yearlings
	130,000 one year old
	58,000 smolts stocked in rivers

Table 2. The survival of 1,000 smolt released upstream in Bygholm River.

Distance from spring km	Locality	Numbers	Numbers in %	Relative change in %
0	Spring	1000	100	
31	Lake inlet	958.9	95.9	-4.1
33.6	Lake outlet	211.8	21.2	-77.9
34	Fiord	211.7	21.2	-0.1

Tabel 3. The survival of 1,000 smolt released in Gudenå River.

Distance from spring km	Locality	Trout Numbers	Trout Numbers in %	Trout Relative change in %	Salmon Numbers	Salmon Numbers in %	Salmon Relative change in %
7	Hammer	1000	100				
11	Tørring				1000	100	
37	Lake inlet	141.8	14.2	-85.8	982.2	98.2	-1.8
41	Vestbirk	44.6	4.5	-68.5	221.5	22.2	-77.4
55	Kloster mill	17.9	1.8	-59.8	219.6	22.0	-0.9
60	Emborg				116.9	11.7	-46.8
94	Resenbro				12.5	1.3	-88.9
110	Kongensbro	1000	100		11.8	1.2	-5.6
121	Tange Powerst.	482.8	48.3	-51.7	0.49	0.05	-95.8
158	Fiord	153,1	15.3	-68.3	0.43	0.04	-12.2

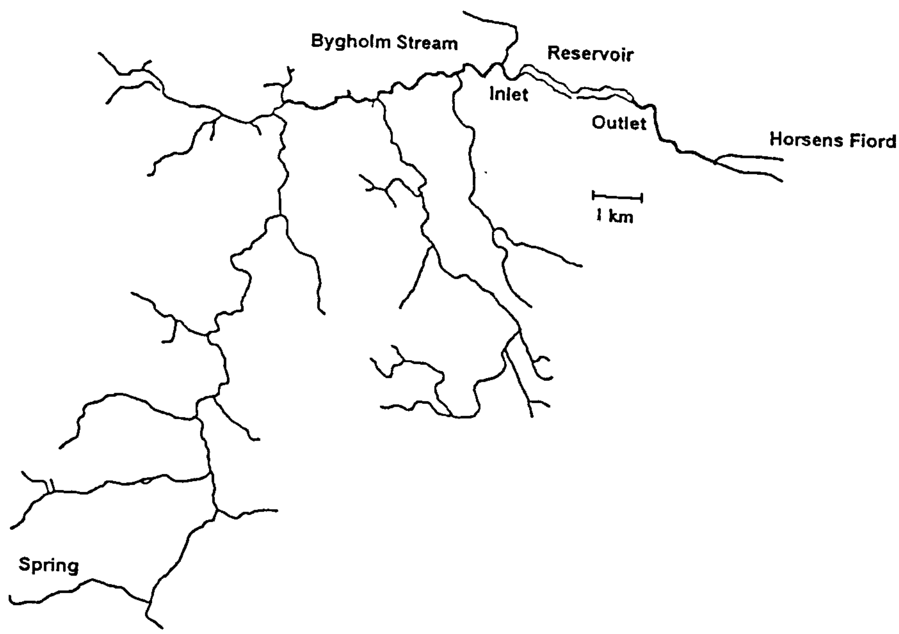
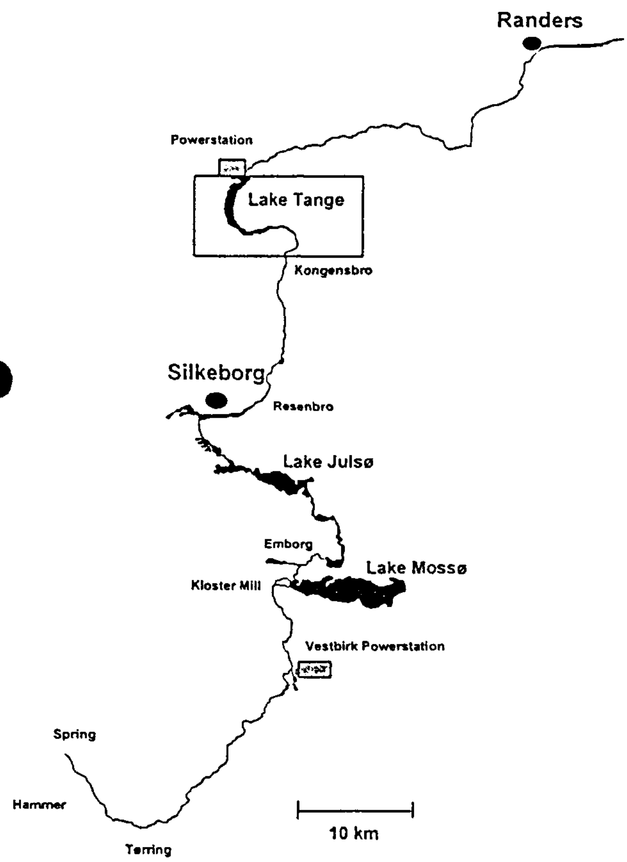


Figure 1. Map of Bygholm River area .



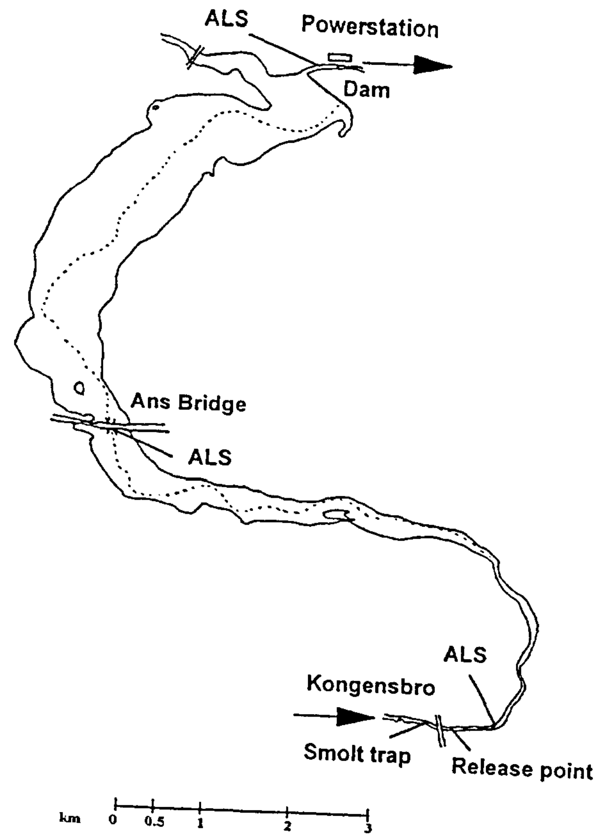


Figure 2. To the left a map showing the Gudenå River system. To the right Lake Tange. ALS = Automatic Listening Station, dotted line in the lake is the old riverbed.

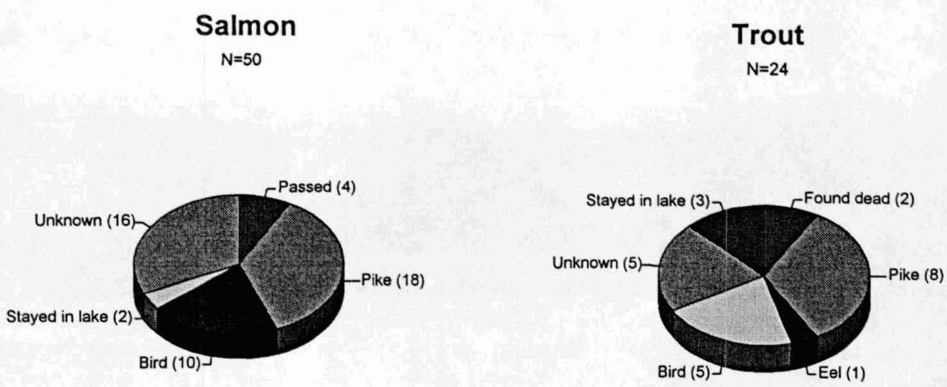


Figure 3. The fate of the radio-tagged smolts.

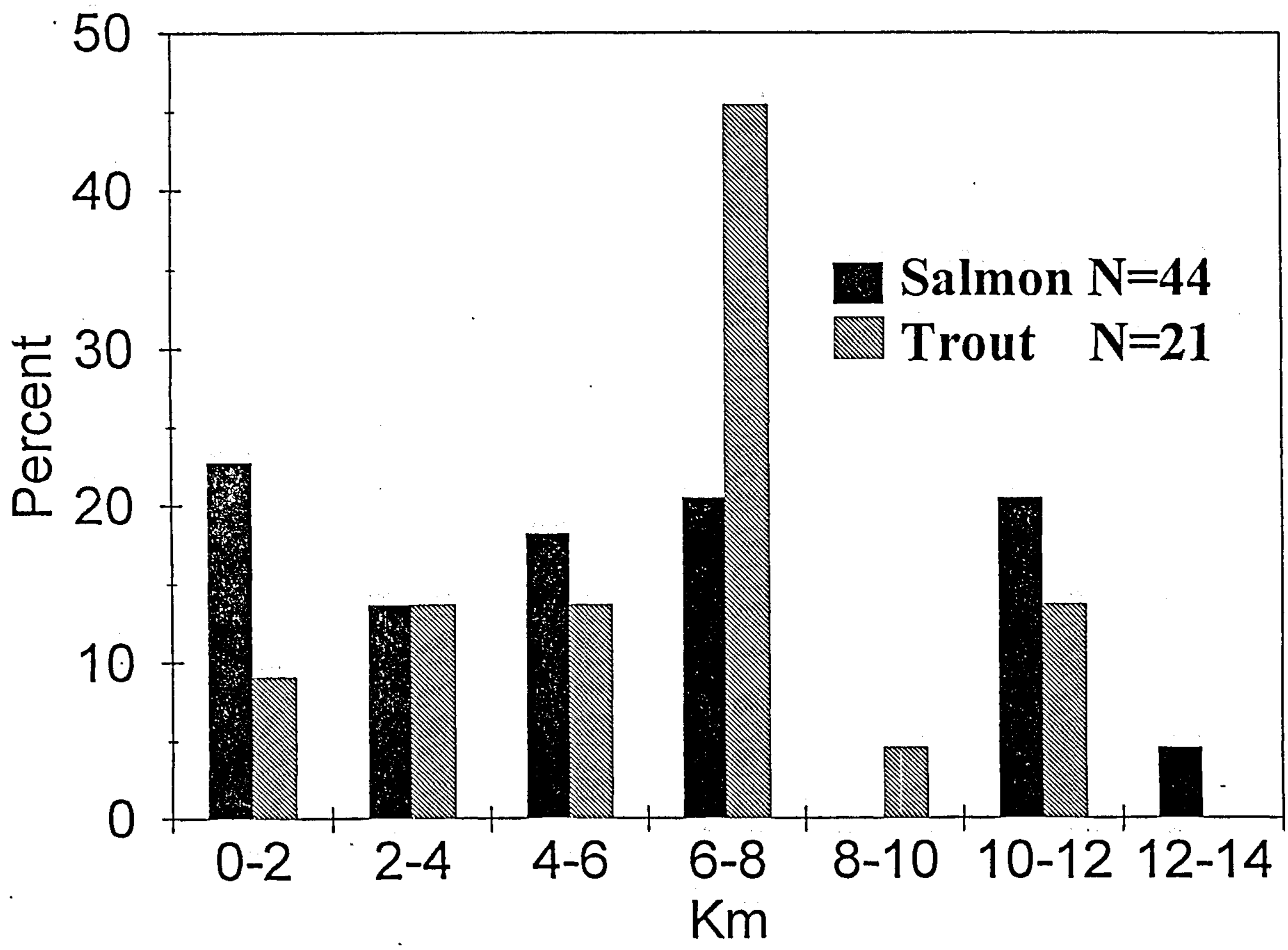


Figure 4. The geographical distribution of the mortalities of radio-tagged smolts in the lake divided in 2 km intervals. 0 km is point of release. Km 12-14 is Tange vig (see Fig. 2).