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Lake Langtjern - fish studies in the Langtjern area 1966-2000

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REPORT

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Abstract:
Langtjern is located 120 km northwest of Oslo east of Gulsvik in the county of Buskerud. The area is underlain by felsic gneisses and granites. The catchment area is 4.69 km^2, the lake surface area is 0.227 km^2 with an average runoff of 750 mm/yr. Langtjern and most of the lakes and ponds in the area are acidified humic lakes. The research activities in the Langtjern area started in 1965. Langtjern lost its population of brown trout in the early 1960's due to effects of acid rain. Recapture of stocked fingerlings (0+) of brook trout and a hybrid between brook trout and Arctic char (baptised brar) in 12 small humic lakes located in the Langtjern area during the years 1966-1975 averaged 28%. For stocked brown trout the recapture was significantly lower. Sporadic stockings of brook trout and brown trout took place from 1976-2000. Brook trout had a high survival with a high percent of recaptures (20-60%), a short life span, and obtained a good quality with red flesh and good condition. After a period of 1-3 years, however, most of the fish had disappeared. The brown trout stockings have given more variable results than the brook trout. The mean annual yield of brook trout and brown trout in Langtjern in the years 1973-2000 was 0.77 kg/ha, 0.42 kg as brown trout and 0,35 as brook trout. The highest yield occurred in 1978 with about 2.1 kg/ha. The improved recapture of the stockings of brown trout may have been caused by the general improvement in water quality during the last 10 years. During the years 1991-1995 11 small ponds in the Langtjern area were stocked with brook trout and brown trout in the spring for growth through the summer season. Fish weighing 20-60 g when stocked grew to weights of 200-300 g during about 110 days. On the average, 10 fish per hectare was stocked and the average yield was 1.5 kg/hectare (range: 1-5 kg). Brook trout gave much better recapture and growth than brown trout.

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1. Fisk	1. Fish
2. Sur nedbør	2. Acid precipitation
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Lake Langtjern

Fish studies in the Langtjern area 1966 - 2000

Preface

In October 1965 I was contacted by Vidar Opsahl, my childhood friend from my birthplace Hokksund in Buskerud county. His father had recently died. Vidar wanted to follow up his father's activities at their property; Lake Holmetjern in Flå community in Buskerud. The fishing was not as good as it used to be in Holmetjern, and his father had thought that liming the lake could make the fishing better. A week later my college, fish biologist Magne Grande, and I went together with Vidar to Holmetjern. This visit was the start of still ongoing activities in the Holmetjern and nearby catchments.

In 1966 we tried to improve the water quality in Holmetjern by putting coarse limestone into the major inlet stream. The limestone was transported about 6 km by means of a snowmobile to which we attached a sled with a wooden case to hold the limestone. It was evident, however, that we were not able to transport enough material to really improve the water quality in the lake itself, and the restricted number of chemical analyses we carried out did not indicate any significant water quality improvement. We had, however, many nice trips during this period, discussing the future activities in the area. The fish population in Holmetjern consisted largely of perch, with occasionally catches of trout. During the years 1966-1970 occasional stocking of trout were carried out without any great longterm success. Also, intensive collection of perch roe was carried out every spring for 3 years to reduce the perch population. In October 1969 we started regular sampling of 22 small lakes including Holmetjern. During the period 1969 to 1974 these lakes were sampled four times a year, in March, May, August and October, as part of a research program to investigate relationships of components in natural waters and the chemistry of humic lakes.

In the 1960's regional lake acidification due to acid rain was not recognised as a problem in Norway. Although we measured pH-values down to 4.4 in some of the sampled lakes, we did not connect these data to acid rain. The problem was discussed within the fishing society, but I can not remember that we ever discussed this possibility in those early years. The acid rain issue took off internationally in 1969 when Svante Oden published his findings in the Swedish newspaper "Dagens Nyheter". In 1972 the extensive Norwegian research project Acid Rain - Effects on Forest and Fish (the SNSF-project) was started. NIVA was a substantial participant in this project. In March 1972 the owner of the nearby lake Langtjern, Kolbjørn Sønsteby, visited us during our winter sampling trip at Holmetjern. At that time we were looking for an acidified lake in eastern Norway that could be included in calibrated catchment studies as part of the SNSF-project. The Langtjern catchment was inspected in the spring of 1972, and in the fall of that year the SNSF-project accepted Lake Langtjern as one of the project's calibrated catchments. A long-term lease contract was established between Kolbjørn Sønsteby and NIVA, which included use of a rather primitive, but well suited cabin. The owner pledged to not carry out any form of forest practice in the catchment. Regular water sampling was started in April 1973.

In 1980 the SNSF-project was ended and all practical activities within the project were terminated during 1979. During this period a group worked out a monitoring program with the intention to follow up some of the long-term activities in the SNSF-project. To continue the long term sampling NIVA supported the further water sampling at Langtjern in 1979. In 1980 the program for monitoring long range transported air pollutants administered by the State Pollution Control Authority (SFT) was started, and Langtjern was included as one of the calibrated catchments.

Since long term activities now were secured at Langtjern, our sampling of lakes in the catchment of Langtjern and Holmetjern could be continued. By 1974 the sampling program was reduced to 11 locations sampled in March every year. In 1986 we extended the program to also sample the lakes in the fall (September). All sampling through the years was carried out during weekends using our spare time. Normally, the sampling trips started when leaving our offices at NIVA on Friday afternoon. On

Saturday morning we began the sampling and ended up at the cabin at Holmetjern, where we stayed overnight together with Vidar Opsahl and two of his friends, Arne Norsted and Steinar Nuland. They joined us in our continued sampling on Sunday. During the years many scientific (and other) topics were discussed during these weekends, both at Langtjern and at Holmetjern. Many scientists from Norway and abroad joined us during those trips and during the work in the SNSF. These sampling trips lead to good personal relationships and also to very good co-operation between scientific groups at NIVA.

Some of the results from Langtjern-Holmetjern area have been published as part of the SNSF-project (see references). In addition to a general description of the Langtjern – Holmetjern area, we report here most fish experiments and results of scientific interest that have derived from the activities in the Holmetjern and Langtjern area during 33 years.

We wish to thank Dr. Steve Norton, University of Maine at Orono, USA, Dr. Bjørn O. Rosseland and Dr. Richard F. Wright, NIVA for helpful comments and suggestions on the manuscript.

Oslo, March, 2002

Arne Henriksen

Contents

Summary

The activities in the Langtjern area started in 1965. Langtjern is located 120 km northwest of Oslo and just east of Gulsvik in the county of Buskerud. The area is underlain by felsic gneisses and granites; thin soils are developed on till of generally the same lithology as the bedrock. The catchment area of Langtjern is 4.69 km^2. Langtjern itself has a surface area of 0.227 km^2. The total water volume of the lake is 560000 m^3. Langtjern is a shallow lake, about 50% of the lake area the depth is 1 m or less. The outlet discharge is 750 mm/yr and the theoretical retention time is 58 days. Most lakes in the Langtjern and Holmetjern area are typical humic, acidic lakes with short retention times. As a consequence of the reduction in sulphur emissions in Europe since the late 1980's the acidification of lakes in the Langtjern area has been significantly reduced. Langtjern is part of "The Norwegian Monitoring Programme for Long Range Transported Air Pollutants" directed by the Norwegian Pollution Control Authority (SFT). A forest site in the catchment of Langtjern is monitored as part of the "Monitoring Programme for Forest Damage" and "Programme for Terrestrial Monitoring" directed by the Norwegian Pollution Control Authority and the Directorate for Nature Management (DN), respectively. Langtjern lost its population of brown trout in the early 1960's due to effects of acid rain. Recovery of stocked fingerlings (0+) of brook trout and a hybrid between brook trout and Arctic char (baptised *brar*) during the years 1966-1975 in 12 small humic lakes located in the Langtjern area averaged 28%. For stocked brown trout the recapture was significantly lower. There was no recapture of stocked rainbow trout. The pH of the lakes varied between 4.6 and 6.2. Some of the lakes had low oxygen concentrations (3 mg O_2/l) under the ice during the winter because of degradation of organic matter. The catch of salmonid fishes was on the average 1.9 kg/ha/yr and varied between 0.6 and 5.4 kg for the lakes. The average weight for brook trout was 150-200 grams the first year after stocking, 280-500 grams the second year, and 350-900 grams the third year. Brook trout and brar grew with similar speed the first and the second year. The largest brook trout had a weight of 910 grams and the largest brar weighed 1850 grams after three years. The condition factors for brook trout and brar were on the average 1-1.5 and the colour of their flesh was red. The nutrition consisted mostly of insects, boatmen being the most common species in the stomach content. Fishing was carried out with nets and ordinary sport fishing. Both brook trout and brar were generally easy to catch with sport equipment, and our experience was that they are less shy and more eager to bite than brown trout. In Langtjern, 37% of the brook trout obtained sexual maturation the first year after stocking as fingerlings (0+) and 86% second year after stocking. The fish spawn in the creeks, but no natural reproduction has ever been observed. The oldest brook trout and brar captured were 7 and 3 years, respectively. In Langtjern 32% of stocked yearlings of brook trout, 1% of brown trout, and 8.5% rainbow trout were caught in an outlet fish trap during the first autumn during their downstream migration.

During the years 1991-1995 11 small ponds in the Langtjern area were stocked with brook trout and brown trout in the spring for growth through the summer season. The pH of the ponds was around 5 and they contained high concentration of dissolved organic carbon (6.3 to 19.2 mgC/l). Fish weighing 20-60 g when stocked grew to weights of 200-300 g during about 110 days, depending on local conditions. Some of the fish obtained a weight of 400 g. On the average, 10 fish per hectare were stocked and the average yield was 1.5 kg/hectare (range: 1-5 kg). Brook trout gave better recapture and growth than brown trout. Comparative experiments in another area in non-acidic ponds (Krokskogen west of Oslo) showed that rainbow trout gave as good results as brook trout. Stocking of brook trout and brar has so far given best results in the form of recaptures in the lakes where they have been tested. Stocking of rainbow trout has so far not given any recaptures. The experiments carried out in the Langtjern area and in many other parts of Norway show that the brook trout is a salmonid species that have a rather narrow ecological

niche in our country. This experience is in accordance with findings in other countries. If the goal is to use watercourses, lakes and ponds for fish production, despite risks for changes in biological diversity, spreading of diseases etc., brook trout have many advantages in preference to brown trout and other salmonid species. This is especially the case in dystrophic lakes and ponds, as well as in creeks and small rivers. The brar is also a fish that could be used in the same way. The positive development in the later years of the effects of acid rain in the form of improved water quality could reduce the suitability of brook trout, but there will still be many localities where the brook trout could be useful for improving fishing conditions. Today, there are many naturalised strains of brook trout in southern Norway, and there should be many suitable watercourses where this fish species could be stocked. If local strains are used as source for stocking there should be no significant risk of negative effects. However, since brook trout is defined as a "foreign" species by the authorities, it is not likely that further stockings of brook trout will be allowed according to present legislation. The brar has also showed promising results as a suitable fish with good growth and high tolerance to acid water. The brar will most probably not reproduce and form a living population in competition with local fish species. This species has consistently been used in acid lakes in the Grenland area in Telemark county with good results. Stocking experiments with brown trout have shown that this species, if it thrives, has a longer life span and grows larger than brook trout. These properties make brown trout more attractive than the brook trout both for food production and for sport fishing. The crucial question will be the water quality and the natural properties of the stocking locality. The stocking experiments with brown trout in Langtjern have shown varying results during the period from 1970 to 2000. There may be many reasons for these variations: water quality, competition with brook trout and predation of larger fish shortly after stocking. Nevertheless, the general improvement in water quality from 1990 to 2000 may be associated with an apparent increased recapture and better quality of brown trout.

1. Lake Langtjern

1.1 Lake and catchment characteristics

Langtjern is located 120 km northwest of Oslo and just east of Gulsvik in the county of Buskerud Figure 1. The area is underlain by felsic gneisses and granites; thin soils are developed on till of generally the same lithology as the bedrock. Within the Langtjern catchment, 63% of the area is covered by forest, 16% by peat deposits or bogs and 16% is exposed bedrock (Wright and Henriksen 1980). Pine (Pinus sylvestris), spruce (Picea abies), and birch (Betula pubescens) dominate the forests. The area is dotted with many small lakes and ponds. Even in the forested areas soils are generally very thin; only 5% of the watershed has thicker soils.

The forest in the Langtjern catchment is not productive according to present standards, although forestry has been going on in earlier years. The last clear cut was carried out in the late 1950's covering about 0.15 km^2, that is 3.2% of the catchment. That area was largely covered by low birch trees and wild raspberry bushes in the late 60's. Today a mixture of birch, pine and spruce trees dominates.

The catchment area of Langtjern is 4.69 km^2. Langtjern itself has a surface area of 0.227 km^2. The depth map and the depth profile diagram of Langtjern Figure 2 and Figure 3 show that the lake consists of three defined basins. The southern basin is the largest and is also the deepest, 12 m (Figure 4)**.** The total water volume of the lake is 560000 m^3. The depth is 1 m or less for about 50% of the lake area. Areas with depth down to two meters represent more than 50% of the total water volume of the lake.

The outlet of Langtjern is controlled through a nicely built stone dam constructed in 1916. Its purpose was to regulate runoff from Langtjern to increase the capacity of a small private power plant downstream that was built 1914. We do not know how long this plant was in operation, but probably until the Gulsvik area was electrified in 1938-1939. (When the dam was built a small lot bordering the dam was bought, probably for quarrying the blocks for the dam. Obligatory renovation for cottages was enforced in the community in the 1990's, and the owner was billed for a renovation fee for the lot).

At Langtjern there is a cabin built in 1926 by the owner of the area. The two rooms indicate the use of the cabin. One room is nicely coloured in red and blue, has its own entrance from a porch and two windows, while the other room is just plain and had one window. Both rooms have their own "kitchenette" and a large oven for cooking food and heating. The hired people working in the forest used the "plain" room, whereas the owner and his family used the "nice" room.

When we visited Langtjern the first time in spring 1972 another cabin was still visible. It consisted of one room with a fireplace, bed and table. Next to this room there was attached a room that could keep one or two horses or cows. Some years in the 1930's a lady stayed there with some cows during the summer, but the area has not been extensively used for summer farming and cannot have had any significant land use influence on the Langtjern catchment itself.

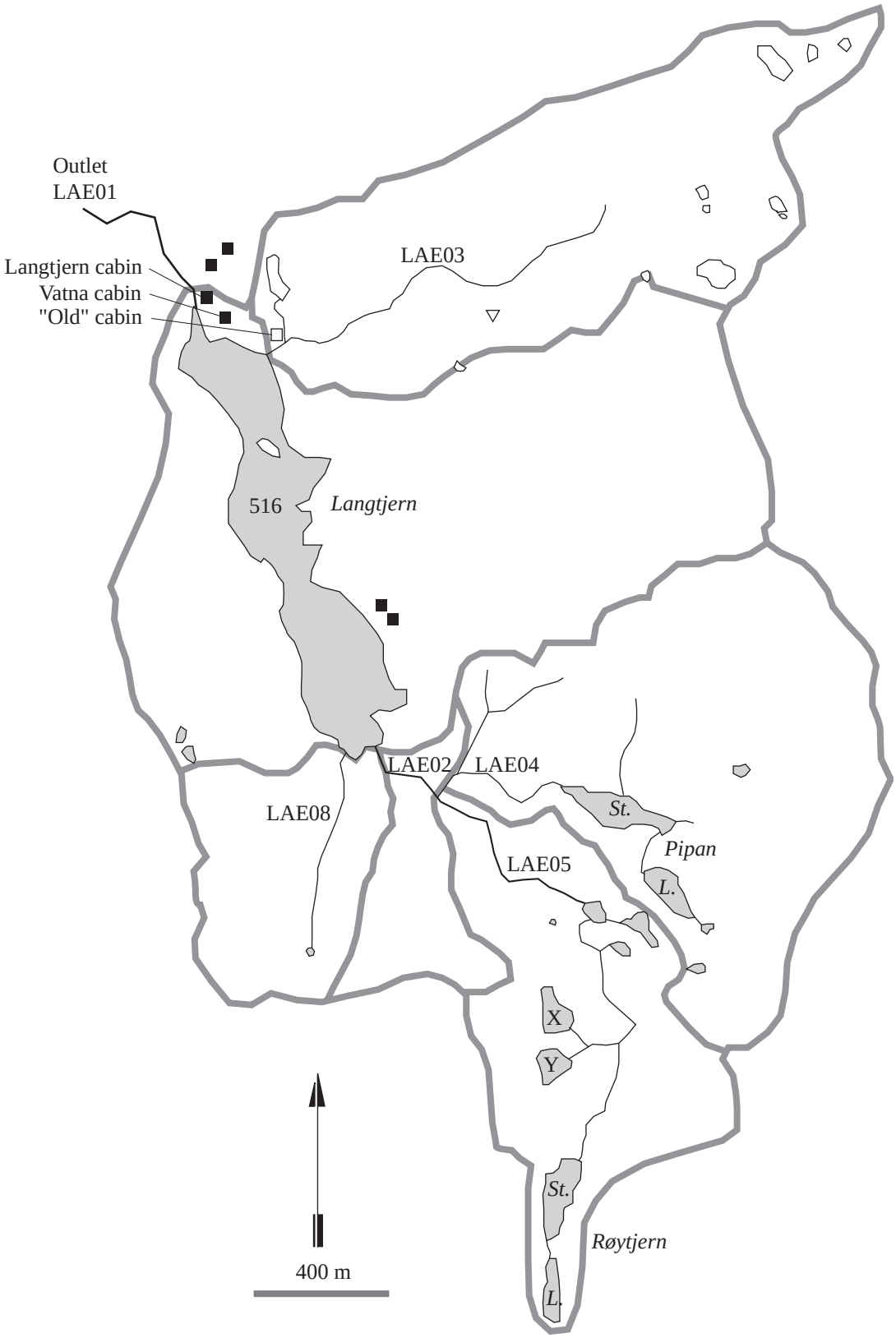

Figure 1. The Langtjern catchment. The locations of the main cabin, the Vatna cabin and the "old" cabin, as well as a cabin belonging to another landowner in the southern basin are marked. Streams sampled for chemical analyses are indicated, as well as the terrestrial (forest) monitoring station (Δ)(NISK).

The catchment of Langtjern has six defined sub-catchments (Figure 1). There are three defined inlet streams to Langtjern named LAE02, LAE03 and LAE08. The inlet LAE02 enters Langtjern after the two streams Pipanbekk (LAE04) and Røytjernbekk (LAE05) join into one stream. These two streams drain areas with a number of small ponds.

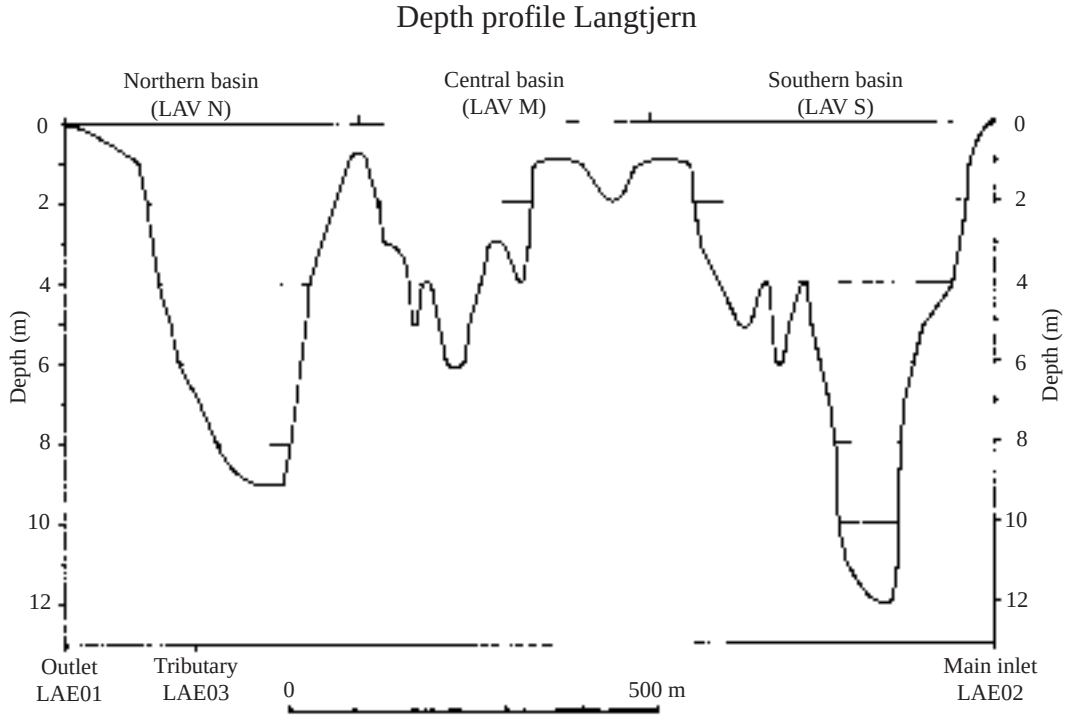

Figure 2. Depth profile of Langtjern following the length profile of the lake (see Figure 1).

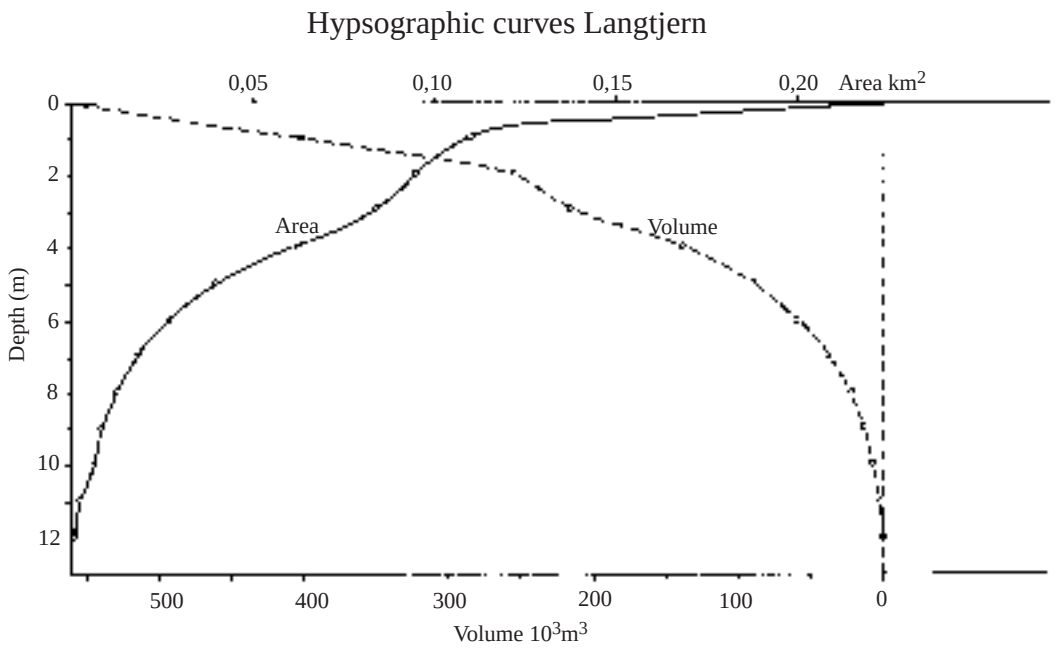

Figure 3. Hypsographic curves for Langtjern

Table 1. summarizes some morphometric and hydrologic data for Langtjern, and Table 2 summarises some data for the sub-catchments. Table 3 summarises corresponding data for sub-catchment LAE02.

Table 1. Morphometric and hydrologic data for Langtjern.

Height above sea level, m	*516*
Length, m	1350
Maximum depth, m	12
Surface area, km^2	0.227
Volume, 10^3 m^3	560
Mean depth, m	2.0
Catchment area, km^2	4.79
Outlet discharge, mm/yr	750
Theoretical retention time, days	58

Table 2. Lake Langtjern. Hydrological data for sub-catchments (see figure 1)

Sub-cathment	*Area* km^2	*Percent of total area*	*Average runoff* $L\ s^{-1}$
Inlet stream (LAE03)	0.98	20.5	22.6
Inlet stream (LAE08)	0.33	6.9	7.6
Inlet stream (LAE02)	1.81	37.8	41.5
Sub-catchment I	0.43	9.0	9.9
Sub-catchment II	1.01	21.1	23.1
Langtjern. surface	0.23	4.8	5.3
Total	4.79	100	110

Table 3. Langtjern. Hydrological data for sub-catchments of the inlet stream LAE02.

Sub-catchment	*Area* km^2	*Percent of total area*	*Average runoff* $L\ s^{-1}$
Pipanbekk (LAE04)	1.06	22.2	24.4
Røytjernbekk (LAE05)	0.59	12.3	13.5
Sub-catchment III	0.16	3.3	3.6
Total	1.81	37.8	41.5

The catchment for inlet stream LAE02 consists of three sub-catchments (Table 3):

1. Pipanbekk (LAE04) drains the largest area. Here, two ponds: Store (Large) Pipan and Lille (small) Pipan, and some small ponds.
2. Røytjernbekk (LAE05). The catchment is about half of that of Pipanbekk. In the catchment are located four ponds, Store (Large) Røytjern and Lille (Little) Røytjern and the ponds X and Y. The latter two ponds were unnamed when we started sampling.
3. Sub-catchment III is small and is drained by a stream with running water only during high flow periods.

Table 4 gives some hydrological data for the ponds in the two sub-catchments Pipanbekken and Røytjernbekken. The water volumes and retention times given are based on only a few depth measurements.

Table 4. Hydrological data for ponds in the sub-catchment LAE02.

Pond	*Area* km^2	*Catchment area* km^2	*Water volume* $10^3\ m^3$	*Retention time* *Days*
Store Pipan	0.0147	0.67	44	38
Lille Pipan	0.0082	0.16	15	53
Store Røytjern	0.0113	0.071	45	365
Lille Røytjern	0.0059	0.019	15	468
Pond X	0.0051	0.066	15	132
Pond Y	0.0054	0.05	8	93

Langtjern is part of "The Norwegian Monitoring Programme for Long Range Transported Air Pollutants" directed by the Norwegian Pollution Control Authority (SFT). A forest site in the catchment of Langtjern is monitored as part of the "Monitoring Programme for Forest Damage" and "Programme for Terrestrial Monitoring" directed by SFT and the Directorate for Nature Management (DN), respectively.

2. Lake Holmetjern

Lake Holmetjern and its catchment (Figure 4) are adjacent to Lake Langtjern. Research activities began here in 1965 (see preface). The catchment area of Holmetjern is 6.5 km^2 and the lake area is 0.28 km^2. The average depth is estimated to be ca. 3 m, and the outlet discharge is 575 mm/yr. From these data we have estimated the retention time to be ca. 100 days, nearly twice the retention time for Langtjern. There are two larger lakes in the Holmetjern catchment: Lauvskartjern and Vestre (Western) Holmetjern. In the catchment there are some small ponds, many of these were sampled during the years 1969-1974 (see Figure 4) and two of these, in addition to Lauvskartjern and Vestre Holmetjern, were included in the yearly fall and winter sampling described in the Preface. Fish stocking experiments were carried out in several of these lakes and ponds in the 1970's. Lake Lauvskartjern was included in the routine sampling until 1997, at which time the owner started liming the lake.

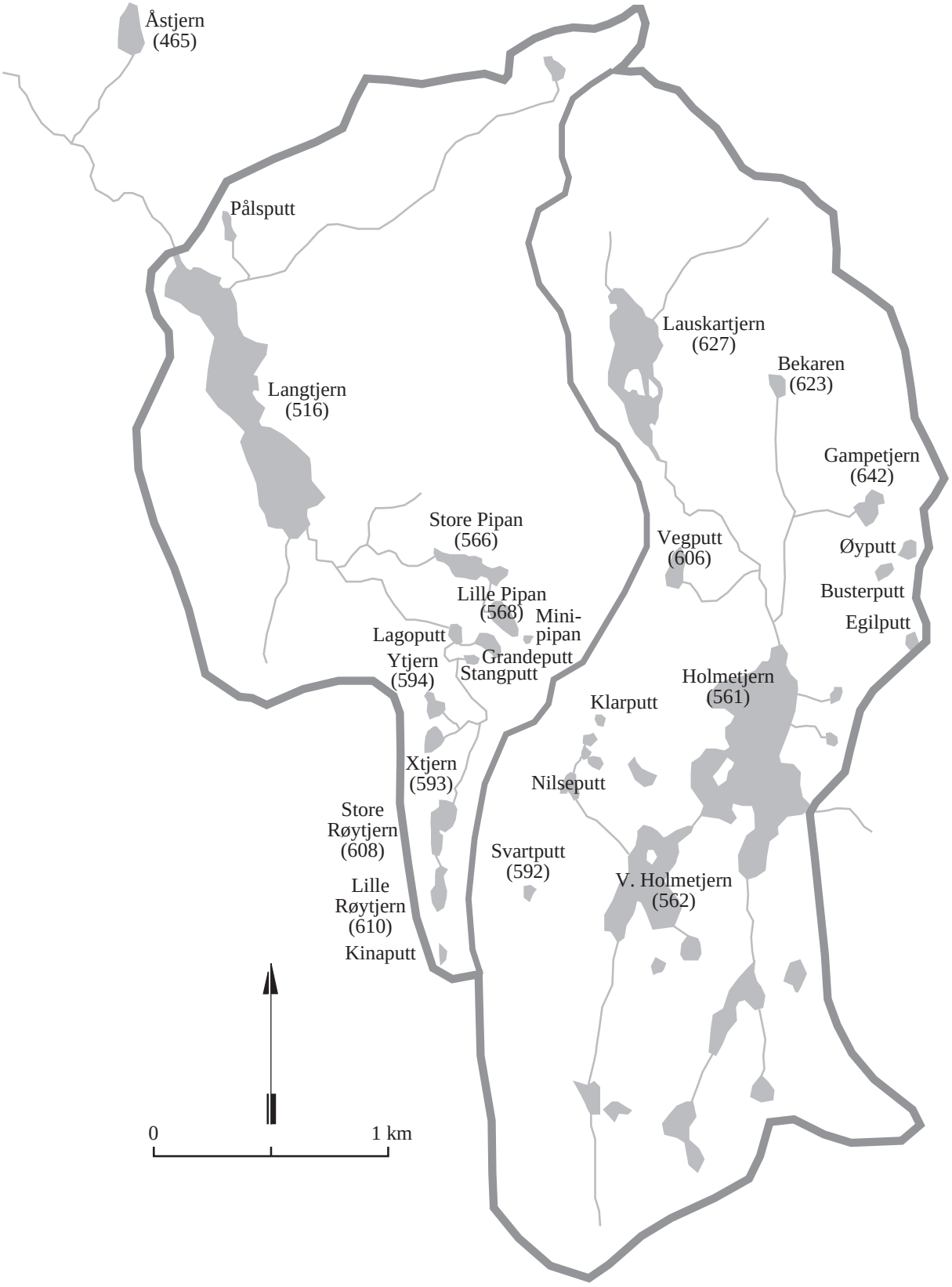

Figure 4. Map of the study area Langtjern and its surroundings.

3. Water chemistry - Summary

The water chemistry and the long-term trends in the area are summarised in tables 5-7 and Figure 5 with average values for some chemical variables for the lakes and for Langtjern and its tributaries. Data are from the SNSF-project and from SFT monitoring program.

Table 5. Average chemistry (1969-2001) of lakes and ponds in the Langtjern area (see Figure 4 for locations).

Name	*St no.*	*pH*	*Ca*	*Mg*	*Na*	*K*	*SO_4*	*NO_3*	*ANC*	*Al-R*	*Al-Org*	*L-Al*	*TOC*	*Tot-N*	*Cl*
			mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µeq/l	µg/l	µg/l	µg/l	mg/l	µg/l	mg/l
Bekaren	4	5.49	2.08	0.46	0.80	0.20	3.6	44	73.6	194	162	32	11	317	0.8
Veiputten	5	5.08	1.00	0.23	0.62	0.13	3.3	22	5.8	171	89	82	5	238	0.6
St. Y	10	4.66	1.07	0.26	0.58	0.14	2.6	17	24.3	176	135	40	13	398	0.7
St. X	12	5.01	1.40	0.30	0.59	0.15	2.7	17	41.3	168	133	35	12	352	0.7
Store Pipan	14	4.94	1.62	0.22	0.65	0.12	3	15	39	215	165	50	11	278	0.7
Lille Pipan	15	6.24	3.45	0.27	0.66	0.17	3.1	19	133.7	90	81	9	9	309	0.6
Lille Røytjern	18	5.14	1.28	0.25	0.49	0.20	2.6	26	30.3	87	68	19	9	353	0.6
Store Røytjern	19	5.14	1.01	0.22	0.47	0.17	2.6	32	15.7	70	49	21	6	295	0.6
V. Holmetjern	21	4.64	1.03	0.22	0.54	0.13	2.8	27	15.2	158	119	39	11	301	0.6
Holmetjern	22	4.96	1.19	0.25	0.57	0.14	3.1	37	20.6	158	113	46	8	274	0.6

Table 6. Average chemistry for inlets (LAE02-LAE05) and outlet of Langtjern (LAE01) for the periods 1974-1977 and for 1999.

1974-1977

Site	*pH*	*Ca*	*Mg*	*Na*	*K*	*SO4*	*NO3N*	*ANC*	*TOC*
LAE01	*4.86*	*1.44*	*0.27*	*0.68*	*0.17*	*4.1*	*26*	*22.0*	*10.1*
LAE02	4.88	1.82	0.28	0.77	0.17	4.6	42	33.5	10.8
LAE03	4.64	1.43	0.31	0.81	0.14	4.6	27	18.5	11.9
LAE04	4.89	1.79	0.26	0.77	0.18	4.6	37	28.2	10.9
LAE05	4.79	1.66	0.27	0.67	0.18	4.2	69	24.5	11.9

1999

Site	*pH*	*Ca*	*Mg*	*Na*	*K*	*SO4*	*NO3N*	*ANC*	*TOC*
LAE01	*5.01*	*0.96*	*0.14*	*0.52*	*0.09*	*1.5*	*15*	*39*	*10.6*
LAE02	5.12	1.18	0.15	0.56	0.11	1.6	25	51	11.1
LAE03	4.79	0.85	0.16	0.62	0.08	1.6	15	39	12.2

Table 7. Change in chemistry from 1974-1977 to 1999 for the outlet stream (LAE01) and two main inlet streams (LAE02, LAE03). Negative values:decrease, positive values: increase.

	pH	*Ca*	*Mg*	*Na*	*K*	*$S0_4$*	*NO_3-N*	*ANC*	*TOC*
LAE01	0.15	-0.48	-0.13	-0.16	-0.08	-2.6	-10.7	17.4	0.5
LAE02	0.24	-0.64	-0.13	-0.21	-0.07	-3.0	-17.2	17.5	0.3
LAE03	0.15	-0.58	-0.15	-0.19	-0.06	-3.1	-11.9	20.8	0.3
Average	0.18	-0.56	-0.13	-0.19	-0.07	-2.9	-13.3	18.6	0.4

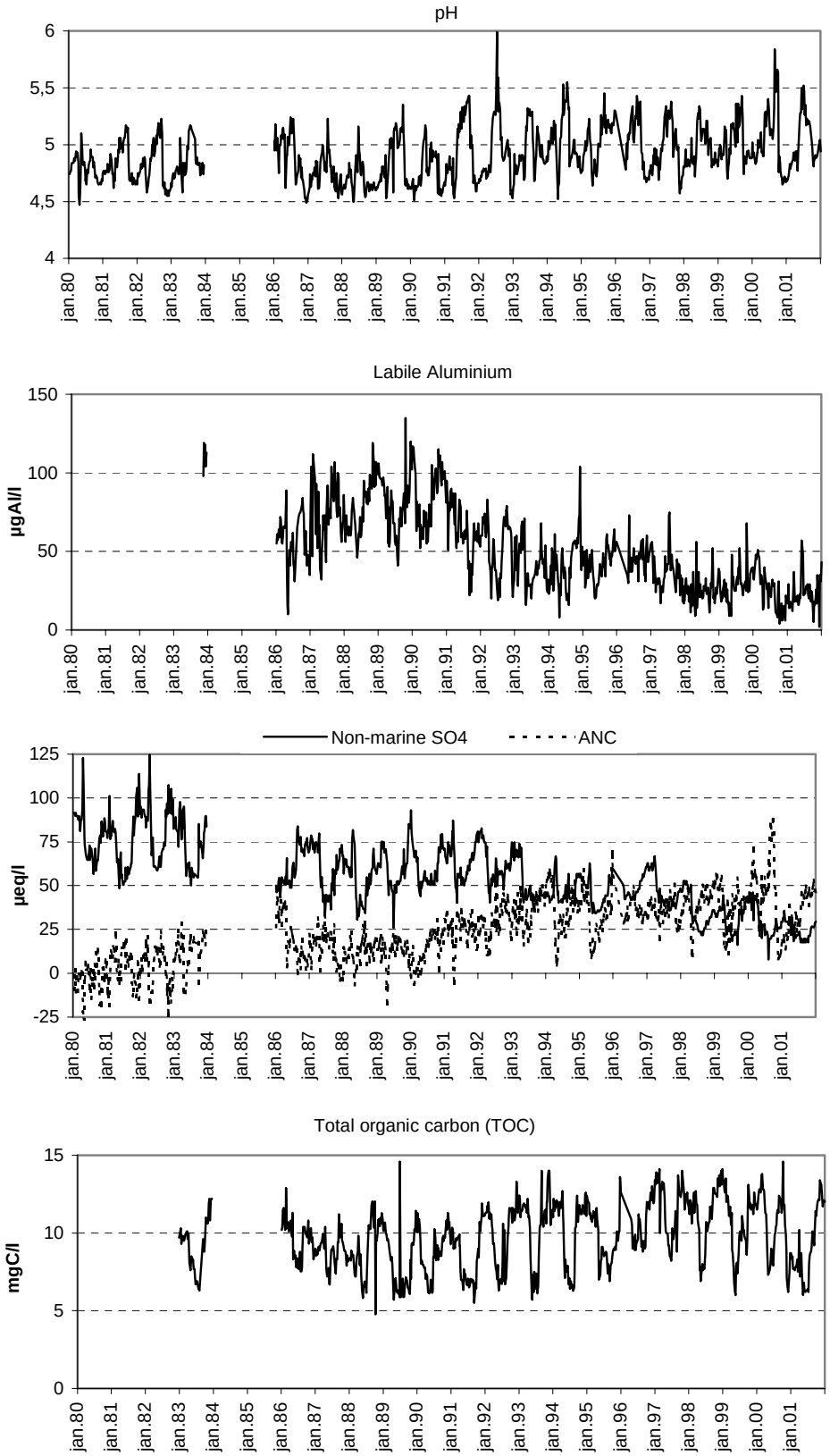

Figure 5. Trends in some chemical variables in the outlet of Langtjern (LAE01) for the period 1980-2001based on weekly samples. No samples were collected during 1984 and 1985 due to reductions in funding. Data are from SFT, 2001.

Most lakes in the Langtjern and Holmetjern area are typical humic, acidic lakes with short retention times. As a consequence of the reduction in sulphur emissions in Europe since the late 1980's the sulphate concentrations in the lakes have gone down, pH has increased and the toxic fraction of aluminium (labile aluminium (LAL) has been reduced as illustrated for Langtjern (Figure 5).

4. Fish studies in the Langtjern area during the years 1966-2000

4.1 Introduction

In the fall of 1966 NIVA was asked by a representative for the landowners in the area, Vidar Opsahl, Hokksund, to assist with water analysis and advice for improving fishing in lake Holmetjern and other small lakes in the Langtjern area. They had no success with stocking of fish in the lakes in the area during the later years.

We carried out several fish stocking experiments from 1966 and onwards. Some of the lakes, located in the Langtjern catchment, were included in the experiments until 1996. We followed the development in fish conditions during the whole period by test fishing and gathering information from the landowners. When Langtjern was included in the SNSF-project in 1972 we concentrated our further experiments to this lake and some other lakes in its catchment.

The experiments have largely dealt with stocking of various species of salmonid fish with controlled capture. Most of the lakes are small, rather acidic and strongly influenced by humic acids (highly coloured) and thus they represent an environment at the limit of what salmonid fish species can tolerate. Thus it was of great interest to study which salmonid species could best tolerate these extreme conditions, that is, which species would give the best results with respect to yield, growth and quality. The species tested were brown trout (*Salmo trutta L.*), rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*) and several hybrids of salmonid fishes. During the later years some experiments were carried out in small bog ponds to see whether they were suitable for production of salmonid species during the summer period. Fish do not survive in these small ponds during the winter because of lack of oxygen.

The fish experiments in the Langtjern area were most extensive from 1966 to the end of the 1970's. Later the activities were concentrated on recording recovery of stocked brown trout and brook trout. The results from the fish experiments in the Langtjern area have been published (Grande 1970, 1972, 1976, 1984, Grande and Andersen 1978 and Grande et al. 1978). The studies in Langtjern led to extensive activities concerning stocking of brook trout in acid lakes in Southern Norway. The experiments have also partly formed the basis for extensive experimental tolerance experiments in the field and in the laboratory with brown trout, brook trout and other salmonid species from the mid 1970's and onwards, especially during the SNSF-project. Reports include: Muniz and Grande (1974, Grande et al. (1978), Muniz and Leivestad (1979), Grande et al. (1980), Rosseland 1980), Rosseland and Skogheim (1984) Qvenild and Holt (1981) and Ousdal (1985).

This report summarizes the experiments and studies with fish carried out in the Langtjern area from 1966 to 2000.

4.2 Experimental area and fish populations – a short historic overview

The Langtjern area with its lakes and ponds is described above. Most lakes are acidic and rich in humic compounds. They are located in a forested area about 500-600 m above sea level, and thus representative for a large number of lakes in southern Norway.

4.2.1 Holmetjern

The family Opsahl inherited the property "The Holmetjern Forest" and their rights in 1937. Since then every fish stocking has been recorded up to 1964. Both wild and domesticated brown trout were stocked in Holmetjern as well as in Lauvskartjern, Store and Lille Pipan, Bekarent, Vegputt and western Holmetjern. One year (1961) 30 fingerlings of rainbow trout were stocked in Holmetjern. Almost every year Holmetjern was stocked with sevreral hundred fingerlings and some fry. The number varied from 50-1900 fingerlings and 200-1500 fry. In 1937, 368 wild-fish caught in the nearby lakes Øvstevatn, Langevatn and the river Rukkedøla were put in Holmetjern, and 28 in Lauvskartjern.

In 1937-1939 Arctic char (*Salvelinus alpinus L.*) were caught in Holmetjern. The origin of these fish is not known, but they were probably stocked some years before. Also perch was present at that time, but the prehistory of this species is also not known. Statistics for the outcome from fishing in Holmetjern and the other lakes and ponds is unfortunately not available, but the fishing was considered excellent in 1940's and the 1950's, especially in Holmetjern, but also in some of the smaller lakes in the area.

4.2.2 Langtjern

No systematic records of the fishing activities in Langtjern are available. In 1972 NIVA entered into a lease agreement for Langtjern and the fishing rights. Until then fishing rights were divided between the Sønsteby farm and the fishing association "IL Vatna". In 1905 the sacristan N. O. Slaatto bought a piece of land with two small cabins in the Langtjern catchment together with the fishing right to the lake. In the deed it is specified clearly that the seller gave away all fishing rights, indicating that Langtjern must have been considered as at least a potential good fishing lake at that time. In 1920 the fishing association "IL Vatna" was formed and the fishing rights were again divided between Sønsteby farm and IL Vatna. Einar Slaatto, the son of N. O. Slaatto and member of IL Vatna told us that when his father took over the property Langtjern had only a population of minnows (*Phoxinus phoxinus*). Around 1906 the lake was stocked with brown trout, and untill 1920 the fishing was excellent. Several times later the lake was stocked, but Slåtto is rather sure that the brown trout reproduced at that time. Vidar Opsahl has told us that his father (the owner of Holmetjern) in 1937/1938 caught small fish in the creeks to Langtjern for stocking in Holmetjern. In 1944 Kolbjørn Sønsteby provided the meal for a christening party by fishing with otter board and nets. He caught seven fish on each fishing tool and this was enough for the dinner. He also participated several times in stocking small fish during the Second World War, and he often observed small fish in the outlet of Langtjern. In the fall of 1958 he caught large fish at the outlet several times. In Figure 6, Gunnar Sønsteby, the younger brother of Kolbjørn, shows a large brown trout he caught in Langtjern in 1951.

Minnows were observed until the end of the 1940's, but appear to have disappeared during the 1950's.

On the back of the window blinds of the cabin earlier owned by "IL Vatna" and located nearby the Langtjern cabin there are noted significant information about fish catches in the period 1923-1967 (Figure 7). This "cabin log" indicates that the brown trout catches often were rather good using nets (brown trout up to 1,5 kg). The last reported catch was in 1967. In 1969 Langtjern was fished with 10-15 nets. The result was only a few small fish. It is thus reasonable to believe that Langtjern lost its fish population at the end of the 1960's and that reproduction failed earlier than that.

From the end of the 1950's and into the 1960's brown trout were stocked in the area, but the catches were few and the stocking activities were stopped in Langtjern, Holmetjern and the nearby lakes and ponds.

In the 1950's frequent observations of disappearing brown trout populations came from several areas in southern Norway, especially from the Agder counties. Also perch disappeared in many lakes. This phenomenon was considered to be related to the observations that acidity of the lakes had increased, and that the acidity of precipitation for some unknown reason was more acidic in southernmost Norway than in the inland (Dannevig, 1959).

Similar observations together with the unsuccessful stocking experiments in the Langtjern area led to NIVA's interest in the area.

Figure 6. Gunnar Sønsteby, the brother of the owner, proudly showing a brown trout catched in Langtjern in 1951.

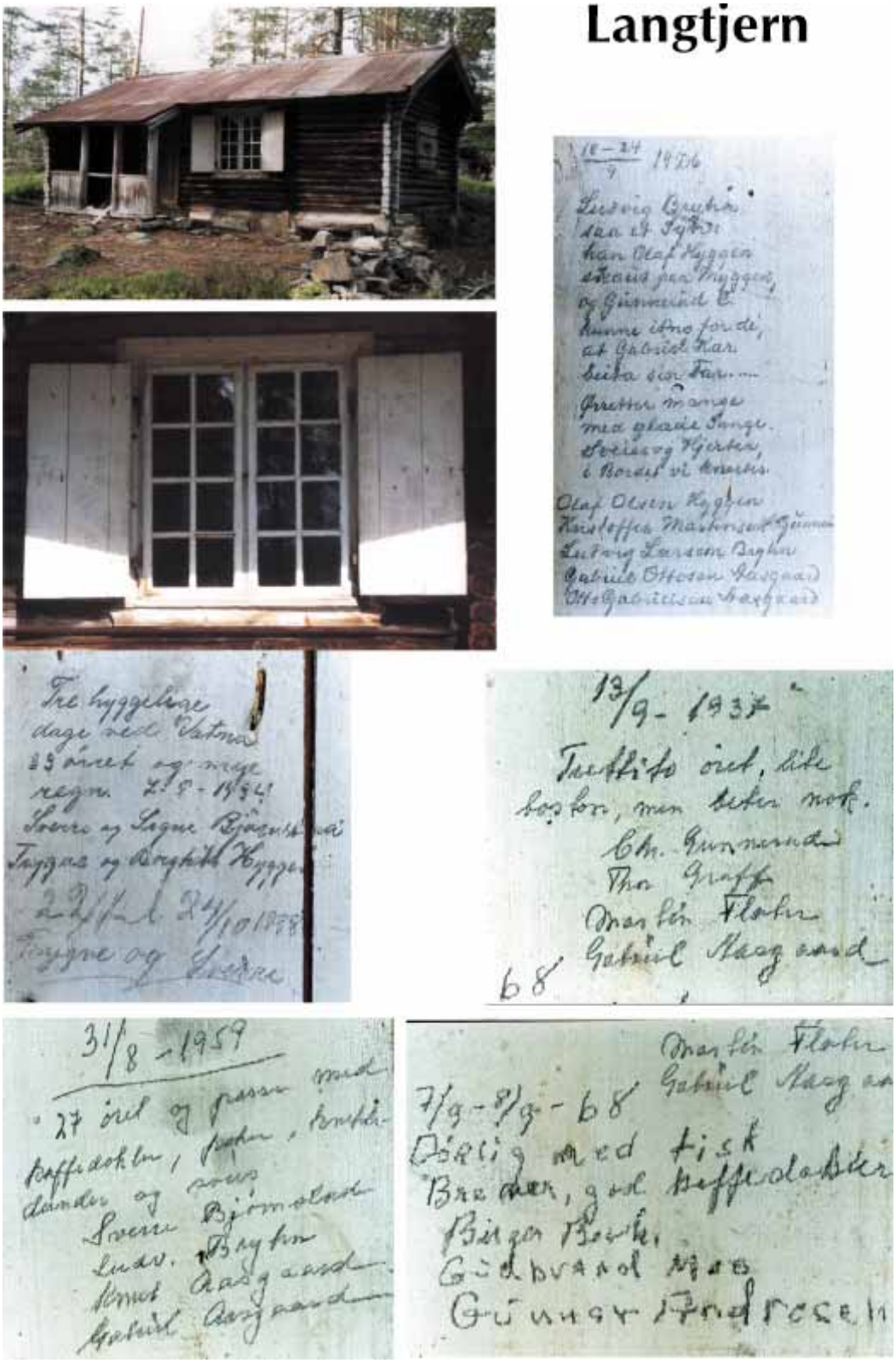

Figure 7. The Vatna cabin and a selection of fishing reports on the back of the window blinds.

4.3 The period 1966-1974

4.3.1 Introduction

The representative of the landowners, Vidar Opsahl, wanted our assistance for creating better brown trout fishing in Holmetjern. Analyses of water samples indicated that the lake was rather acidic (pH 4.7) in 1966. Further, test fishing indicated that the population of perch was large. NIVA suggested that three measures should be taken.

1. Reducing perch population by intensive fishing
2. Liming of tributaries
3. Stocking of brown trout

The landowner showed great interest in testing these measures. The following activities included intensive perch fishing through fish traps, net fishing, sport fishing and removal of roe during the spawning season. The main inlet was limed by spreading limestone on the bottom some 100 m upstream. Holmetjern and the nearby lakes were stocked with brown trout. This work was started in 1966. Langtjern was included in the stocking activities from 1972. The results from all these stocking experiments are presented and discussed here.

4.3.2 Background

At the time when our experiments were started it was known that stocking of fingerlings and even larger fish often was unsuccessful. Based on experience from many areas in Norway, stocking of yearlings seldom was successful in lakes with pH 5 or lower. Stocking with larger fish, for example wild fish from natural waters, on the other hand, was often successful. It was observed that perch, northern pike and some carp-fish species could live and reproduce at lower pH-values than brown trout. Those species are, however, generally of little interest for fishing and their establisment in lakes is undesirable.

Experience from Sweden indicated that stocking of brook trout in small humic ponds often gave good results. Wild brook trout was naturalised in one watershed in Norway (Øyfjell, Telemark (Grande 1964)). In Sweden Alm (1955) experimented with hybrids of different salmonid species, and especially a hybrid of brook trout with Arctic char (baptized *brar*) resulted in a high percentage of hatching and fertile offspring. This hybrid showed better growth than both parent breeds, and Alm suggested that this species could have a potential for stocking, in contrast to other breeds he tried. The brar has later been stocked in lakes in Sweden, however, without much succes. (Nilsson 1983). Based on the experiments of Alm we wished to test whether the brar could be a choice for stocking fishless lakes in Norway.

In 1966 and 1967 we stocked some of the lakes and ponds in the Holmetjern area with larger brown trout and fingerlings of brar and rainbow trout. Later, we also experimented with stocking of brook trout, brown trout and Arctic char in the same area.

4.3.3 Materials and methods

As stocking fish we used fingerling (0+) and yearling (1+) brook trout, rainbow trout, brown trout and brar. The brook trout used originated partly from the wild population in Øyfjell, partly of fish from a Danish hatchery. The rainbow trout and the brook trout came from a Norwegian hatchery, whereas the Arctic char were descendents from wild fish from Lake Katnosa in Nordmarka near Oslo. In addition to these some large wild brown trouts caught by electric gear from a creek near Bærum close to Oslo were also stocked. The water quality of some of these localities is given in Table 8. The fish used in

these experiments were largely hatched and stored in NIVAs hatchery and storage tanks before stocking. The pH of the hatchery water was 6.3, electrical conductivity 2.8 mS/m and water hardness 5.6 mg CaO/l. Some of the year-classes were marked by cutting off the adipose fin. The fish were transported in plastic bags filled with oxygenated water. The transport time was ca. 3 hours from transferring the fish into the plastic bags untill stocking.

Table 8. Water chemistry for localities from where stocked fish originated.

Locality	*Sampling time*	*pH*	*El.conductivity mS/m*	*Colour mg Pt/l*	*Permanganate value, mg O/l*
1 Creek in Bærum	13.11.70	7.1	8.9	12	2.2
2 Creek in Øyfjell	July, 1959	6.2	2.8		
3 Lakes in Nordmarka	Mean values 1959-1960	6.5	3.3	20	3.1

The stocked fish were recaptured with different kinds of sport equipment and nets. Time and place for catch, the length, weight, sex, maturity and flesh colour were noted. The length was measured to the nearest 0.5 cm from the nose tip to the outer end of the tail fin. Stomach samples were taken from some fish. Up to 1975-1980 it is probable that all fish caught were recorded, because very few, if any other than NIVA-people, were fishing in Langtjern. After 1980 some illegal fishing may have taken place.

In order to catch and record migrating fish a trap was mounted in the outlet stream of the lake Langtjern. The trap consisted of a trap mounted in a fine meshed metal fence. Fry and fingerlings could pass through the fence and thus the trap was not efficient for them.

4.3.4 Results

Stocking and recapture

Table 9 shows stockings of summer old (0+) fish carried out by the landowners in 1964 and their recapture.

Table 9. Stocked (1964) and recovered brown trout (1966-1970)

Locality		*Number stocked*	*Recovered*	
No.	Name		Number	%
2	Lauvskartjern	110	1	0.9
4	Store Pipan	80	2	2.5
6	Vesle Pipan	25	0	0
7	Veiputten	24	2(1?)	4

Because of some uncertainty in age determination and also some possible unregistered recaptures in the first part of the experimental period, these recapture figures are low estimates.

In 1961 Holmetjern was stocked with 30 rainbow trout weighing up to 250 grams. One of these was recaptured shortly after stocking. No more were caught.

In Holmetjern brown trout were regularly caught every year that most likely were stocked fish. However, because of natural reproduction, immigration from other lakes and some uncertainties in age determination, it was not possible to calculate recovery figures for this lake.

Table 10 summarises stocking during the years 1966-1970 and the recapture. During August – September, 321 brown trout caught in the creek in Bærum were stocked in Holmetjern. Of these 26, or

8.1% were recovered. In September 1967, 145 brown trout from the same creek were stocked in western Holmetjern. None of these were ever re-captured. Of 28 brown trout stocked in Store Røytjern and Vesle Røytjern, only 1 was re-caught. In total, 522 brown trout from the creek in Bærum were stocked. Altogether, 27, or 5.2%, were recaptured.

Table 10. Stocked (1966-67) and recaptured brown trout, brar and rainbow trout. (1968-1970).

Locality	Brown trout			Brar			Rainbow trout		
	Stocked	Re-capt		Stocked	Re-capt		Stocked	Re-capt	
No. Name	Number	Number	%	Number	Number	%	Number	Number	%
1 Holmetjern	349[1)]	26	7.4	0	23		10	0	
2 Lauvskartjern				137	29	14.6			
3 Western Holmetjern	145	0	0	29	0		12	0	
4 Store Pipan				38	5	13.2	12	0	
5 Store Røytjern	18	1	5.5	7	3	43			
6 Vesle Pipan				23	4	17.4	7	0	
7 Veiputten				30	6	20	10	1	10
8 Vesle Røytjern	10	0	0	6	2	33.3			
9 Y				10	0	0			
10 X				10	2	20			
11 Bekaren				30	8	26.6	10	0	
12 Grandeputt				3	0	0			
Sum	522	27	5.2	323	73	22.6	61	1	1.6

1) 321 stocked in 1966.

Summerold rainbow trouts were stocked in 6 lakes in the end of June 1967. Of 61 stocked fish, only one was re-caught in 1967.

During the period 15 June - 1 September, 1967, 323 fingerling (0+) of brars were stocked in 11 lakes and ponds. 73 (22%) of these were recaptured. No fish were recaptured in western Holmetjern, the pond Y and Grandeputt. No brar were stocked in Holmetjern, but 23 fish were recaptured. Thus, they must have migrated from the lakes Lauvskartjern, western Holmetjern and Bekaren, most likely during the period 1967-68. The highest recovery was in Store Røytjern, 3 out of 7 (43%).

The figures 8, 9 and 10 present results from three parallell stockings of brook trout, rainbow trout and brown trout. Each fish recaptured is plotted in a diagram with respect to the length of the fish (CM) and time of recapture. The average weight at different lenghts to indicate the weight of the fish (see also figure 11).

Fig. 8 show results from a stocking in 1972 in Langtjern of 500 fingerlings (0+) of each species. This corresponds to a stocking density of 75 fish per hectare. The lake was practically fishless in spite of earlier stockings of brown trout. The recaptured fish (mostly by net fishing) were 24% brook trout, 0,4% brown trout and no rainbow trout. These figures correspond to 26.3 kg Brook trout and 1,2 kg Brown trout. The average weights for brook trout were 170, 286 and 340 grams 1, 2 and 3 summers, respectively, after stocking.

In 1974 Langtjern was stocked with 176 brook trout, 117 rainbow trout and 98 brown trout (20 fish per hectare). The fish were one year old (1+), with a length between 9 and 13 cm (Figure 9. The recapture (also by net fishing) in 1975 was 60% brook trout, 16% brown trout and 0% rainbow trout, respectively. These figures correspond to 31.2 kg brook trout and 2.9 kg brown trout. The weights of

the recaptured fish the first year after stocking was 294 grams for brook trout and 182 grams for brown trout.

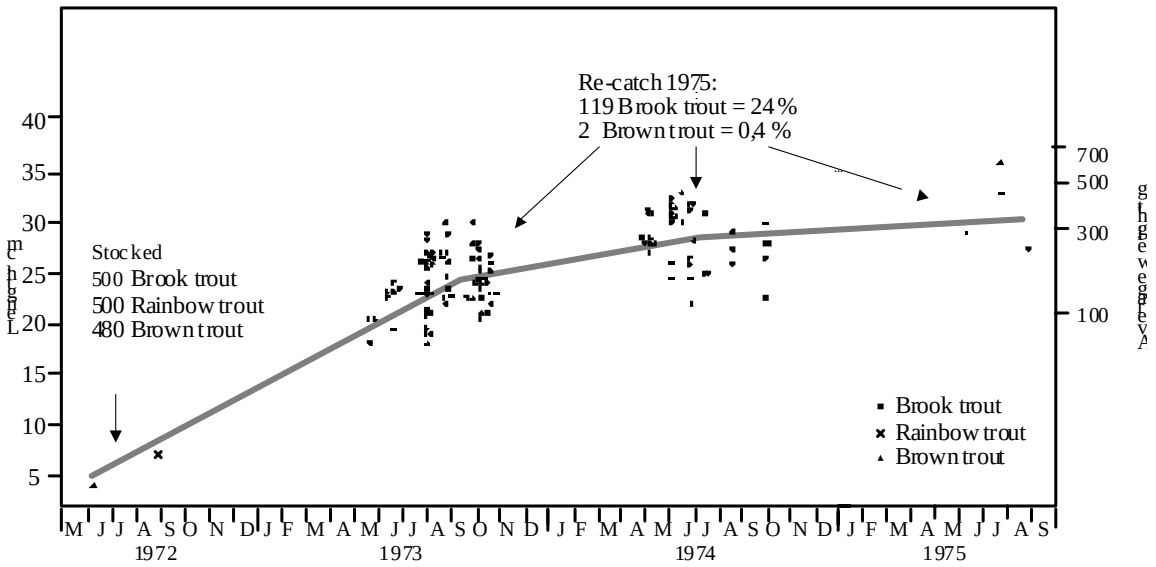

Figure 8. Stockings of fingerlings (0+), recaptures and length and weight distibution of brook trout, brown trout and rainbow trout in Langtjern 1972-1974.

Figure 10 shows results from a stocking of Åstjern with 50 summer old fish of each species. The recapture from this experiment was 98% for brook trout (only one fish not recaptured!), 4% for brown trout and 0% for rainbow trout. These correspond to 18.3 kg brook trout and 1.1 kg brown trout. The average weights for brook trout were 210 grams the first year after stocking, whereas the second year the average weight was 400 grams.

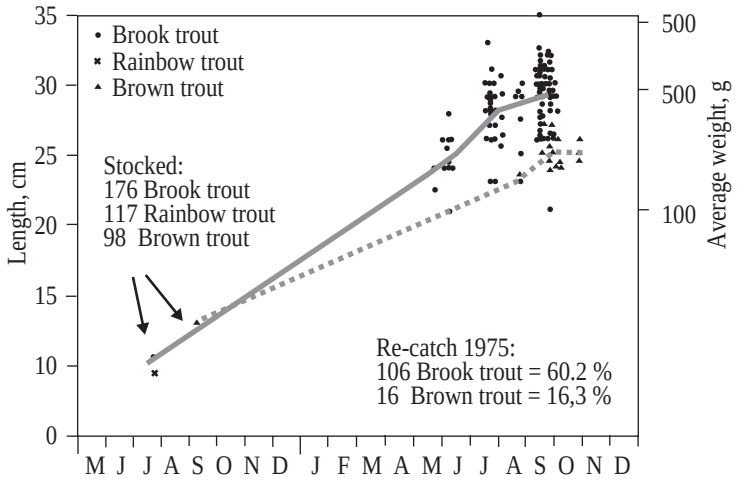

Figure 9. Stockings of yearlings (1+), recaptures and length and weight distibution of brook trout, brown trout and rainbow trout in Langtjern 1974-1975.

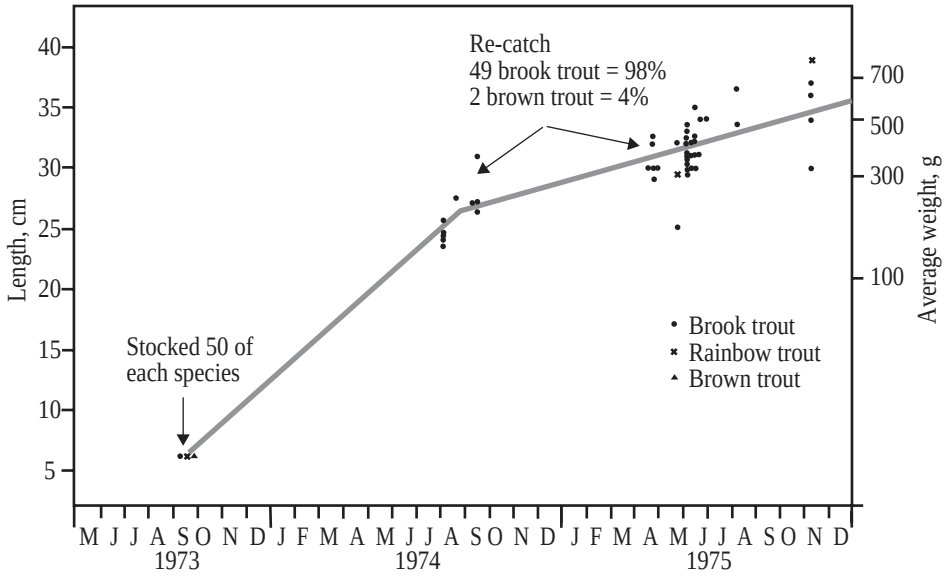

Figure 10. Stockings of fingerlings (0+), recaptures and length and weight distibution of brook trout, brown trout and rainbow trout in Åstjern 1973-1975.

Table 11. Fish catches, grams/hectare/year. Observation period: 3 years (Åstjern 2 years).

Locality		Lake Size	Average pH	Grams/hectare/year					Years
No.	Name	Hectare	1969-74	Brown trout	Brar	Brook trout	Perch	Total	
1	**Holmetjern**	28	5,1	447	110		4460	5017	68-70
2	**Lauvskartjern**	10	5,0	68	670			738	68-70
3	**Vestre Holmetjern**	7,0	4,7	10			684	694	68-70
4	**Store Pipan**	1,47	5,0	426	818			1244	68-70
5	**Store Røytjern**	1,13	5,2	155	1356			1511	68-70
6	**Vesle Pipan**	0,82	6,2		1122			1122	68-70
7	**Veiputten**	0,9	5,2	431	936			1367	68-70
8	**Vesle Røytjern**	0,67	5,2		1367			1367	68-70
9	**Y**	0,54	4,8					0	68-70
10	**X**	0,51	5,0		1427			1427	68-70
11	**Bekaren**	4,8	5,5	2111	1393			3504	68-70
12	**Grandeputt**	4,3	4,8					0	68-70
13	**Langtjern**	23	5,1	20		1015		1035	73-75
14	**Åstjern**	16,9	6,1			5416		5416	74-75

Catches

Table 11 gives an overview of the catches from the different localities. For most of the lakes the observation period was 3 years (1968-1970). Langtjern was observed for three years after the 1972 stocking. For Åstjern the observation period was only two years. There, 49 out of 50 fish were recaptured.

Locality 1, Holmetjern, gave the highest yearly catch of 5 kg/ha. A significant amount of this catch was perch caught in traps in the spring. There, intense trap fishing occurred for 5 years. The yearly catch from this trap fishing was almost 4.5 kg/ha. The catch from fishing of brown trout and brar was low, about 0.5 kg/ha/year during a three-year period.

The largest quantity of salmonid fish per unit area was caught at localities 11 and 14. The yields were 3.5 and 5.4 kg/ha/yr, respectively. No fish were caught in the localities 9 and 12, whereas locality 3 only gave a yield of 10 g/ha/yr of brown trout (1 fish) and 690 g/ha/yr of perch. The yield for the other localities ranged between 0.7 to 1.5 kg/ha/yr.

The variations in catch for the localities are due to physical-chemical conditions for the lakes, as well as the intensity of stocking and fishing. The catch for the most acidic lakes were generally the lowest.

Growth

Table 12 gives the average length and weight for brar and brown trout recaptured during the period 1968-1970. The lowest growth for brar was recorded for Bekaren (11) with an average weight of 333 grams after 3 years. The largest growth recorded was for one single fish caught at locality 10, weighing 1825 grams when it was recaptured This fish was stocked as a fingerling in September 1967 and recovered in October 1970. Generally, the average weight after three years varied from 500 to 1500 grams.

The average weight of the brown trout caught in Holmetjern was 250 grams. They were stocked as fingerlings in 1966. The Brar stocked in 1967 and caught in 1970 had an average weight of 430 grams. In Store Røytjern we caught a brown trout weighing 510 grams in 1970. The average weight of brar, stocked at the same time, was 1500 grams.

Growth- and age-determinations have been carried out based on scale samples from brown trout and some of the brars. The analyses indicate that some of the earlier stocked brown trouts have grown faster than those stocked in 1967. One single brown trout caught in Lauvskartjern appears to have grown to 1660 grams after 5 years.

Table 12. Average length and weight for brar stocked in 1967 and recaptured in the period 1968-70. The brown trout were stocked in 1966. No fishing in 1968 and 1969 in Store Røytjern and Vesle Røytjern.

			Recovered								
Species	**Locality**	**No. stocked**	**1968**			**1969**			**1970**		
			No.	cm	grams	No.	cm	grams	No.	cm	grams
Brar	Holmetjern	0	2	21	105	17	25.5	278	4	31	432
Brar	Lauvskartjern	137	2	22.5	123	5	33	550	13	41	1005
Brar	Store Pipan	38	2	29.5	315	1	39	775	2	42	1133
Brar	Store Røytjern	7							3	46	1492
Brar	Vesle Pipan	23	1	26.5	235	1	37	670	2	41	950
Brar	Veiputten	30	2	24	138	2	27.5	255	2	34	543
Brar	Vesle Røytjern	6							2	43	1210
Brar	X	10	1	28	315				1	48	1825
Brar	Bekaren	30	1	17,5	60	4	27	223	3	31	333
Brown trout	Holmetjern	349	2	20.5	120	21	24.5	188	3	28	255
Brown trout	Store Røytjern	18							1	37	510

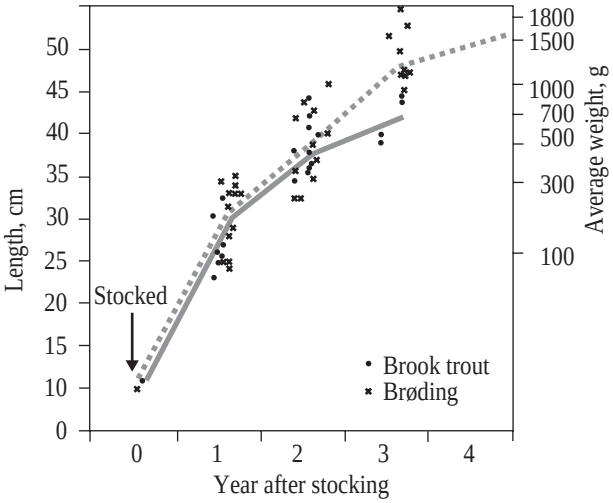

Figure 11. Brook trout and brar (Brøding): distribution of length and average weight. Fingerlings (0+) were stocked.

Figure 11 compares the growth of brook trout and brar from the same lakes. Both species showed similar growth the two first years, whereas the brar was longer and heavier the third year.

Quality and condition

Figure 12 shows length and weight for brook trout and brar from some of the lakes. The condition factor [K = (weight in grams)*100/(length in cm)^3] for different groups of length have been calculated on the basis of the drawn curve and are indicated in the figure. At a length of 20 cm the average K-factor is 1.00, and increases gradually to 1.52 at a length of 48 cm.

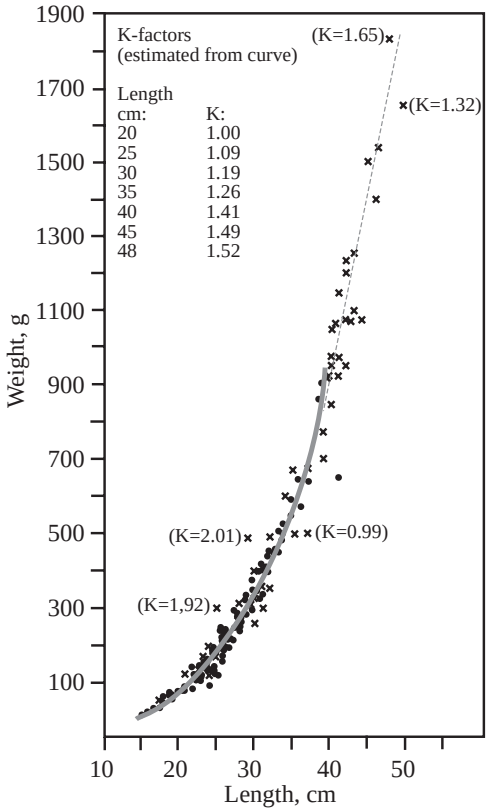

Figure 12. Brook trout (●) and brar (x): ratios of length and weight. Some examples of K-factors are indicated.

Both the brook trout and the brar caught in the lakes had mostly red flesh. The flesh colour of the brown trout varied from white to light red, depending on the lake, whereas the brook trout in all lakes had red flesh. Thus, the brown trout had generally whiter meat than brook trout where they occurred together. In the lakes Holmetjern, Langtjern and Lauvskarstjern the flesh of the brown trout was often white, whereas brook trout and brar had red flesh.

Food

The stomach content for 60 brook trout caught in Langtjern during the period May to September 1973 were analysed and the results (as frequency percent) are given in Table 13. Water dwelling insects dominated for all months. Boatmen were the most frequent group in all months except in May, when phantom midges dominated in most fishes. Otherwise, beetles and larvae of caddis flies, dragon flies and damselflies were important groups in most of the months. Planctonic crustaceans were only found in one fish in September. In some of the stomach samples large numbers of larvaes of alderflies and phantom midges were found. Terrestrial insects ants, water beetles, and different other hymenoptera and diptera also were present. The food choice of the fish in Langtjern is probably not significantly different from that in the other lakes in the area. On weight basis boatmen *(Corixidae)*, dragon damsel and caddis flies might be the most important groups in summer.

Table 13. Stomach content of brook trout from Langtjern caught during summer 1973. Unit: Frequency percent. Number of stomach samples with nutrient group represented.

Group	**May**	**June**	**July**	**Aug.**	**Sept.**
Planktonic crustaceans (Entomostraca)					3
Mayflies (Ephemeroptera)	45				
Alder flies (Sialidae)	45	1		20	
Caddis flies (Trichoptera)	45	36	67	20	30
Dragon flies (Anisoptera)	2	3			17
Damsel flies (Zygoptera)	27	1	33		
Phantom midges (Chaoborus)	64				
Midges (Chironomidae)	1				3
Boatmen (Corixidae)	2	91	100	80	87
Beetles (Coleoptera)	45	55	67	20	13
No. of fish analysed	**11**	**11**	**3**	**5**	**30**

The food choice for brar, brook trout and brown trout apparently are similar. The sample size is, however, too small to detect significant differences in food intake between the species.

Sexual maturation

Table 14 gives an overview of the age of maturation for brook trout caught in Langtjern and for brar caught in some other lakes. The male fish matured earlier than the females. After one year 56% of the brook trout males and 71% of the brar males were mature. After two winters more than 80% of both males and females of brook trout were mature. This was also the case for the male brars, whereas only 38% of the females of brar were mature. After three years all brars were mature. This is early maturation and may be due to fast growth and use of domestic fish as stockning material. Previous inverstigations have indicated that the fast growing specimens of brook trout mature earlier than slow growing fish (Grande, 1960). Domestic fish are often selected for fast growth and therefore earlier maturation (Vincent, 1960).

Table 14. Sexual maturation of brook trout and brar. 73 and 98 studied samples of brar and brook trout, respectively. Unit: percent frequency.

Species	Sex	Age		
		1+	2+	3+
Brook trout	♂	56	89	-
	♀	18	83	-
Brar	♂	71	83	100
	♀	0	38	100

Spawning of brar were observed in the inlet creek of Holmetjern in the beginning of October, at the same times as for brook trout and brown trout. Significant natural recruitment in the form of new generations for brar, brook trout or stocked brown trout has, however, never been observed in the registration of the year classes in the catches. Mortality of eggs placed in boxes in the gravels of creeks in the Langtjern area (1995 and 2001) have been high or complete.

Migrations

In order to study migration of fish after stocking the outlet of Langtjern was closed by a fine meshed metal net and a trap for migrating fish. The recorded migration is given in figure 12 and table 15. After stocking of one-year old (1+) brook trout, brown trout and rainbow trout in 1974 only a few fish migrated through the outlet during the first two days. There was, however, a marked migration of both mature and non-mature fish during September – October.

Table 15. Migration from Langtjern of one-year old brook trout, rainbow trout and brown trout stocked at age 1+.

Species	No. stocked	Migration in %	
		Autumn 1974	Autumn 1975
Brook trout	176	32.9	1.7
Brown trout	98	1	0
Rainbow trout	117	8.5	0

The brook trout migrated to a much larger degree than both the brown trout and the rainbow trout. Thus the first autumn after stocking (1974) as many as 32.9% of the brook trout yearlings migrated compared to only 1% of the brown trout. Of the migrated 10 rainbow trouts that migrated the first autumn four were found dead in the trap. Fish caught in the trap were put into the lake again. One reason for the low number of fish (3) in the trap the second fall (1975) might have been that 106 (60%) of the fish stocked in 1974 was caught during the second summer, and/or that that the migratory drive is strongest in the earlier life history stage.

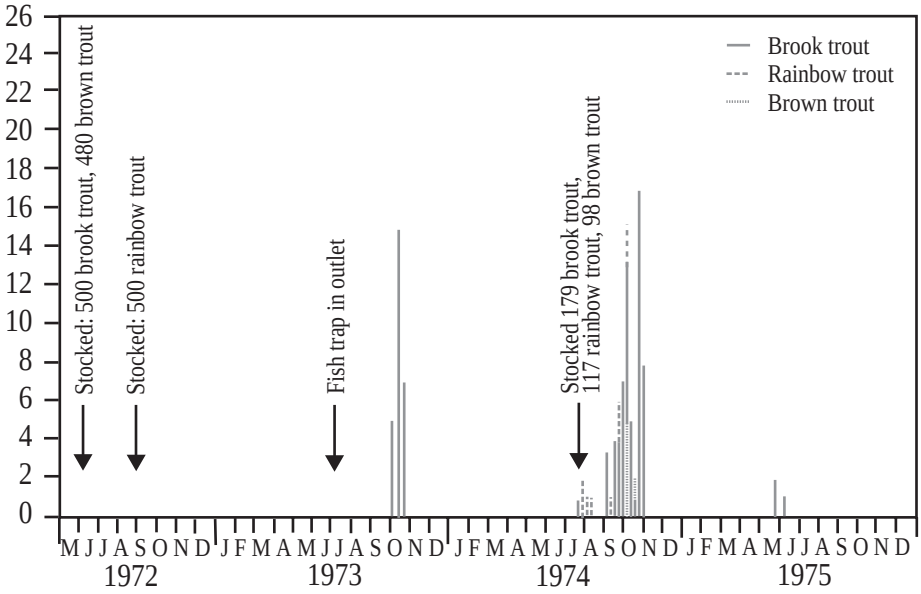

Figure 13. Fish catch in the trap placed at the outlet of Langtjern.

4.4 The period 1975-2000

4.4.1 Introduction

In contrast to the first period, the second period of the experimental stocking of fish and registration of recaptures concentrated on Langtjern. The exception is stocking experiments carried out in small ponds, described in a later chapter. The experiments in Langtjern were also followed up less intensively. One reason for this was that from 1976 extensive experiments with stocking of brook trout were carried out in a number of acidic lakes in southernmost Norway. These experiments were a direct outcome of the successful results with brook trout in the Langtjern area (Grande et al. 1980). We report here the stockings done in Langtjern in this period and the results obtained. Since 1990 the water quality of Langtjern has improved significantly due to less sulphur in precipitation as reflected in the lake water (Figure 5). These changes may have influenced the fish results in the later years.

4.4.2 Materials and methods

Brook trout was stocked in Langtjern irregularly until 1990. In 1976 we tried a hybrid of lake trout and brook trout ("splake"). The splake were obtained from Semlan fish hatchery near Østersund, Sweden. The lake trout were descendents of fish from Lake Superior, Canada, imported to Sweden in the 1960's. The brook trout were descendents from fish kept in Swedish hatcheries for many generations and from natural populations in several watercourses. The splake were originally obtained for stocking in the "Oslomarka", the recreational area outside Oslo, and kept in the hatchery owned by OFA (the fish administration of "Oslomarka"). One hundred splakes were stocked in Langtjern in 1976. Some splake were caught in the fish trap shortly after stocking and in 1977 only a few were recaptured. The experiments with this fish species were then terminated.

In 1977, 800 yearlings (0+) of brook trout were stocked in Langtjern. Of these, 400 were imported as eyed eggs from the Adirondack Mountains area in New York, U.S.A. The roe were provided by Professor Dwight A. Webster at Cornell University and were brought from the Adirondack League Club Hatchery. These brook trout were of the Temiscamie strain originating from the Temiscamie River ending in the Hudson Bay in Quebec, Canada. This strain is known for slow growth, longevity

and high tolerance to acidic water. The Norwegian brook trout strain was a mixture of the Øyfjell strain and a Danish strain cultivated in NIVA's laboratories for a few generations. The intention of this experiment was to see whether we could see any significant differences between the strains with repect to acid tolerance, growth and age.

Brown trout were stocked irregularly during the whole period. From 1992 only brown trout have been stocked. Fish of different origin have been stocked, including fish from Nordmarka, Tunhovd in Buskerud county and Fossbekken in Rogaland county. The recapture of brown trout can give some indications of yield through the years.

All stockings were followed by registations of recovery by fishing carried out by people visiting the cabin at Langtjern. Some fish may not have been recorded, some marked fish may have been over-seen and in some cases there may have been misidentification of the species that were caught. It may be difficult for non-qualified people to distinguish between splake and brook trout

4.4.3 Results

Splake

One hundred splake were stocked as yearlings (1+) on 24 may, 1976 and recaptured several times during the first summer in the outlet trap and in Langtjern itself. The number of splakes caught was somewhat unsure, because some of the splakes could have been mistaken to be brook trout. The recapture has, however, most likely not been more than about 10-15 fishes in 1976. In 1977 only six of this hybrid was caught. Thus, the total recapture was 15-20%, which is not much, considering that fish at age 1+ were stocked. The largest splake caught weighed 330 grams and the mean weight in 1977 was about 250 grams.

Brook trout

Brook trout of at least two different strains were stocked in Langtjern regularly from 1972 to 1990 and the recaptures have varied (Figure 14 and Table 18). Some of the variations can be due to the quality of the stocked fish, such as conditions when they were stocked, possible differences in strain tolerances, water quality variations, and possible predation from larger fish.

Differences in strains have not been systematically studied. However, Table 16 show results from parallell stocking of the imported American strain Temiscamie and the Norwegian/Danish mixed strain. The table indicates that there were more recaptures of the Norwegian strain one year after the stocking, whereas the recapture of the Temiscamie strain was more frequent the year after. Totally, the recapture was about 28 and 32% for the Norwegian and the American strains, respectively. The total weights of the recaptures were 21 kg and 14 kg for the Temiscamie and the Norwegian strains, respectively. The American strain may grow somewat slower and may live a little longer. The final result may thus be a higher yield in kg/ha. Otherwise, it is not possible to conclude anything about possible differences in reactions of the two strains, for example, tolerance to acidic waters, growth rate, and duration of life. Brook trout with different and partly unknown origin have been stocked regularly, without any significant differences in survival.

In summer 1983, 500 brook trout of the Temiscamie strain (1+) were stocked. Of these, 5 were recaptured in September 1983 and an additional 96 were recaptured in 1984. None were recaptured in 1985. Thus, the total recapture was 101 fish with a total weight of approximately 30 kg. These results do not indicate that this particular strain has a longer life span than the Norwegian/Danish strain, as in the first experiment.

Table 16. Total stocking and catches of brown trout and brook trout in Langtjern for the years 1973-2000.

Year	No. stocked		No. caught		Ave. weight, g		Weight, g		
	Brown trout	Brook trout	Brown trout	Brook trout	Brown trout	Brook trout	Brown trout	Brook trout	Total
1972	480	500							
1973			1	75	170	172	170	12900	13070
1974	98	176	1	40	410	286	410	11440	11850
1975	1511		16	116	220	280	3515	32465	35980
1976		500	85	37	141	63	11985	2331	14316
1977		800	164	51	198	179	32435	9115	41550
1978			144	114	270	75	38865	8586	47451
1979	200	200	32	157	333	196	10670	30815	41485
1980			25	13	477	425	11915	5530	17445
1981			21	27	562	179	11805	4820	16625
1982			17	33	698	348	11870	11490	23360
1983		500	18	5	662	224	11910	1120	13030
1984			1	96	840	312	840	29880	30720
1985		270	3	0	803	0	2410	0	2410
1986			0	2	0	75	0	150	150
1987		300	2	118	1120	275	2240	32500	34740
1988			0	10	0	400	0	4000	4000
1989	25		2	18	250	400	500	7200	7700
1990		200	0	0	0	0	0	0	0
1991	500		0	17	0	375	0	6375	6375
1992			0	0	0	0	0	0	0
1993	200		10	0	150	0	1500	0	1500
1994			43	9	277	0	11895	0	11895
1995	200		63	0	390	0	24588	0	24588
1996			25	0	619	0	15470	0	15470
1997	150		26	1	670	1300	17420	1300	18720
1998			30	0	928	0	27835	0	27835
1999	400		2	0	850	0	1700	0	1700
2000			16	0	621	0	9930	0	9930
Sum	**3764**	**3446**	**729**	**939**			**261878**	**212017**	**473895**

Table 17. Recapture of Temiscamie and "Norwegian" strains of brook trout during the years 1978-1980. 400 (0+) of each strain were stocked on 23 September, 1977.

	1978				1979			
Strain	No.	%	Weight, g	Av. weight, g	No.	%	Weight, g	Av. weight, g
Temiscamie	39	9.8	2331	60	81	20.3	14930	184
Norwegian	71	17.8	5336	75	39	9.8	8395	215
Total	111	14	7696	69	120*	15	23325	194

	1980				Total		
Strain	No.	%	Weight, g	Av. weight, g	No.	%	Weight, g
Temiscamie	9	2.3	3880	431	129	32.3	21141
Norwegian	1	0.3	440	440	111	28	14171
Total	10	1.3	4320	432	240	30	35312

*In 1979 about 37 fish were not recorded as marked or not, they are not included in the material, but add to the total number of fish recovered.

From 1975 to the last stocking of brook trout, brown trout were also stocked. The relationship between these two species is shown by the yearly recaptures (Figure 14).

The stockings in this period confirm the earlier observations that brook trout grow faster and are captured earlier than brown trout. On the other hand, the brook trout is normally rather shortlived (3-4 years). The brown trout, however, may – if they survive the acidic water – be recaptured for many years and grow considerably larger. In 1997 a brook trout weighing 1300 g was caught in Langtjern. This fish was most likely stocked in 1990. This is the oldest (7 years) and largest brook trout ever caught in the Langtjern area.

Brown trout

The stockings of brown trout are shown in Figure 14 and Table 16. In 1972, 480 brown trout (Slidre strain) were stocked followed by 98 fish in 1974. Fifteen hundred and eleven brown trout (0+) of the Tunhovd strain) were stocked in July 1975. A small number of brown trout were stocked in 1980. From 1992 and onwards only brown trout were stocked in Langtjern in numbers of 150 to 500 at a time. The recaptures are given in figure 14. Few brown trout were recaptured from the first stocking. One reason for this could be the relative acidic water quality during parts of this year, as well as the competition with the more acidic tolerant brook trout that were stocked simultaneously. The stocking of yearlings (1+) in 1974 was not successful either. Most of the fish (16 percent) were recaptured the year after stocking, giving only 5 kg of fish (an average of 51 grams per stocked fish). The stocking carried out in 1975, however, was a success and fish from this stocking were recaptured up to the late 1980's. Up to 1981, when it was possible by certainty to determine recaptures of this particular stocking, 456 brown trout were caught, that is 30.2 percent corresponding to totally 111 kg. Later, and up to 1985 some more fish were caught that most likely originated from this stocking. These year classes of brown trout were not marked by fin cutting. These weighed up to 1.6 kg. After 1985 it is impossible to separate fish from the stocking in 1975 from the other stockings in 1972, 1974 and 1980. The total reacapture of the 1975 stocking was about 480 fish amounting to 131 kg. This corresponds to a total recovery of 32 percent. It is typical for a successful stocking of brown trout in that it gives recaptures over more years than brook trout, and in this particular case up to 9 years and fish up to 1.6 kg in size. Figure 15 shows length, weights and condition factors for recaptured fish up to 1983 from the 1975 stocking.

The growth and the condition of the 1975-year class are most likely more determinded by the density of fish. In 1974, 1976 and 1977 brown trout and brook trout were also stocked. The stocking of brook trout was quite large in 1977 (800 fish) There were an apparent stagnation of growth (Figure 15) during the years 1977-1979. The condition factors for those years were also low (figure 15). In the 1980's, however, growth and condition were very good for the reminding fish from this year class. In 1980 200 (0+) brown trout were again stocked together with 200 (0+) brook trout and 100 rainbow trout (1+). About 13 of those brown trouts were recaptured (6.5 percent weighing 6.74 kg, Table 18). For comparison, 62 (31%) of the stocked brook trouts were recaptured with a total weight of 16.8 kg. No rainbow trout were ever recaptured. In the years 1982, 1983 and 1985 the recaptured brown trouts had average weights of 193, 223 and 803 grams and condition factors of 1.15, 1.15 and 1.39, respectively, values that are relatively high.

Table 18. Recapture of 200 brown trout and 200 brook trout stocked 19.09.1980. Both in class 0+.

Year	1980	1981	1982	1983	1984	1985	1986	1987	Total	Recapture, %
Brown trout		0	3	6	0	3	0	1	13	6,5
Brook trout		26	33	3	0	0	0	0	62	31

In 1989 25 (1+) brown trout were stocked in Langtjern. None of them were recaptured. From a stocking in 1991, however, some fish were recaptured, 10 fish in 1993 (ca 1 kg) and 43 (11.8 kg) in

1994. Because of frequent stockings and no marking of the fish in the later years the year classes can not be separated from each other. Summing up the stocked brown trout from 1992 and to 1997 and comparing with the recapture until 2000, we end up with 1050 fish stocked and 215 fish recaptured: 20.5 % weighing 111 kg. There is most certainly some fish left in Langtjern from the stockings in 1995 and 1997. The figures given are thus minimum figures for survival.

We do not know whether there has been any illegal fishing in the lake. There are signs forbidding fishing without permitance along the shoreline of Langtjern. We do not, however, expect that many fish have been caught by illegal fishing, especially because it is difficult to catch fish without access to a boat.

The quality of the brown trout has varied during the whole period. In three periods 1976-1980, 1981-1987 and 1995-2000 the average condition factors were 0.97, 1.18 and 1.15, respectively. It is difficult to see that these variations are related to water quality or other reasons. The condition factors are somewhat dependent on the size of the fish stocking density and the population size. At the end of the 1970's the fish population in Langtjern was relatively large because of many and large stockings. This could explain the lower condition factors for this period. In addition to the condition factor, the colour of the flesh can be an excellent indicator of the fish quality. We have not measured the colour quantitatively by means of a colour scale. The general impression is, however, that the flesh colour of the brown trout has been largely white to light red in the 1970' and 1980's. In the 1990's the colour has been largely red. The brook trout have mostly had stronger red colour than the brown trout, and very few fish have had white coloured flesh.

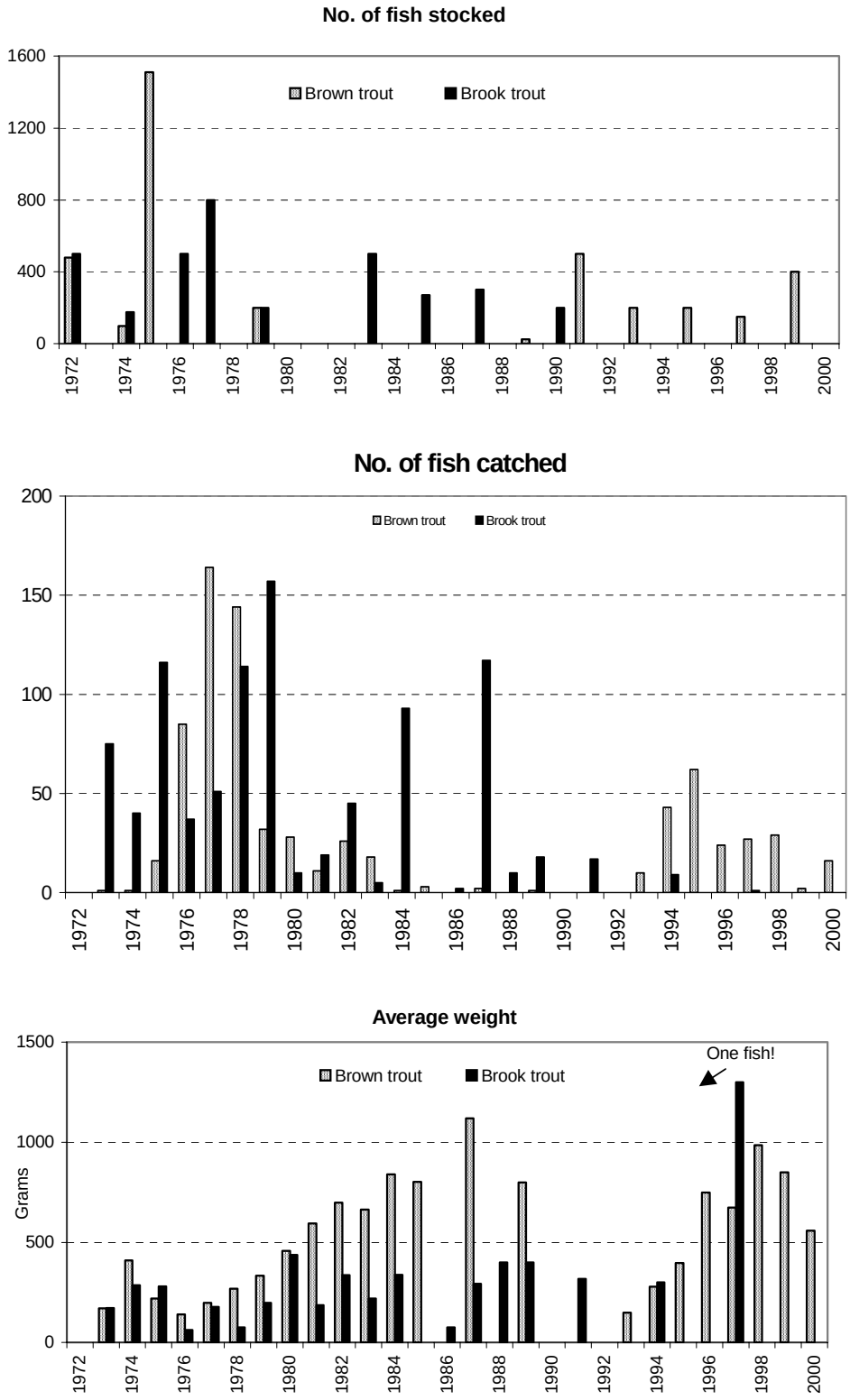

Figure 14. Stocking and recapture of brook trout and brown trout in Langtjern for the period 1972-2000. Data from Table 16.

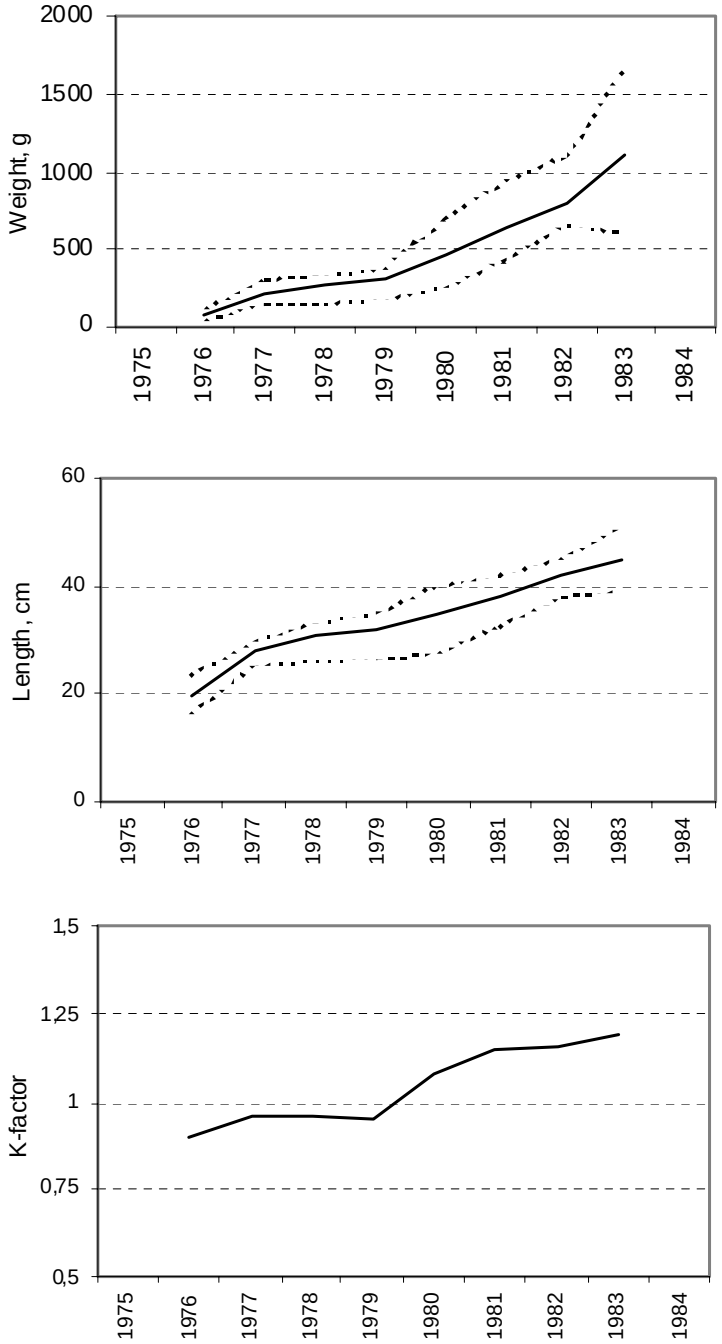

Figure 15. Yearly average weights, lengths and K-factors for brown trout stocked 10.07.1975 in Langtjern. Dotted line indicates maximum and minimum values.

5. Growing fish in small ponds during summer ("Put and take")

5.1 Background

A number of small fishless ponds are scattered all over the Langtjern area. These are mostly located in boggy areas and do not have visible inlets or outlets. Their surface areas are from 0.1 to 0.5 ha and their maximum depths are from 1–3 meters. These kind of ponds have never been considered interesting for fish stocking, because they are commonly acid and lose most of the oxygen during the ice covered season. The oxygen loss is largely due to decomposition of organic matter and their very low through-flow. The oxygen content of these kinds of ponds can go down to zero during late winter (e.g., Grande and Andersen 1970). Salmonid fish cannot survive the winter in such ponds.

This class of ponds has, however, a significant production potential for fish during the summer season. The high production of insects can provide food for fish. Fish species that can grow to catchable size during the summer season, and that will thrive in the often acidic water quality must be used. Because of the good stocking experience with the tough brook trout it was considered interesting to stock some of these ponds in the Langtjern area with this fish species. Brown trout was stocked in some ponds for comparison.

In order to collect more data similar experiments were carried out in an area at Krokskogen in Ringerike community. In all experiments the fish was stocked in early summer (late May – early June) and caught in late autumn. Water samples for chemical analyses were collected from all sites. We present here the results from these studies.

5.2 Methods

The studies were carried out during 1991 to 1995. Lake size and accessibility were used for selecting the test sites. Chemical data were available for some of the sites. Water samples were collected when the fishing was carried out in the autumn and analysed at NIVA's analytical laboratory. The surface area of the ponds was measured from maps (1:10.000). The depth was measured from the ice surface.

We used one- or two-year old (1+, 2+) brook trout and brown trout, 12-24 cm and 20-150 g. The brook trout came from the hatchery of Oslomarka Fish Administration (OFA) located in Sørkedalen near Oslo or from the hatchery at NIVA. They were of unknown original breed. The brown trout also came from the hatchery of OFA, being of the Gjedrem breed. This breed is selected for a better tolerance to acidic water (Gjedrem 1980, Rosseland and Skogheim 1987 and Dalziel et al. 1995). The water quality of the two hatcheries is fairly similar (pH about 6.5). The fish were transported in plastic bags for 3-5 hours with oxygen-saturated water. The fish were stocked 25/5 (1991) – 14/6 (1993). The recapture was carried out in the time period 23/9 –27/10. The fish were caught with one or two nets (29-35 mm), depending on the expected fish size and the size of the pond. In many cases all stocked fish were caught. For those sites where only some of the fish were caught we can not know whether the remaining fish were dead, too small to be caught in the net, or avoided recapture. These factors limit the interpretations of the results.

Each fish was weighed and its total length measured from nose to outer end of the tail. In most cases the flesh colour, sex, maturity and stomach content were recorded (Jonsson and Matzow 1979). The growth increase was estimated as the average weight when caught minus the average weight when stocked. Daily growth (g/day) was calculated as growth increase divided by number of days between stocking day and recapture day. Specific growth rate (G_v, % per day) was calculated according to:

$$G_v = \frac{(\ln V_2 - \ln V_1)}{t} \cdot 100 \qquad (1)$$

Where V_1 is weight when stocked, V_2 is weight when caught and t number of days between stocking and harvesting (Sandlund and Forseth 1994). The logarithm of the weights was used because of differences in size of the fish at stocking.

Finally, the fish were prepared in a culinary way by our chief cook (T. S. Traaen) and eaten for empirical quality assessment.

5.3 Results

5.3.1 The experimental ponds

Eleven ponds were selected in the Langtjern area for the experiments (Table 19). Chemical data for the ponds are given in Table 20.

Table 19. Morphometric data for the experimental ponds in the Langtjern area. The sites no. 4, 5 and 7 were stocked only in 1991, and there were no recaptured fish.

Site no	Name	a.s.l. m	Area, ha	Depth, m
1	Åsputt	460	0.12	1
2	Treputt	450	0.33	1
3	Pålsputt	510	0.26	2.5
4	Sanputt	600	0.06	1
5	Siggen	600	0.10	1.5
6	Herborgputt	570	0.42	1.4
7	Nilsputt	580	0.16	1
8	Svartputt	590	0.18	2.9
9	Y	590	0.55	-
10	Grandeputt	570	0.30	3
11	Lagoputt	570	0.23	2
Mean		554	0.25	1.8
Range		450-600	0.06-0.55	1-3

The ponds have an average area of ca. 0.25 da and an average depth of about 2 m (Table 19). They are all acidic with an average pH of 4.9 Table 20). The calcium concentrations are low (0.23-1.06 mg/l). They are all high TOC-ponds (6.3-13 mg C/l). Lakes with such water chemistry would generally be considered as unsuitable for salmonid fishes despite the size of lake. Brook trout and some tough strains of brown trout may, however, survive through summer, even thrive and grow well if the food availability is good.

Table 20. Water chemistry of ponds stocked with fish. All sites were sampled in May 1991. Those where fish were recovered were also sampled in autumn 1992.

LOK	Year	Date	pH	K25	Ca	Mg	Na	K	Cl	SO4	NO3	TOC	R-Al	Il-Al	L-Al	TotN
		Mo/D		MS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µgN/l	MgC/l	µg/l	µg/l	µg/l	µgN/l
1	1991	5/22	5	1.67	0.82	0.21	0.83	0.2	0.5	2.2	M 1	11.3	167	116	51	393
1	1992	9/18	4.7	2.33	1.34	0.29	0.89	0.1	1	2.7	M 1	15.4	284	212	72	300
2	1991	5/22	5.3	1.48	1.03	0.2	0.7	0.2	0.6	1.9	4	8.66	86	67	19	252
2	1992	9/18	4.7	2.24	1.22	0.24	0.76	0.2	1.1	2.3	5	13	143	108	35	273
3	1991	5/22	5.4	1.32	1.06	0.18	0.57	0.2	0.5	1.6	M 1	9.52	106	79	27	287
3	1992	9/19	4.8	1.76	1.48	0.26	0.72	0.1	0.9	2.6	11	15	196	153	43	420
4	1991	5/22	4.7	1.45	0.23	0.07	0.37	0.2	0.4	0.8	M 1	8.09	24	15	9	311
5	1991	5/22	4.7	1.52	0.35	0.11	0.44	0.3	0.6	0.9	1	9.98	33	24	9	387
6	1991	5/22	5.1	1.35	0.81	0.14	0.46	0.2	0.5	2.1	9	6.29	105	61	44	375
6	1992	9/19	4.8	1.79	0.89	0.15	0.49	0.1	0.7	2.5	38	10	169	122	47	635
7	1991	5/22	4.6	1.82	0.34	0.11	0.41	0.2	0.6	2	20	6.41	55	24	31	351
8	1991	5/22	4.6	2.13	0.81	0.17	0.57	0.2	0.6	2	M 1	12.5	139	96	43	323
8	1992	9/19	4.4	3.13	1.19	0.25	0.66	0.1	0.8	2.4	8	19.2	260	190	70	411
9	1991	5/22	4.7	1.99	0.84	0.18	0.52	0.1	0.6	2.2	M 1	10.7	127	88	39	345
10	1991	5/22	4.9	1.59	0.95	0.12	0.42	0.2	0.5	2.1	M 1	8.63	87	65	22	281
10	1992	9/18	4.6	2.21	1.22	0.14	0.46	0.1	0.7	2.3	19	13.8	158	129	29	539
11	1991	5/22	4.8	1.78	0.84	0.14	0.52	0.1	0.6	2.3	M 1	8.8	121	88	33	210
11	1992	9/18	4.4	2.29	1.1	0.19	0.58	0.1	0.7	2.5	5	14.4	189	156	33	393

5.3.2 Recapture of fish

The recapture of brook trout was about 60% on the average, whereas only 9% of the brown trout were recaptured. Most likely the brook trout can better tolerate the special chemical conditions in the ponds and/or the brown trout did not reach a sufficient size to be captured in the nets.

Table 21. Total stocking and recapture of fish in all the experimental ponds.

Year	Species	No. stocked	No. caught	Recovery %	breed age, weight when stocked (average)
1991	Brook trout	25	17	68	OFA/NIVA 1+ 29 g
1992	Brook trout	29	17	59	NIVA 1+ 19 g
1993	Brook trout	20	11	55	OFA 1+ 30 g
1994	Brook trout	7	5	71	OFA 2+ 60 g
1994	Brown trout	13	2	15	Gjedrem 2+ 60 g*
1995	Brown trout	9	0	0	Gjedrem 1+ 10 g

*Brown trout early fed, thus reaching the same weight as the brook trout when stocked.

5.3.3 Growth ability

Table 22. *Growth of recaptured fish from all experimental ponds.*

Year	Species	No. of days	Weight (g) when stocked	Growth range*	Average growth	Growth, g/day	Growth rate G_v	Av. no. of recaptured fish/ha	Av. growth of recaptured fish, kg/ha
91	Brook trout	123	29	240-337	291	2.4	1.95	7	2.1
92	Brook trout	103	19	165-282	225	2.2	2.49	7	1.6
93	Brook trout	105	30	180-265	217	2,1	2.00	4.6	1.0
94	Brook trout	112	60	230-300	272	2.4	1.54	3.8	1.0
94	Brown trout	112	60	190-280	235	2.1	1.43	1.2	0.29
Average	Brook trout	111	35	203-296	251	2.3	2.00	5.6	1.4

Table 22 gives the yearly growth and average daily growth during summer season. Average growth is stocked weight minus weight at recapture. (For fish species and age when stocked, see table 19).

The average growth of brook trout in the 8 ponds with recorded recapture was 250 g. The daily growth was 2.3 g, and the value for the specific growth rate (G_v,) was 2.0. The growth per hectare averaged 1.4 kg. This is a minimum value, because we do not know how many fish survived and avoided recapture. In several ponds, however, all fish were recaptured. Of these, the highest recorded growth for 1991 for the sites 1, 8 and 6 (see table 19) was 5.1, 2.9 and 2.4 kg/ha, respectively. For those sites the growth period was 123 days (1/3 year).

In 1990 two ponds (2 and 3) were stocked with larger fish (150 g each) than those stocked in the following years. For those fish the growth rate was 0.98 and 1.18, respectively, or a growth of 2.7 and 3.7 g/day, corresponding to 2.8 and 3.2 kg per hectare. These values are 2-3 times higher than for the following years. Thus, it might be possible that larger fish can improve the yield, because they can utilise larger animals.

The brown trout showed less growth than the brook trout from the same pond. One reason for the low recapture yield could be that only a few brown trout grew large enough to be caught in the nets.

5.3.4 Fish quality, condition and maturity

All recaptured brook trout had red flesh. Figure 16 shows the most typical colour of the fish from the area. The colour varied somewhat and a few species were light red.

Figure 16. Characteristic colour of recaptured fish from small ponds.

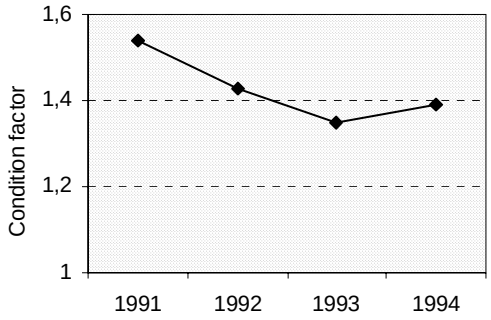

Figure 17. Average condition factors for the recaptured brook trout during the experimental period.

The condition factors for the recaptured brook trout decreased during the years 1991-1994 (see figure 17). Both the male and the female brook trout were largely in stadium 5 or 6, indicating they were ready for spawning. Of the 27 brook trout for which the stadium was recorded, 21 (78%) were ready for spawning. The recaptured brown trout had an average condition factor of 1.27, somewhat lower than for the brook trout. They had all light red flesh. None of the recaptured brown trout were mature.

5.3.5 Stomach content

The stomach content of the recaptured fish consisted mainly of Dragon fly larvae (*Anisoptera*) and boatmen (*Corixidae*). Phantom midges (C*haeoborus* sp.) were also common. Some of the fish had their stomach completely full of Phantom midge larvae. The stomach content was largely similar, most likely because the fish were recaptured almost at the same time (23/9-2/10) each year.

5.3.6 The experimental ponds at Krokskogen

In the Langtjern area fish were stocked in acidic ponds with an average pH of 4.9. We stocked primarily with brook trout. Similar stockings were carried out in an area at Krokskogen, Ringerike community. At Krogskogen 9 ponds were stocked, but only 4 were stocked for several years (1991-1995). The average area of the four ponds was 2.4 hectares, and they are located within a few hundred meters of each other. Of these, three had average values for pH: 6.8, 7.1 mg Ca/l and TOC = 9.7 mg C/l. One pond had pH = 5.1 Ca = 1.5 mg Ca/l and TOC = 13 mg C/l, which is a water quality more similar to that in the Langtjern area.

The ponds were stocked with brook trout, rainbow trout, brown trout and Arctic char. In the non-acidic ponds the recovery of rainbow trout was about similar, or a little lower, than the recovery for brook trout. However, only brook trout was recovered in the acid ponds. The recovery of the brown trout was considerably lower than the recovery of both rainbow trout and brook trout. The growth of the rainbow trout was somewhat higher than for the brook trout. In 1993, for example, in one pond the average growth for brook trout and rainbow trout was 340 g and 350 g, respectively, whereas in another pond the corresponding figures were 212 g and 258 grams. These results indicate that stocking of rainbow trout in non-acidic ponds can produce larger fish, but since the recapture was lower, the total yield was lower for rainbow trout than for brook trout. The brown trout gave, as for the Langtjern area, significantly lower recapture yields than the brook trout. None of the Arctic char stocked in the acidic pond was recaptured, whereas for two of the non-acidic ponds the recapture was 100%. The growth rate of the char was, however, significantly lower than for both rainbow trout and brook trout. Brook trout grew better in the three non-acidic ponds than in the Langtjern area, most likely because of better food availability in those ponds. Chironomidea, Dragonflies, Caddisflies and Corixidae were important food in these ponds. *Gammarus lacustris* was also found in large numbers in the stomach content of

fish from one of the ponds This animal is most likely not present in water with pH less than 6 (Økland 1975).

5.3.7 Discussion

Based on the experiments carried out in the Langtjern area and in Krokskogen, it appears that brook trout is the most suited species for stocking in acidic ponds. Also rainbow trout can give good yields in non-acidic ponds (pH>6). Brown trout yields lower recovery and lower growth both in acidic and non-acidic ponds. The experiments with Arctic char are too few to draw rigorous conclusions, but this species seem less suited.

Stocking of relatively large fish (100-200g) gives the highest yield. However, such a fish size is more costly, troublesome to stock, and, if wild fish is used, the growth potential could be low because of high age. Fish of size 20-50g (1+, 2+) from hatcheries are easier to stock and produce sizes 200-400g at the end of the growing season if the fish density is 10-20 fish per hectare (1-2 per decar). Increasing the number of fish will most likely result in too low growth. The fish should at least gain a weight of about 200g in order to make the effort profitable.

The fish have been re-captured by net fishing, which in most case have given 100% recapture of brook trout. Some sport fishing with worms and spinners in the end of September had little success. A disadvantage with late recapture is that the brook trout at this time is close to complete maturity. However, the condition of the fish is so good that the quality is not significantly influenced. Even though the fish have been in stadium 4-5 they were delicious.

Stocking of fish is strongly controlled by the Directorate for Nature Management. Brook trout and rainbow trout are both “strangers” to the Norwegian fauna, although both species are found as reproducing populations in southern Norway. The brook trout has existed in Norway for at least 80 years. Today it is illegal to stock these fish species in Norway, whether they are present in the watercourse or not. Stocking of the type carried out in the Langtjern and Krokskogen areas are thus not currently allowed. Ponds may also have populations of rare or threatened species, as for example amphibians. Stocking of predatory fish can be a threat to such species.

Although stocking of the kind described here is not at present practical, the results should be of general interest. There is undoubtedly a significant potential for fish production during the summer season in many small ponds and lakes. Species other than those discussed here may also be of interest.

6. General discussion

In the 1960’s a catastrophic decline in fish populations occurred in lakes and rivers in parts of southern Norway. The decline was particularly marked in the southwestern counties, such as West and East Agder and parts of Rogaland and Telemark and from the more centrally located counties Buskerud, Østfold and Akershus. NIVA was contacted concurrently to give advice for improving fishing conditions in Lake Holmetjern and the closely located lakes in the Langtjern catchment. The description of the activities of the fish studies in the Langtjern area must be seen in the light of the development in the knowledge of the acidification problems during the more than 30 years that have elapsed since our studies began. In the first years we did not know the reason for the decline in fish populations. Nor did we know the differences in tolerance to acidic waters between species and between strains. The mechanisms for the effect of acid water on fish were not known before the end of the 1970’s (Schofield 1977, Dickson 1979, Muniz and Leivestad 1980). The attitude to stocking of different fish species at that time was much less restrictive that it is today. Therefore, there were no restrictions involved in carrying out stocking experiments using different salmonid strains and species. The stocking experiments with different categories of brown trout as well as brook trout, brar, splake

and rainbow trout resulted in interesting results. This led to further research as in the Norwegian SNSF (Acid Precipitation – Effects on Forest and Fish) project (Seip and Tollan 1980), and consequently also internationally (Rosseland 1980, Rosseland and Skogheim 1984). In particular, the good results obtained with brook trout/brar resulted in extensive experiments with stocking of these fish species in acidic water in other parts of Norway (Ousdal 1985, Kleiven 1995).

Because of the extensive fish research conducted by the SNSF-project and increased international activity in this topic the fish research activities in the Langtjern area were reduced. Experiments were undertaken in other areas, such as Tovdal, Bygland, and Marnadal with acidic waters and local fish species and fish strains (Gjedrem 1976a 1976b, Rosseland 1980, Rosseland and Skogheim 1984). In the early 1990's some experiments with growing fish in small ponds during summer season were carried out in the Langtjern area, but these experiments were not directly related to the acid rain problem.

The stocking of brook trout in the 1970's and 1980's lead to the formation of several reproducing strains, especially in southernmost Norway (Grande 1964, Grande 1982, Eken 1988, Kleiven 1995). Before that only two such strains were known – in Øyfjell, Telemark and in Åmot, Buskerud. These occurences are 80-100 years old and the strains still exist. Thus, the brook trout is in fact "naturalised" in Norway today. The brook trout, that originally occurred in the northeastern parts of North America, has formed self reproducing populations in other parts of North America, South America, Asia, Afrika, New Zealand, and in many other European countries (McGrimmon and Campbell 1969, Karas 1997). The general impression of the brook trout in all these areas appears to be that it is rather weak in competition with other salmonid fishes such as brown trout and rainbow trout in areas where these species thrive (Qvenild 1986). There are many examples in North America where brown trout (imported from Europe) and rainbow trout have replaced the brook trout, especially in the lower parts of the watercourses. Here, competition with other fish species, high temperature and strong fishing pressure act as negative factors to the brook trout (Karas 1997). In the upper parts of a catchment and also in acidic localities, however, it seems that the brook trout exists together with and partly replaces these species. It is also known that the brook trout has ousted the "cut-throat" trout in the western parts of North America (Griffith 1988, Karas 1997). It is now generally prohibited to stock fish-species in watercourses were they are not or have never been present. This ban includes brook trout as well as many other "original" Norwegian species.

The experiments carried out in the Langtjern area and in many other parts of Norway show that the brook trout is a salmonid species that has a rather narrow ecological niche in our country. This experience is in accordance with findings in other countries. If the goal is to use watercourses, lakes and ponds for producing fish, and despite risks to biological diversity, or spreading of diseases, brook trout shows many advantages over brown trout and other salmonid species. This is especially true in dystrophic lakes and ponds, as well as in creeks and small rivers. Qvenild (1986) has given guidelines for stocking and fishing efforts for brook trout. However, its short life span and early maturation are negative as to a normal exploitation strategy. The brar is also a fish that could be used in the same way. The positive development in the later years of the effects of acid rain in the form of improved water quality (Skjelkvaale et al. 2000) could reduce the suitability of brook trout, but there will still be many localities where the brook trout could be useful for improving fishing conditions.

Today, there are many naturalised strains of brook trout in southern Norway, and there should be many suitable watercourses where this fish species could be stocked. Using local strains as source for stocking there present no significant risk of negative effects. However, since brook trout is defined as a "foreign" species by the authorities, it is unlikely that further stocking of brook trout will be allowed according to present legislation.

The brar has also showed promise as a suitable fish with good growth and high tolerance to acidic water. This breed between brook trout and Arctic char will most probably not reproduce and form a

living population in competition with local fish species. This species has, however, consistently been used in acidic lakes in the Grenland area in Telemark county with good results. This fish, however, has never been defined as local, and will thus not be allowed for stocking according to present legislation.

The stocking experiments with brown trout have shown that this species may have a longer life span and grow larger that brook trout. These properties make brown trout more attractive both for food production and for sport fishing than the brook trout. There is, however, a question if the stocking material of brook trout, which mostly is of domestic origin, is comparable to the brown trout, which is offspring of wild strains. It is known from North America that wild strains may live longer and maturate at a higher age (Power, 1980, Karas 1997, Vincent 1960 and Scott and Crossman 1973). Also the naturalised Øyfjell strain has a longer life span than those observed in the Langtjern area. The crucial questions will be the water quality and the natural properties of the stocking locality.

The stocking experiments with brown trout in Langtjern have shown varying results during the period from 1970 to 2000. The reasons for these variations include water quality, competition with brook trout and predation by larger fish shortly after stocking. The general improvement in water quality during the last 10 years has, however, allowed increased recapture and return of the stocked fish.

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