

UTILIZATION OF
FLUVIAL AND LACUSTRINE HABITAT BY A WILD STOCK
OF ANADROMOUS ATLANTIC SALMON (SALMO SALAR L.)
IN AN ICELANDIC WATERSHED

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I herby declare that this thesis has
been composed entirely by me and that
all the work herein was carried out
by me alone, except where otherwise
acknowledged.

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ABSTRACT

A study was made of the utilization of a wild stock of anadromous Atlantic salmon, Salmo salar L. of a fluvial and lacustrine habitat within an Icelandic watershed.

Within the fluvial habitat, differences were found in density, standing crop and growth rate of young salmon. The highest density, standing crop and growth rate was found below a lake outlet and this was attributed mainly to high densities of Simuliidae larvae found below the outlet and partly to higher water temperature.

In lacustrine habitat young salmon had a widespread distribution on rocky substrate in shallow, littoral areas and their growth rate was equal to or better than found in fluvial habitat. Salmon spent most of their lifecycle in lacustrine environment and were found as early as at the fry stage in the lake studied.

A study of smolts migrating from the lake revealed that the smolt run was highly influenced by water temperature and the run commenced when water temperature reached 9 °C. Variation in smolt size was found between years, but no annual difference in mean age. Production of smolts migrating from the lake varied from 0.005 to 0.035 g X m⁻² X yr⁻¹.

A study of adult salmon in the area revealed that the lake outlet was extensively used as spawning grounds of salmon that move into the lake during summer.

It is hypothesized that the use of lacustrine habitat depends on its availability and physical characteristics of watersheds.

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TABLE OF CONTENTS

CHAPTER 1.	INTRODUCTION	
1.1	AIMS AND BACKGROUND OF THE STUDY	1
CHAPTER 2.	STUDY AREA	
2.1	LOCALITY	3
2.2	RIVER TYPES	3
2.3	GEOLOGY AND VEGETATION	5
2.4	CLIMATE	5
2.5	HABITAT	6
2.6	WATER TEMPERATURE	12
2.7	SPECIES OF FISH	13
2.8	FISHERY	14
CHAPTER 3.	DENSITY, STANDING CROP AND GROWTH OF YOUNG SALMON IN THE STUDY RIVERS IN RELATION TO ENVIRONMENTAL FACTORS	
3.1	INTRODUCTION	18
3.2	METHODS	19
3.2.1	Sample sites	19
3.2.2	Bottom fauna	26
3.2.3	Capture and examination of fish	28
3.2.4	Population estimates	30
3.2.5	Growth in length	31
3.2.6	Standing crop	32
3.3	RESULTS	32
3.3.1	Bottom fauna	32
3.3.2	Catch by species	36
3.3.3	Length and age distribution of salmon	39
3.3.4	Density and standing crop of young salmon	45
3.3.5	Growth in length.....	49

3.4	DISCUSSION	55
3.4.1	Bottom fauna	55
3.4.2	Population estimates	57
3.4.3	Density and standing crop of juvenile salmon	59
3.4.4	Growth of juvenile salmon	61
3.5	SUMMARY	63
CHAPTER 4.	LAKE USE BY A WILD STOCK OF ANADROMOUS ATLANTIC SALMON	
4.1	INTRODUCTION	72
4.2	METHODS	75
4.2.1	Sample sites	75
4.2.2	Capture methods	75
4.2.3	Calculation of relative density	82
4.2.4	Calculation of growth	84
4.3	RESULTS	84
4.3.1	Distribution of juvenile salmon	84
4.3.2	Catch by species	88
4.3.3	Length and age distribution of salmon	88
4.3.4	Relative density	89
4.3.5	Growth in length	93
4.4	DISCUSSION	94
4.4.1	Lake use by wild stocks of juvenile salmon	94
4.4.2	Distribution of juvenile salmon within L. Medalfellsvatn	95
4.4.3	Movement of juvenile salmon to lake environment	96
4.5	SUMMARY	101
CHAPTER 5.	THE SMOLT MIGRATION FROM LAKE MEDALFELLSVATN	
5.1	INTRODUCTION	102

5.2	METHODS	103
5.2.1	Sampling gear and sampling sites	103
5.2.2	Sampling procedures	106
5.2.3	Statistical analysis	109
5.3	RESULTS	110
5.3.1	Magnitude of the smolt migration	110
5.3.2	The timing of the smolt migration	110
5.3.3	Size composition	118
5.3.4	Age composition	123
5.3.5	Sex composition	123
5.3.6	Smolt condition, weight and standing crop	123
5.3.7	Lake production of smolts	129
5.3.8	Back-calculated growth	129
5.4	DISCUSSION	133
5.4.1	The timing and magnitude of the smolt migration	133
5.4.2	Length distribution	139
5.4.3	Age composition	140
5.4.4	Sex composition	141
5.4.5	Lake production	142
5.5	SUMMARY	144

CHAPTER 6. MOVEMENTS OF SPAWNERS BETWEEN LAKE AND RIVERS

6.1	INTRODUCTION	146
6.2	METHODS	147
6.2.1	Sample sites	147
6.2.2	Capture methods	149
6.2.3	Tagging of salmon	151
6.2.4	Location of spawning grounds ..	152
6.3	RESULTS	152
6.3.1	Capture and tagging of salmon	152

6.3.2	Age frequency and sex of salmon	155
6.3.3	Population size of spawners in the outlet	158
6.3.4	Movements of adults	158
6.3.5	Spawning survey	161
6.4	DISCUSSION	163
6.4.1	Population estimate	163
6.4.2	Movement of spawners and spawning areas	164
6.5	SUMMARY	167
	REFERENCES	170

CHAPTER 1

INTRODUCTION

1.1. AIMS AND BACKGROUND OF THE STUDY

In Iceland five species of freshwater fish are native to the country, Atlantic salmon Salmo salar L., brown trout Salmo trutta L., arctic charr Salvelinus alpinus L., European eel Anguilla anguilla L. and the three-spined stickleback Gasterosteus aculeatus L. Arctic charr and brown trout occur in two varieties. Some are resident in freshwater and others migrate to sea to feed (Gudjónsson 1978).

Of the three salmonid species present in Iceland, Atlantic salmon has the greatest economic value. Owing to its commercial and recreative value information on the ecology of salmon populations is needed to provide a basis for developing and improving present fisheries.

In most Atlantic salmon populations the carrying capacity of a river for juvenile salmon is the most important factor in limiting population size (Symons 1979). Juvenile salmon are strongly territorial (Lindroth 1955, Kalleberg 1958, Keenleyside and Yamamoto 1962, Symons and Heland 1978) and the number of effective territories is finite. Therefore the potential freshwater production of Atlantic salmon is usually estimated by the amount of fluvial habitat available to salmon parr (Elson 1975). This assumption has not been tested in Icelandic watersheds where salmon parr have been found in lacustrine habitat (Kristjánsson 1973, Jónsson 1981). Atlantic salmon parr are commonly found in

the lacustrine habitat in Newfoundland Canada (Pepper 1976) and are known to contribute significantly to overall smolt production in some watersheds (Chadwick and Green 1985, Ryan 1986). Since lakes are an important component of many stream drainages in Iceland it is necessary to know the relative importance of Atlantic salmon production in fluvial and lacustrine habitat respectively.

The aims of the present study were to investigate the utilization of different habitats by juvenile salmon in an Icelandic watershed especially the contribution of a lake to the overall production of juvenile Atlantic salmon.

Chapter 2 is an introduction to the study area and in chapter 3 I examine density, growth and standing crop in fluvial habitat within the river system.

Chapter 4 examines the use of a lake in the river system as a rearing habitat for juvenile salmon and gives information on the distribution, age structure and habitat preferences of juvenile salmon in the lake.

In chapter 5 I further explore the importance of the lake for the production of juvenile salmon and assess production of salmon smolts from the lake and document some of the biological characteristics of the smolt migration from the lake.

Finally in Chapter, 6 movements of adult salmon within the lake are investigated in an attempt to locate spawning grounds of salmon that dwell in the lake.

CHAPTER 2

STUDY AREA

2.1 LOCALITY

The study area is a part of the Laxá in Kjós river system in southwestern Iceland (Figure 2.1). The River Bugða originates in Lake Medalfellsvatn (60°20'N and 21°35'W) about 30 km NW of the capital Reykjavík. The lake is fed by two small direct run-off rivers, River Sandsá and River Flekkudalsá with drainage areas of 18 and 13 km² respectively. About 800 m below the outlet from L. Medalfellsvatn the R. Bugða is joined by a small tributary, the River Daelisá. The R. Bugða joins the main river Laxá about 1 km above its estuary in the Hvalfjörður Bay. The drainage area of L. Medalfellsvatn to the outlet is 37 km² and that of the R. Bugða at its confluence with the R. Laxá is 64 km². The catchment is characterized by mountains 500-800 m high.

2.2 RIVER TYPES

Rist (1956) classified Icelandic rivers as glacial, direct run-off and spring fed according to their origin. Glacial rivers are typically of brown color in the summer due to the turbidity of snowmelt. Spring fed rivers are characterized by constant flow and stable temperature throughout the year. Direct run-off rivers are formed by the confluence of smaller rivers. Because of the impervious bedrock the flow in these rivers depends on season and weather. The rivers are characterized by unstable flow and temperature which is controlled mainly by

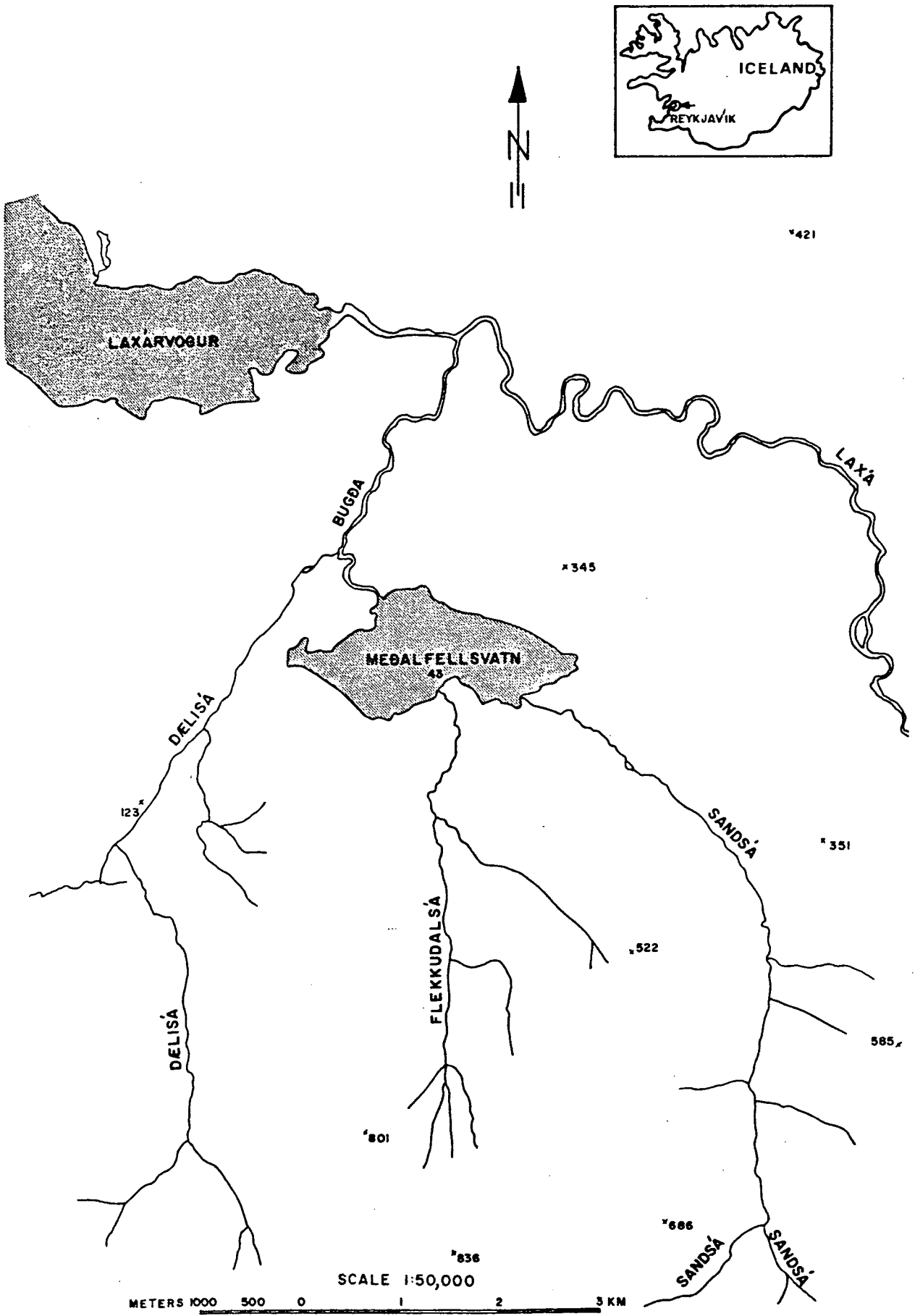


FIGURE 2.1: The Laxá in Kjós riversystem in Iceland

drainage area and air temperature (Rist 1956). A number of Icelandic rivers originate in lakes and tend to be more stable in discharge and temperature. The rivers Sandsá, Flekkudalsá and Daelisá have been classified as typical direct run-off rivers and the R. Bugda as a combination of lake-fed and a direct run off river (Rist 1956).

2.3 GEOLOGY AND VEGETATION

Geologically the area is characterized by a relatively tight basaltbedrock so surface water accumulates quickly when it rains and decreases quickly during dry weather.

Vegetation is sparse. No trees are found and the land consists mainly of cultivated grassland, meadows and bogs. Surrounding mountains are grazed by sheep during the summer.

2.4 CLIMATE

The climate of Iceland is cool, temperate and oceanic with rapid changes. The summers are cool and the winters are relatively warm. The average temperatures in Reykjavík over the period 1931-1960 is +11.2 °C in July and -0.4 °C in January. The annual average temperature is 5.0 °C (Eythórsson and Sigtryggsson 1971). The mean annual precipitation in the valley Kjós is about 2000 mm (Icelandic Meteorological Office, Annual Report). The months May and June are generally the driest and October has the highest precipitation.

2.5 HABITAT

L. Medalfellsvatn (Figure 2.1) has a surface area of 2.03 km² (200 ha), lies 43 m above sea level and is oligotrophic. Its maximum depth is 18.5 m, but generally the lake is shallow and more than half of its surface area lies within the 5 m depth line. The shallow area is limited to the western part of the lake towards the outlet into the R. Bugda. The mean depth of the lake is 4.5 m and the volume is 8.9 G1 (Stefánsson 1952). The lake's maximum length is 2.9 km and at its maximum is 1.4 km² wide. The difference between maximum and minimum water level is 30 cm with the highest water levels in the spring and the lowest levels in July and August (Stefánsson 1952). Transparency in the lake is between 2-6 m, the water temperature is closely related to air temperature and the lake is usually saturated with oxygen (Stefánsson 1952).

Results of stream drainage characteristics of the study rivers which were investigated by the method of Herrington and Dunham (1967) are presented in Table 2.1.

The two rivers feeding L. Medalfellsvatn, R. Sandsá and R. Flekkudalsá originate at 500-800 m above sea level (Figure 2.2) in the mountains on the northern side of Mt Esja. Both rivers are very short and steep with numerous waterfalls. R. Flekkudalsá is 5 km long with an average gradient of 7.5% while R. Sandsá is 8 km long with a gradient of 4%. In the survey only the bottom parts, i.e. areas open to migratory fish up to the first impassable waterfall, were investigated. Due to their steep gradient the rivers flow in shallow riffles most of the time and have only a small number of pools. The substrate is unstable due to great fluctuations in flow. Bottom topography is composed mainly of rubble and gravel.

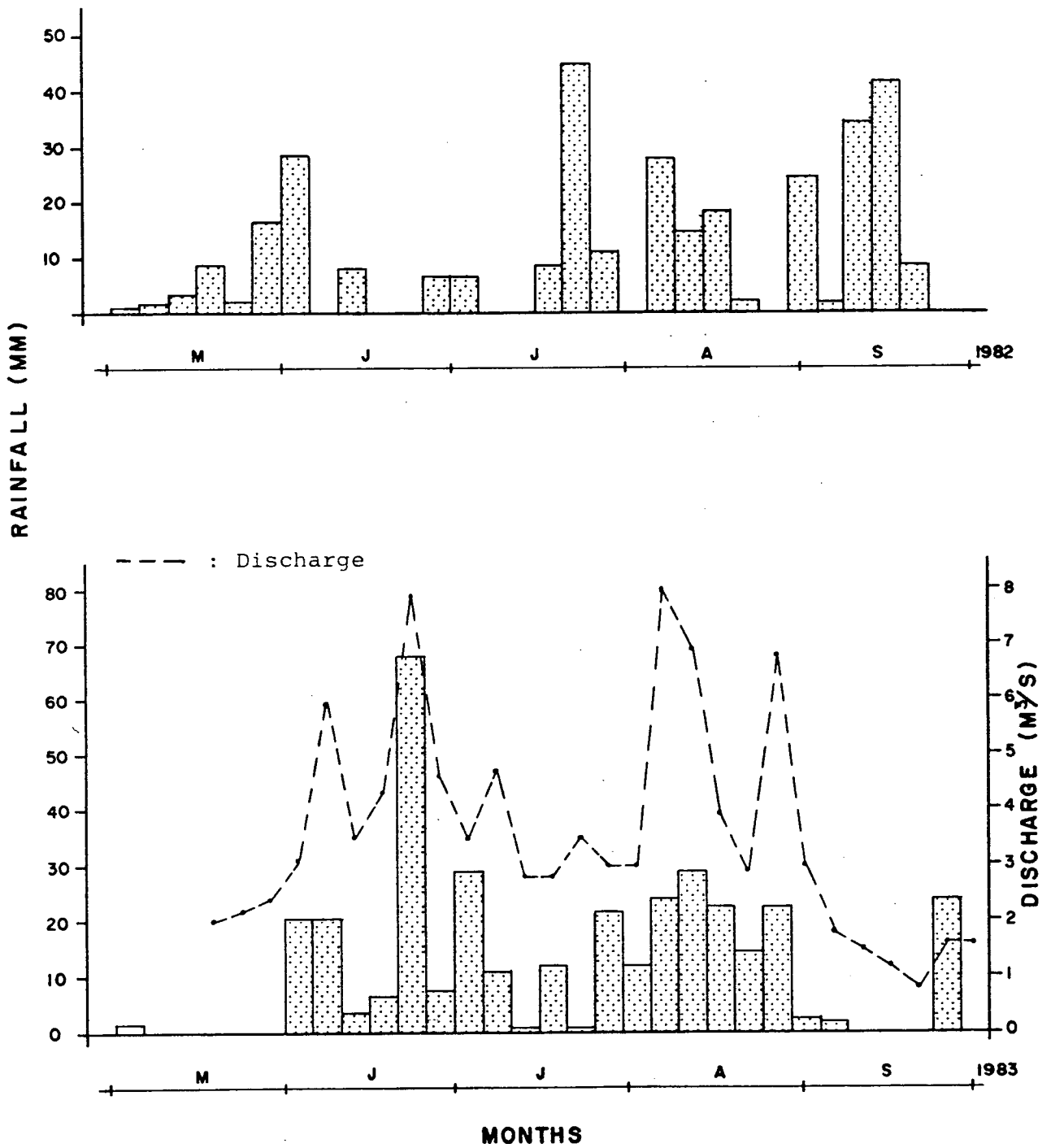


FIGURE 2.3: Precipitation mm at the Medalfell farm during May-October 1982 and 1983 and the discharge of river Buqda during May - October 1983

R. Sandsá has a higher proportion of gravel due to less gradient in the lower section. Bank cover is characterized by shingle or stones and grassbanks.

The R. Daelisá is similar in character to R. Flekkudalsá and R. Sandsá but is not as steep (Figure 2.2) and has a higher proportion of pools. The substrate is dominated by gravel and rubble and is unstable. The banks are composed of shingle or stones and grass and are more stable than in R. Flekkudalsá and R. Sandsá.

The R. Bugda is very different in character compared to the other rivers. The river length is 3.5 km and the gradient about 1 ‰. Due to its lake origin the river is more stable in discharge and temperature than the other rivers. Although the gradient is relatively steep it is even throughout the course of the river and no waterfalls are found. As a habitat, R. Bugda can be divided in two parts. The upper part from the outlet to the confluence with R. Daelisá has a higher proportion of stable substrate and stable banks than the lower part, which is more in character with direct run-off rivers. The bottom topography is mainly composed of boulders, rubble and gravel in the upper section but gravel dominates the lower reaches (Table 2.1).

Discharge of the study rivers was measured by Rist (1956) in 1952 and 1955. The mean discharge of the rivers Sandsá, Flekkudalsá and Bugda was estimated to be 1.5, 1.0 and 3.5 m³/s respectively. The discharge of R. Bugda was surveyed regularly during the summer of 1983 (Figure 2.3). May and September were the driest months with a mean discharge of around 1.5 m³/s. Discharge during May to August ranged from 3.4-5.2 m³/s. Precipitation in the study area during the summer of 1982 and 1983 ranged from 323.2 mm in 1982 to 355.4 in 1983 (Figure 2.3).

TABLE 2.1

Summary of stream drainage characteristics for Flekkudalsá, Sandsá, Bugda and Daelisá.(a)

	Flekkudalsá		Sandsá		Bugda(I)		Bugda(II)		Bugda(Comb.)		Daelisá	
	No.	% Area	No.	% Area	No.	% Area	No.	% Area	No.	% Area	No.	% Area
Transects	42		78		15		39		54		54	
Surveyed riv.												
length(km)	1.5		2.7		1.0		2.7		3.7		1.8	
Average												
width(m)	6.9		9.1		20.9		16.1		17.4		12.2	
Surface												
area(ha)		1.0		2.5		2.1		4.4		6.4		2.2
Riffle area	88.4	0.9	97.8	2.4	60.8	1.3	54.0	2.4	56.3	3.6	62.3	1.5
Pool area	11.6	0.1	2.2	0.1	39.2	0.8	46.0	2.0	43.7	2.8	37.7	0.7
Stable banks(%)	17.8		7.7		90.0		46.1		58.3		41.2	
<u>Proportion of pool area by pool class:</u>												
Class 1	0		0		0		0		0		13.0	
Class 2	37.5		0		0		10.8		7.9		0	
Class 3	12.5		0		0		39.2		27.6		0	
Class 4	0		60.0		14.5		24.3		21.1		0	
Class 5	50.0		40.0		85.5		25.7		43.4		87.7	
<u>Proportion of bottom area by material class:</u>												
Bedrock	5.8		0.4		18.7		0		6.3		0.2	
Boulder	20.3		1.9		9.6		2.5		4.6		5.0	
Rubble	53.3		44.8		18.7		8.1		11.4		36.6	
Gravel	20.6		51.9		49.8		85.7		73.7		52.2	
Sand/Silt	0		1.0		3.2		3.7		4.0		6.0	
Other	0		0		0		0		0		0	
<u>Bank cover types (%):</u>												
Rock	7.2		7.1		10.0		3.8		5.6		4.7	
Grass	33.2		9.0		70.0		53.9		58.3		47.0	
Stones	59.6		83.9		20.0		42.3		36.1		47.3	
Average Depth												
(cm)	29.4		21.9		26.3		36.9		34.0		25.2	
Average												
gradient(%)	3.3		2.0		1.0		1.0		1.0		1.7	

(a) after Herrington and Dunham (1967)

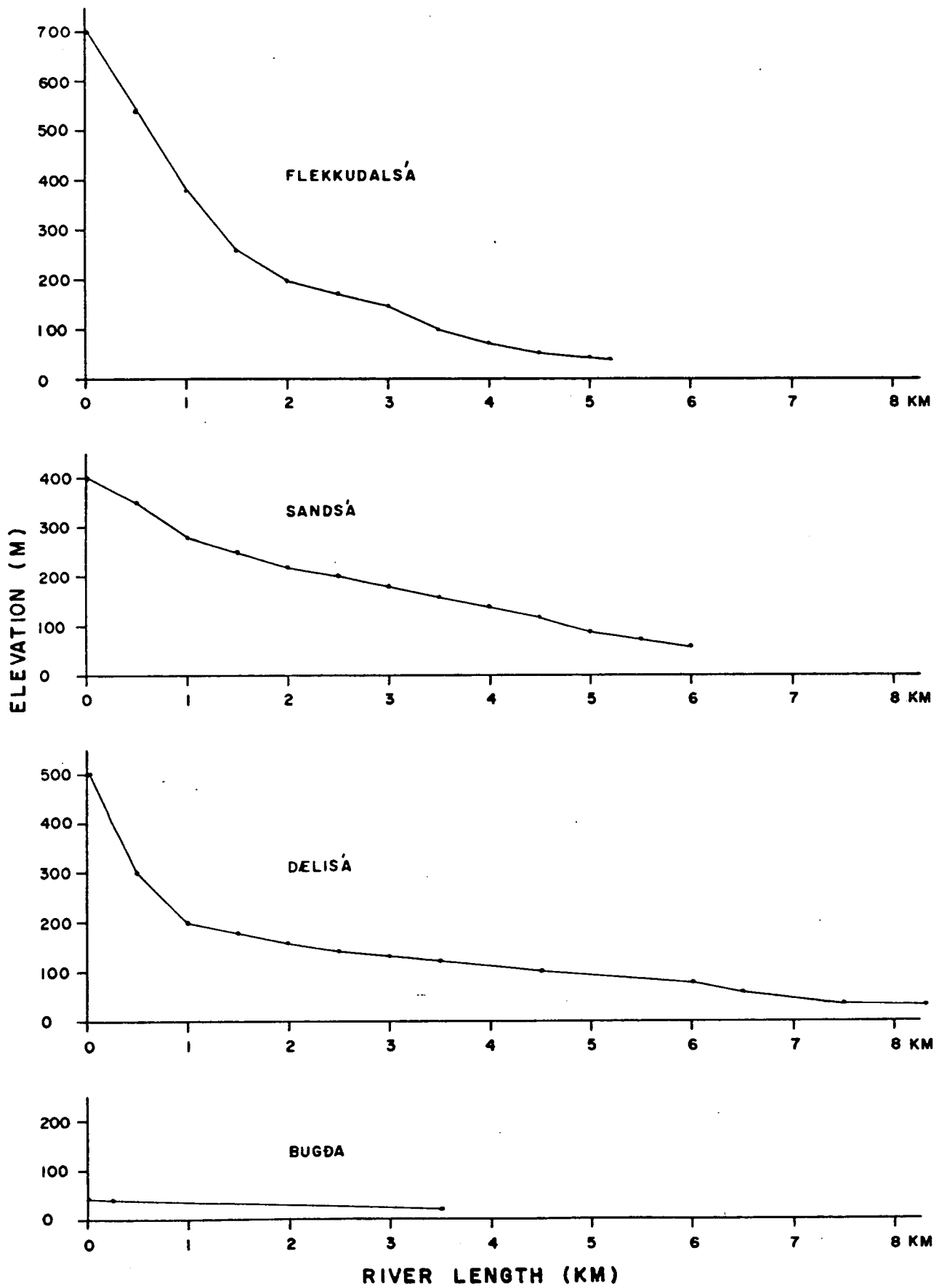


FIGURE 2.2: The gradient of the study rivers

TABLE 2.2

Analysis of water samples from Flekkudalsá, Sandsá, Bugda and Daelisá. Samples were taken on the 28th of August 1982

	<u>Flekku-</u> <u>dalsá</u>	<u>Sandsá</u>	<u>Bugda</u>	<u>Daelisá</u>
Total oxidized Nitrogen (mg/l)	< 0.1	0.1	< 0.1	0.2
Ph	6.9	7.1	7.2	7.4
Conductivity (µs/cm)	39.5	56.0	53.0	56.0
Suspended solids (mg/l)	2.0	3.0	1.0	3.0
Ammoniacal Nitrogen (mg/l)	< 0.1	< 0.1	< 0.1	< 0.1
Nitrite (mg/l)	< 0.01	< 0.01	< 0.1	< 0.01
Chloride (mg/l)	5.0	6.0		7.0
Boron (mg/l)	< 0.05	< 0.05		< 0.05
Total Alkalinity (mg/l)	15.0	20.0	20.0	25.0
Silica (mg/l)	7.4	8.9	6.5	9.2
Orthophosphate (mg/l)	< 0.01	< 0.01	< 0.01	< 0.01
Sulphate (mg/l)	7.0	7.0	7.0	5.0
Calcium (mg/l)	1.8	4.0	3.2	3.9
Magnesium (mg/l)	1.2	0.4	2.2	0.6
Potassium (mg/l)	0.3	0.4	0.5	0.3
Sodium (mg/l)	4.7	5.8	6.0	6.2
Iron (mg/l)	0.07	0.1	0.18	0.34

Water samples were taken in all of the study rivers for analysis of water chemistry. The samples were taken in polythene bottles and analyzed in Scotland by the Forth River Purification Board. The results are summarized in Table 2.2.

2.6 WATER TEMPERATURE

The mean weekly water temperatures for two of the study rivers R. Bugda and R. Daelisá during the summer of 1982 and 1983 is presented in figure 2.4. Temperatures in R. Bugda were taken 100 m below the outlet and in R. Daelisá about 200 m above the confluence with R. Bugda. Temperatures were registered hourly with a continuous temperature recorder.

The R. Daelisá is on average 2-5 °C colder than R. Bugda through the summer. This difference reflects the different origin of the rivers. R. Daelisá, being a short and steep direct run-off river, fluctuates with air temperature, and snowmelt keeps it cold through the early part of the summer. The temperature of R. Bugda is more stable and higher due to its lake origin. The lake warms up earlier and is probably more influenced by solar radiation than the direct run off rivers. The temperature measurements also show great differences between years. The year 1983 was one of the coldest this century with average temperatures 1.5 °C below normal and in southwestern Iceland the summer was the coldest since 1886 (Vedrátan 1983). Temperatures for the other study rivers were not recorded continuously, but spot measurements of temperatures were taken throughout the summer of 1982 with 4-5 day intervals by the farmers fisheries association in Laxá in Kjós

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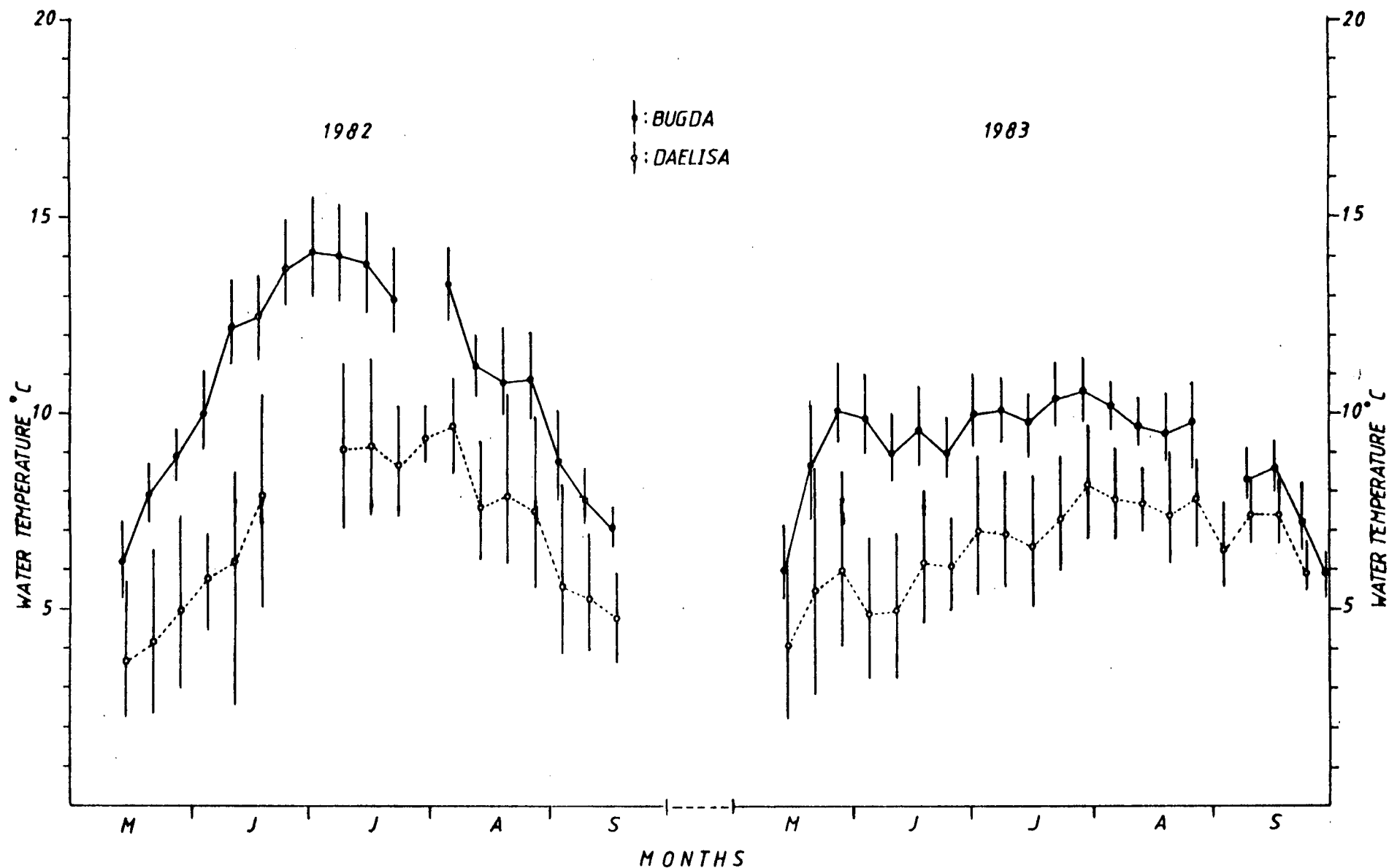


FIGURE 2.4: Mean weekly water temperature ($^{\circ}\text{C}$) of R. Bugda and R. Daelisá from May to October 1982-1983. Vertical lines indicate mean maximum and minimum weekly water temperature.

(Appendix 2.1). The temperatures of R. Sandsá and R. Flekkudalsá show that these two rivers are very similar to R. Daelisá but R. Flekkudalsá is the coldest being usually 1-2 °C lower than the other two. The temperature of R. Bugda follows very closely the surface temperature of L. Medalfellsvatn. Temperatures in the lower part of R. Bugda are on the average 1 °C lower than in the upper half presumably due to the cooling effect of R. Daelisá.

2.7 SPECIES OF FISH

All the species of freshwater fish native to Iceland, Atlantic salmon Salmo salar L., brown trout Salmo trutta L., arctic charr Salvelinus alpinus L., European eel Anguilla anguilla L. and the three-spined stickleback Gasterosteus aculeatus L. are found in the study area.

L. Medalfellsvatn is dominated by resident arctic charr and brown trout (Gudjónsson 1954). The lake according to Kristjánsson (1973) is overpopulated by arctic charr. Adult salmon are also found in the lake. Kristjánsson (1973) found that the lake was used as a habitat by salmon parr. Eels and sticklebacks also inhabit the lake.

The fish population of the R. Bugda is dominated by salmon, but sea trout, arctic charr and sticklebacks also occur, but their relative density is low compared to salmon. In R. Sandsá, R. Flekkudalsá and R. Daelisá fish densities are low but salmon dominates, except in R. Flekkudalsá where Arctic charr is the dominant species.

2.8 FISHERY.

As in other Icelandic rivers the fishing right belongs to the land owners who in most cases are farmers living locally. A farmers fisheries association in Laxá in Kjós was founded in 1949. Salmon is of the greatest economic value. Fishing is only allowed by rod and the fishing season opens on the 10th of June and extends to the 10th of September. The whole river system is leased to one fishing club with the exception of L. Medalfellsvatn which is managed by the farmers themselves.

The main river Laxá along with the R. Bugda is one of the best salmon rivers in Iceland. The average annual catch of salmon for the period 1970-1983 was 1528 in R. Laxá and 270 in R. Bugda (Figure 2.5). The salmon stock in R. Bugda is on average composed of 81 % grilse but the R. Laxá has a higher proportion of salmon (Scarnecchia 1983).

Salmon ascend into L. Medalfellsvatn and there is considerable fishing for salmon, trout and charr both by rod and commercial gill netting. The average annual catch of salmon for the period 1970-1983 (Figure 2.5) was 81 salmon. These are minimal values since fishing records for the lake are incomplete. The catch of other species is also badly recorded. Guðjónsson (1954) found that the yield of trout and charr in the lake were 2.9 kg/ha in 1953 and 3.0 kg/ha in 1952 when the lake was only fished by rod. Kristjánsson(1973) estimated that the yield of trout and charr for the period 1965-1971 was 3.4-5.13 kg/ha/year.

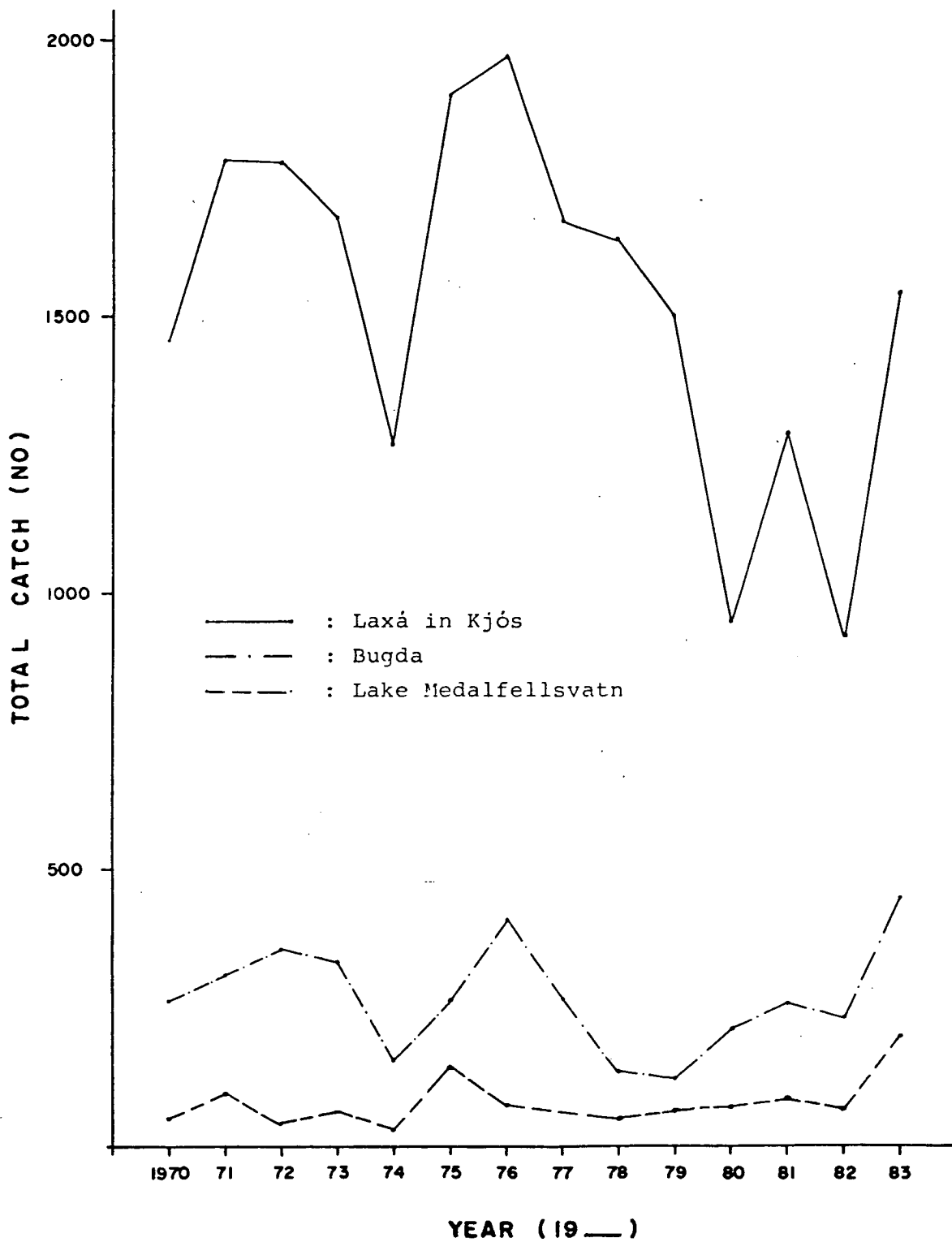


FIGURE 2.5: Total rod catch of Atlantic salmon for Laxá in Kjós, Bugda and Lake Medalfellsvatn for the years 1970-1983

No fishing occurs in R. Sandsá, R. Flekkudalsá and R. Daelisá. R. Sandsá is believed to be the main spawning river for the lake trout (Gudjónsson 1954). Kristjánsson (Pers. com.) found ca. 200 adult trout and one salmon during seine netting in R. Sandsá in September 1972.

APPENDIX 2.1

Spot temperature measurements in R.Flekkudalsá, R.Sandsá, L.Medalfellsvatn, R.Bugða and R.Daelisá during the summer of 1982. The measurements were taken by the farmers fisheries association in Laxá in Kjós and are daily means (°C) of two measurements at 9⁰⁰ and 18⁰⁰ hrs.

<u>Date</u>	<u>Flekku- dalsá</u>	<u>Sandsá</u>	<u>Medal- fellsv.</u>	<u>Bugða (I)</u>	<u>Bugða (II)</u>	<u>Daelisá</u>
13/6	5.0	6.3	12.3	11.0	9.3	6.5
20/6	7.5	9.0	13.7	12.8	11.3	9.3
24/6	7.8	9.5	14.0	13.8	12.0	9.3
28/6	8.8	10.3	14.3	14.0	12.5	10.3
4/7	9.3	11.0	14.3	14.3	13.3	11.8
8/7	10.5	11.0	13.3	13.3	11.8	10.5
12/7	10.5	11.5	14.3	14.3	12.5	11.3
15/7	10.3	12.3	16.5	15.5	13.5	11.8
18/7	8.3	9.5	12.8	12.3	11.5	9.3
25/7	9.5	9.8	13.0	12.8	11.8	9.3
29/7	9.3	11.5	14.0	12.3	11.5	9.5
1/8	11.8	12.5	14.5	14.0	13.8	12.5
5/8	10.0	10.8	14.0	13.8	12.8	11.5
9/8	8.8	9.5	11.0	11.0	10.0	8.5
13/8	8.8	9.5	10.5	10.8	10.0	8.3
17/8	9.3	8.5	11.5	11.0	10.0	8.5

CHAPTER 3

DENSITY, STANDING CROP AND GROWTH OF YOUNG SALMON IN THE STUDY RIVERS IN RELATION TO ENVIRONMENTAL FACTORS

3.1. INTRODUCTION

The aims of this chapter were to obtain information on density, standing crop and growth of young salmon in fluvial habitat within the Laxá in Kjós river system in relation to several environmental factors.

Production of salmon includes both a numerical component which is determined by reproduction, immigration, mortality and emigration and a weight component determined by growth (Allen 1969). Any environmental factors that affect density and growth of salmon therefore can potentially limit production.

Atlantic salmon are strongly territorial (Lindroth 1955, Kalleberg 1958, Keenleyside and Yamamoto 1962, Symons and Heland 1978) and this is generally considered to provide a mechanism for limiting population size since it determines through the size of the territory the maximum numerical density of fish that a streambed can support (Allen 1969, LeCren 1973, Symons 1979).

The other component of production i.e. growth is affected by many factors but is basically dependent on the amount of food consumed and the efficiency with which the food is converted into fish flesh (Allen 1969, Brett et. al. 1969, Elliot 1975). The

invertebrate fauna is the most usual source of food for young salmonids in streams but is sometimes supplemented by terrestrial animals falling into the stream (Thomas 1962, Egglshaw 1967, Waters 1969, Wankowski and Thorpe 1979). The bottom fauna animals may be taken either directly of the stream bed or as they drift downstream.

Several physical characteristics are also important in regulating juvenile salmonid population such as water depth and flow, cover and substrate type (Mills 1971).

Climatic factors, particularly water temperature may also exert direct influence on growth rate and production. Power (1969) maintains that the limit for successful survival of Atlantic salmon appears to be reached when the period with a mean temperature of 6 °C or higher falls below 100 days. At temperatures below 7 °C young salmon move from riffles to pools and reduce or cease feeding (Allen 1940, Saunders and Henderson 1969). Above 7 °C the growth rate of Atlantic salmon fry increases reaching a maximum at 16.6 °C (Siginevich 1967).

3.2. METHODS

3.2.1. Sample sites

A detailed description of the study rivers, R. Flekkudalsá, R. Sandsá, R. Bugda and R. Daelisá is given in chapter 2.

The location of the sample sites is shown in Figure 3.1. One station was sampled in each of the inlets of L. Medalfellsvatn, R. Flekkudalsá and R. Sandsá

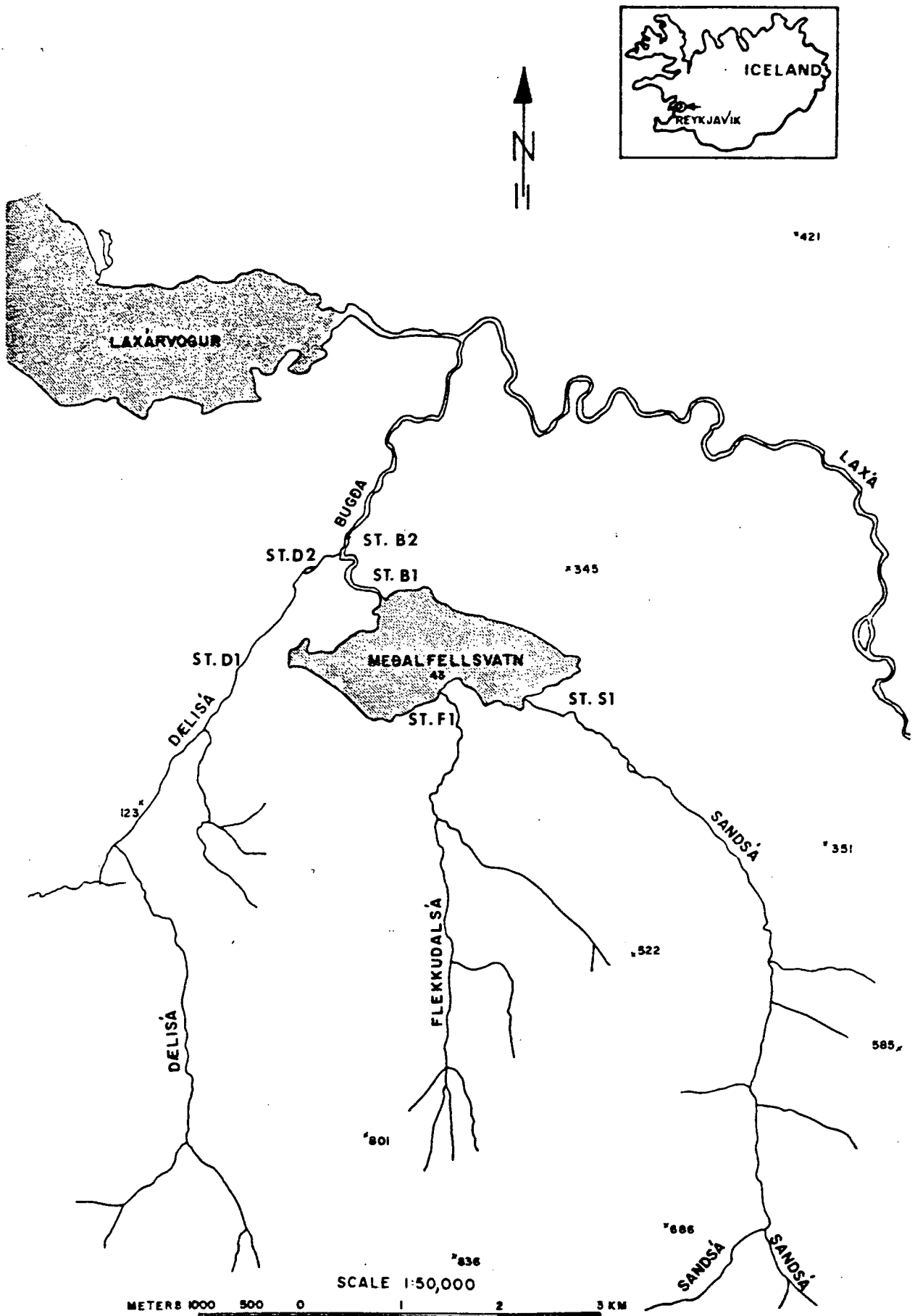


FIGURE 3.1: Location of the sample sites in the study rivers.



PLATE 3.1: The lower reaches of R. Sandsá (Station S1)
(Photo by Dr Derek H Mills, August 1982)



PLATE 3.2: The lower reaches of R. Flekkudalsá
(Photo by Dr Derek H Mills, August 1982).



PLATE 3.3: Electrofishing in R. Daelisá (Station D1
(Photo by Dr Derek H Mills, August 1982).



PLATE 3.4: R. Bugda below the outlet of L. Medalfellsvatn
(Station B1) (Photo by Dr Derek H Mills, August
1982).

TABLE 3.1

Physical characteristics of the sample sites

<u>Characteristic</u>	<u>Sample sites</u>					
	<u>F1</u>	<u>S1</u>	<u>B1</u>	<u>B2</u>	<u>D1</u>	<u>D2</u>
Length (m)	33	20	26	26	32.5	32.6
Width (m)	6	10.3	16.5	20	14	10.4
Area (m ²)	198	206	429	520	455	339
Average depth (cm)	15	16	31	31	22	18
<u>Bottom material (%)</u>						
Bedrock	0	0	0	0	0	0
Boulder	0	0	26.9	16.7	10.0	3.8
Rubble	100	20	45.7	42.7	78.7	42.3
Gravel	0	80	27.4	40.6	9.4	53.9
Sand/silt	0	0	0	0	1.9	0
Riffle area (%)	100	100	76	51.2	98.1	100
Pool area	0	0	24	48.8	1.9	0
<u>Bank cover types (%)</u>						
Rock	0	0	0	0	0	0
Grass	0	0	50	50	50	0
Stones	100	100	50	50	50	100

(Plate 3.1 and Plate 3.2) and two stations were sampled in the outlet river R. Bugda (Plate 3.4) and R. Daelisá (Plate 3.3) the tributary of R. Bugda. The physical characteristics of each sample site are presented in Table 3.1.

3.2.2. Bottom fauna

Samples of benthic invertebrates were taken twice during the study period on each sample site respectively (Table 3.2).

Quantitative samples of benthic invertebrates were obtained using the stone scrubbing method (Albrecht 1961) which has been shown to be well suited to sample invertebrates that cling to the surface such as blackflies (Albrecht 1961, Carlsson, Nilsson, Svensson, Ulfstrand and Wooton 1977, Gíslason 1985). Six stones were removed at random from the river bottom. By holding a net downstream, all dislodged larvae were collected (Carlsson et.al 1977). Each stone was treated separately giving 6 replicate counts. The stones were then scrubbed with a soft brush and searched for remaining animals. The water was then sieved through a laboratory test sieve (pore size 63 μm) and the contents of the sieve preserved in 70% alcohol. Each stone was arranged on a graph paper and its outline drawn with a pencil. The area was calculated and used to estimate the number of larvae per 1 m^2 .

In the laboratory the stone surface samples were washed on a test sieve (pore size 63 μm) to remove the preservative. The invertebrate fauna was identified to species, genus, families or higher classification entities using the keys of Macan (1958).

TABLE 3.2

Sampling dates in each station in R. Flekkudalsá,
R. Sandsá, R. Bugða and R. Daelisá in 1982.

(E=Electrofishing, B=Bottom fauna)

<u>Date</u>	<u>Station</u>					
	<u>F1</u>	<u>S1</u>	<u>B1</u>	<u>B2</u>	<u>D1</u>	<u>D2</u>
19.06			E,B			
20.06				E,B		
03.07	E					
04.07		E				
06.07						E
07.07					E	
15.07	B	B			B	B
19.08					E	
20.08						E
25.08	E	E				
26.08			E	E		
04.09	B	B	B	B	B	B
19.10					E	
20.10			E	E		
21.10	E					

3.2.3. Capture and examination of fish

All sampling of fish in the study rivers was carried out by electrofishing. The type of electrofishing gear used is described in detail in chapter 4.

Electrofishing is one of the least selective of all methods of fishing and is best adapted for use in streams (Libosvářsky and Lelek 1965). It involves creating an electric field in the water by passing a current between two submerged electrodes. The fishing gear used in this study creates a direct current (d.c) which induces "galvanotaxis". The reaction of the fish is to swim actively towards the positive electrode and remain there. Usually the fish do not lose consciousness at any time and show no sign of distress (Mills 1971).

The boundaries of each fishing area was marked by iron poles to ensure that exactly the same area was fished throughout the study period. Table 3.2. gives details on dates when sampling was carried out during the study.

On each sample date every site was fished 2-5 times. Catches from each fishing period were kept separate in holding boxes while the fishing was carried out. After examination of the fish they were returned to the fishing area and distributed evenly to the particular stretch of river fished.

Due to the relatively large size of the study rivers and their turbulent nature it was not possible to isolate each fishing area with stop nets. Theoretically fish therefore could migrate into and out of each site while fishing was carried out.

All fish caught in each station were anaesthetized with MS-222 to make handling easier. All fish were identified to species and their length measured in cm from the tip of the nose to the fork of the tail. Wet weights of fish to the nearest 0.1 g were taken of live fish in the field of part of the catch with Pesula spring balances.

Samples of fish for analysis of age were taken outside each fishing area and for each fish its species, length (cm) and weight (g) was recorded. Samples for analysis of age were taken by two methods, by scale samples and otolith samples. Scale samples were removed from the area just above the lateral line behind the dorsal fin by plucking 10-15 scales with forceps. This is the region where scales first develop on young salmonids (Power 1969) and should have the most circuli and give best indication of the first annulus.

The otoliths were removed by splitting the skull of the fish antero-posteriorly along the mid-cranial suture. Then the sagitta were removed and cleaned by peeling off any membranes.

Scales and otoliths were then placed in envelopes for later examination.

Scale ages were determined independently from otolith ages. In the laboratory impressions of scales were made by rolling selected scales on acetate strips. The scales were then aged at 55X magnification with a Microps microprojector. The criterion for an annulus was the first complete circulus surrounding and overcutting previous circuli. Annuli were located by examining the outer edge of each band of closely spaced circuli of winter growth. Several scales (5-6) were examined for each fish to ensure that no annuli were missed.

Otoliths were viewed against a black background and submersed in a 2:1 solution of benzyl benzoate and methyl salicylate (Johnson 1980). The dark hyaline bands were counted, the outer edge of these bands considered as an annuli.

3.2.4. Population estimates

There are a number of methods used for the estimation of fish populations (Youngs and Robson 1978, Cowx 1983). The most common method has been based on the mark-recapture method. An other method is to use quantitative depletion sampling or survey removal data.

The method used in this study is based on the survey removal method. The principle of this type of sampling is that for a closed population the catch per unit effort is proportional to the population number present at a time. A series of samples therefore show a decline in catch per unit effort.

Two methods based on the survey removal data were used throughout the study period.

When two successive catches were done the two catch method (Seber and LeCren 1967) was used. The method is based on the maximum likelihood theory (Moran 1951). The population size is calculated as:

$$3.1. \quad N_0 = \frac{C_1^2}{C_1 - C_2}$$

where: N_0 = Original population size
 C_1 = Number of fish caught in catch 1
 C_2 = Number of fish caught in catch 2

Standard error (S_e) is estimated using:

$$3.2. \quad S_e = \frac{C_1 \times C_2}{(C_1 - C_2)^2} \sqrt{C_1 \times C_2}$$

When three or more successive catches were made the maximum weighted likelihood method (Carle and Strub 1978) was used. The population size is estimated using:

$$3.3. \quad \left(\frac{N_0 + 1}{N_0 - T + 1} \right) \left(\frac{k \times N_0 - M - T + 0.5k}{k \times N_0 - M + 1 + 0.5k} \right) \ll 1$$

where: N_0 = Original population size
 T = Total catch in all samples
 $M = C_i (k-1)$
 k = Number of samples

Values of k , M , T (known) and N_0 (unknown) are substituted into the equation until balanced.

Probability of capture (p) is estimated using:

$$3.4. \quad p = \frac{T}{k \times N_0 - M}$$

Standard error of the population size is calculated according to Zippin (1956,1958):

$$3.5. \quad S_e = \sqrt{\frac{N_0 (N_0 - T) T}{T^2 - N_0 (N_0 - T) [(kxp)/(1-p)]}}$$

3.2.5. Growth in length

The mean length of each ageclass was calculated with 95% confidence intervals (Elliot 1977) for each

station on each sample date. Differences in mean lengths were tested with students t-test (Elliot 1977).

3.2.6 Standing crop

Length weight regressions were calculated using the equation

$$3.6 \quad \text{Log } w = a + b (\text{Log } l)$$

where: w = weight (g)
 l = length (cm)

The results (Appendix 3.7) were used to estimate mean weights (g) of each age class of juvenile salmon for each sample site.

Standing crop (per 100 m²) was estimated using the equation

$$3.7 \quad SC = N_0 \times W$$

Where SC = Standing crop (g)
 N_0 = Population size per 100 m²
 W = Mean weight (g) of an ageclass.

3.3 RESULTS

3.3.1 Bottom fauna

Estimated density ($N \times m^{-2}$) and relative density (%) of bottom fauna animals is summarized in Table 3.3 and Table 3.4 for the summer and autumn samples respectively.

TABLE 3.3

Estimated density ($N \times m^{-2}$) and relative density (%) of bottom fauna in the study rivers
 19.-20.06 in stations B1 and B2 and 15.07 in stations F1, S1, D1 and D2 in 1982.
 Standard error of means is shown in parentheses (l=larvae, p=pupae)

Organism	F1		S1		B1		B2		D1		D2	
	R. Flekkudalsá		R. Sandsá		R. Bugda		R. Bugda		R. Daelisá		R. Daelisá	
	N	%	N	%	N	%	N	%	N	%	N	%
Chironomidae l.	3815 (457)	83.6	11228 (1726)	97.5	6029 (2200)	19.4	10112 (2205)	90.7	12481 (2465)	91.2	6995 (992)	94.2
Chironomidae p.	220 (42)	4.8	204 (56)	1.8	192 (109)	0.4	230 (130)	2.1	155 (52)	1.1	151 (31)	2.1
Simuliidae l.	98 (45)	2.2	25 (25)	0.1	40400 (15165)	71.1	266 (105)	2.4	954 (590)	7.0	112 (28)	1.6
Simuliidae p.	98 (45)	2.2	37 (27)	0.3	1326 (283)	3.8	72 (40)	0.6			17 (11)	0.3
Other Diptera l.			9 (9)	0.1								
Trichoptera l.											10 (10)	0.2
Plecoptera l.												
Oligochaeta	203 (74)	4.5			648 (286)	2.1	41 (16)	0.4	43 (25)	0.3	45 (16)	0.6
Hydracarina	50 (33)	1.1	18 (11)	0.2	904 (127)	3.2	421 (355)	3.8	55 (22)	0.4	62 (23)	0.8
Araneida											7 (7)	0.1
Unidentified remains	73 (53)	1.6			12 (12)	-					8 (8)	0.1
Total number	4557 (613)	100.0	11521 (1807)	100.0	49511 (17473)	100.0	11142 (2411)	100.0	13688 (2582)	100.0	7407 (998)	100.0

TABLE 3.4

Estimated density ($N \times m^{-2}$) and relative density (%) of bottom fauna in the study rivers 04.09.1982
 Standard error of means is shown in parentheses (l=larvae, p=pupae)

Organism	F1		S1		B1		B2		D1		D2	
	R. Flekkudalsá		R. Sandsá		R. Bugða		R. Bugða		R. Daelisá		R. Daelisá	
	N	%	N	%	N	%	N	%	N	%	N	%
Chironomidae l.	4270	93.8	14511	89.4	4562	6.9	1465	51.8	3380	73.9	7998	94.9
	(596)		(1225)		(915)		(220)		(847)		(990)	
Chironomidae p.	32	0.9	255	1.6	764	1.2	230	7.0	172	4.2	136	1.6
	(14)		(55)		(170)		(121)		(38)		(55)	
Simuliidae l.	69	1.9	1150	6.7	70195	89.5	1243	33.3	23	0.3	70	0.8
	(19)		(591)		(13427)		(503)		(15)		(47)	
Simuliidae p.					808	1.2	62	1.6				
					(181)		(30)					
Other Diptera l.												
Trichoptera l.			15	0.1								
			(15)									
Plecoptera l.			13	0.1							11	0.1
			(13)								(11)	
Oligochaeta	88	2.3	216	1.4	697	1.0	116	4.7	34	0.9	135	1.6
	(26)		(56)		(410)		(38)		(16)		(110)	
Hydracarina	55	1.1	116	0.6	116	0.2	36	1.6	1298	20.7		
	(12)		(52)		(61)		(15)		(480)			
Araneida												
Unidentified remains			13	0.1							85	1.0
			(13)								(45)	
Total number	4514	100.0	16289	100.0	77142	100.0	3152	100.0	4907	100.0	8435	100.0
	(584)		(1378)		(12870)		(753)		(1352)		(895)	

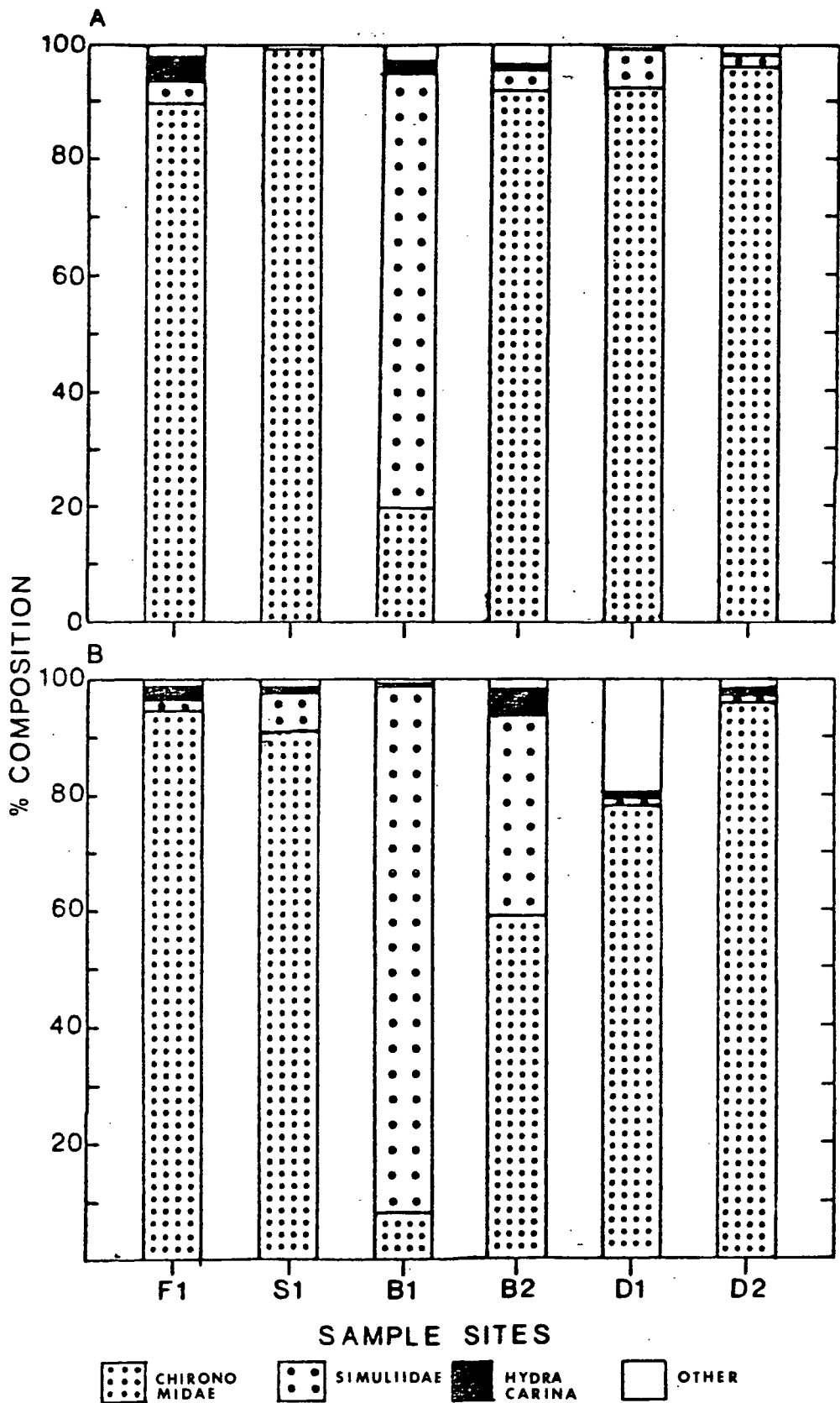


FIGURE 3.2: Composition of the bottom fauna on six sample sites in the Laxá in Kjós river system (A: Samples taken from 19.06-15.09.1982, B: Samples taken 4.09.1982).

On all sample sites, Diptera larvae and pupae dominated the bottom fauna and made up 78.4-99.8% of the total number of animals present both in summer and autumn (Table 3.3, Table 3.4). Other groups present were Trichoptera larvae, Plecoptera larvae, Oligochaeta, Hydracarina and Araneida.

Chironomidae larvae and pupae dominated the bottom fauna on all sample sites, except on St. B1 in R. Bugda where black fly larvae and pupae replaced Chironomidae as a dominating group (Figure 3.2).

Density of bottom fauna animals varied little between sample sites except on St. B1 where density of bottom fauna was 4-11 times higher in summer than on the other sample sites and 5-25 times higher in September. This large number of animals on St. B1 was entirely due to large quantities of blackfly larvae and pupae which ranged from 41726 per m² in June to 71003 per m² in September.

3.3.2 Catch by species

Juvenile salmon usually dominated the catches (Table 3.5). Other species that occurred were brown trout, arctic charr and sticklebacks.

In the inflowing streams of L.Medalfellsvatn, R. Flekkudalsá and R. Sandsá, arctic charr was the dominant species (Table 3.5) in R. Flekkudalsá, but salmon predominated in R. Sandsá. Brown trout also occurred in low numbers.

In R. Bugda salmon dominated on both sample sites and represented 93.8-98.3% of the total catch. Arctic charr, brown trout and stickleback occurred in low numbers (Table 3.5).

TABLE 3.5

Total number of fish of each species caught by sample
site and date

<u>Species</u>	<u>N</u> <u>%</u>	<u>N</u> <u>%</u>	<u>N</u> <u>%</u>
<u>St.B1</u>	<u>19.06</u>	<u>26.08</u>	<u>20.10</u>
Salmon	226 (98.3)	2528 (94.3)	1797 (98.3)
Arctic charr	0 (0.0)	0 (0.0)	0 (0.0)
Brown trout	1 (0.4)	150 (5.6)	31 (1.7)
Sticklebacks	<u>3 (1.3)</u>	<u>3 (0.1)</u>	<u>0 (0.0)</u>
	230 (100.0)	2681 (100.0)	1828 (100.0)
 <u>St.B2</u>	 <u>20.06</u>	 <u>26.08</u>	 <u>20.10</u>
Salmon	102 (97.0)	319 (93.8)	316 (97.5)
Arctic charr	1 (1.0)	7 (2.1)	2 (0.6)
Brown trout	2 (2.0)	14 (4.1)	6 (1.9)
Sticklebacks	<u>0 (0.0)</u>	<u>0 (0.0)</u>	<u>0 (0.0)</u>
	105 (100.0)	340 (100.0)	324 (100.0)
 <u>St.D1</u>	 <u>07.07</u>	 <u>19.08</u>	 <u>19.10</u>
Salmon	161 (100.0)	324 (100.0)	458 (98.8)
Arctic charr	0 (0.0)	0 (0.0)	2 (0.4)
Brown trout	0 (0.0)	0 (0.0)	4 (0.8)
Sticklebacks	<u>0 (0.0)</u>	<u>0 (0.0)</u>	<u>0 (0.0)</u>
	161 (100.0)	324 (100.0)	464 (100.0)
 <u>St.D2</u>	 <u>06.07</u>	 <u>20.08</u>	 <u>19.10</u>
Salmon	88 (100.0)	125 (91.9)	145 (94.2)
Arctic charr	0 (0.0)	0 (0.0)	2 (1.3)
Brown trout	0 (0.0)	11 (8.1)	7 (4.5)
Sticklebacks	<u>0 (0.0)</u>	<u>0 (0.0)</u>	<u>0 (0.0)</u>
	88 (100.0)	136 (100.0)	154 (100.0)

<u>Species</u>	<u>N</u> <u>%</u>	<u>N</u> <u>%</u>	<u>N</u> <u>%</u>
<u>St.F1</u>	<u>03.07</u>	<u>25.08</u>	<u>21.10</u>
Salmon	16 (17.8)	18 (23.7)	2 (7.4)
Arctic charr	71 (78.9)	46 (60.5)	20 (74.1)
Brown trout	3 (3.3)	12 (15.8)	5 (18.5)
Sticklebacks	0 (0.0)	0 (0.0)	0 (0.0)
	<u>90 (100.0)</u>	<u>76 (100.0)</u>	<u>27 (100.0)</u>
<u>St.S1</u>	<u>04.07</u>	<u>25.08</u>	
Salmon	67 (64.4)	33 (62.3)	
Arctic charr	34 (32.7)	14 (26.4)	
Brown trout	3 (2.9)	6 (11.3)	
Sticklebacks	0 (0.0)	0 (0.0)	
	<u>104 (100.0)</u>	<u>53 (100.0)</u>	

In R. Daelisá salmon was the dominate species and represented 91.9-100.0% of the total catch. Brown trout and arctic charr also occurred.

3.3.3 Length and age distribution of salmon

The total number of salmon caught according to 0.5 cm length classes is shown in Figures 3.3-3.7 for each sample site by date. Generally it was found that the length distribution was a valid method of separating age classes and there was little overlap in length between different age classes. Three age classes of salmon were found in R. Bugda on both sample sites (0+, 1+ and 2+).

On St. B1 fry were present in the catches on all sample dates. On 19 June fry had recently emerged but in August and October, fry represented the bulk of the catches (Figure 3.3). In October the size of fry ranged from 3.7-6.4 cm. Salmon parr were also numerous on St. B1. The parr were predominantly 1+ and at the end of October the size of 1+ parr ranged from 6.6-12.5 cm. Older parr (2+) were relatively scarce on all sample dates.

On St. B2 fry were not present in June, but were numerous both in August and October (Figure 3.4). At the end of October the size of fry ranged from 2.7-5.5 cm. Parr were numerous on all sample dates both 1+ and 2+, but 2+ parr were relatively more common than on St. B1. At the end of October the size of 1+ parr ranged from 5.6-8.9 cm but 2+ parr ranged from 8.6-14.0 cm.

In R. Daelisá three age classes of salmon were present (0+, 1+ and 2+).

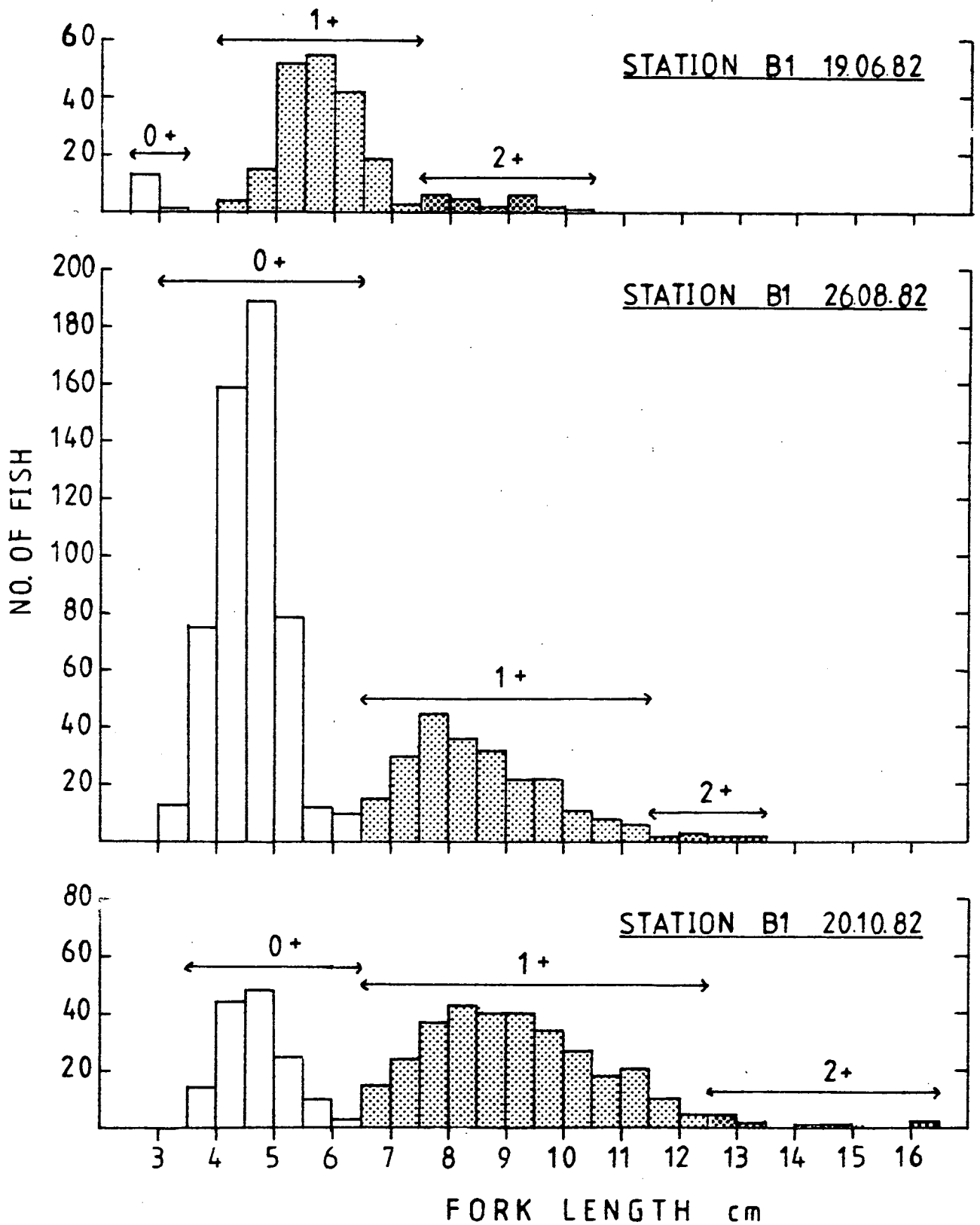


FIGURE 3.3: Length and age distribution of juvenile salmon in R. Bugda (St. B1) on three sample dates in 1982.

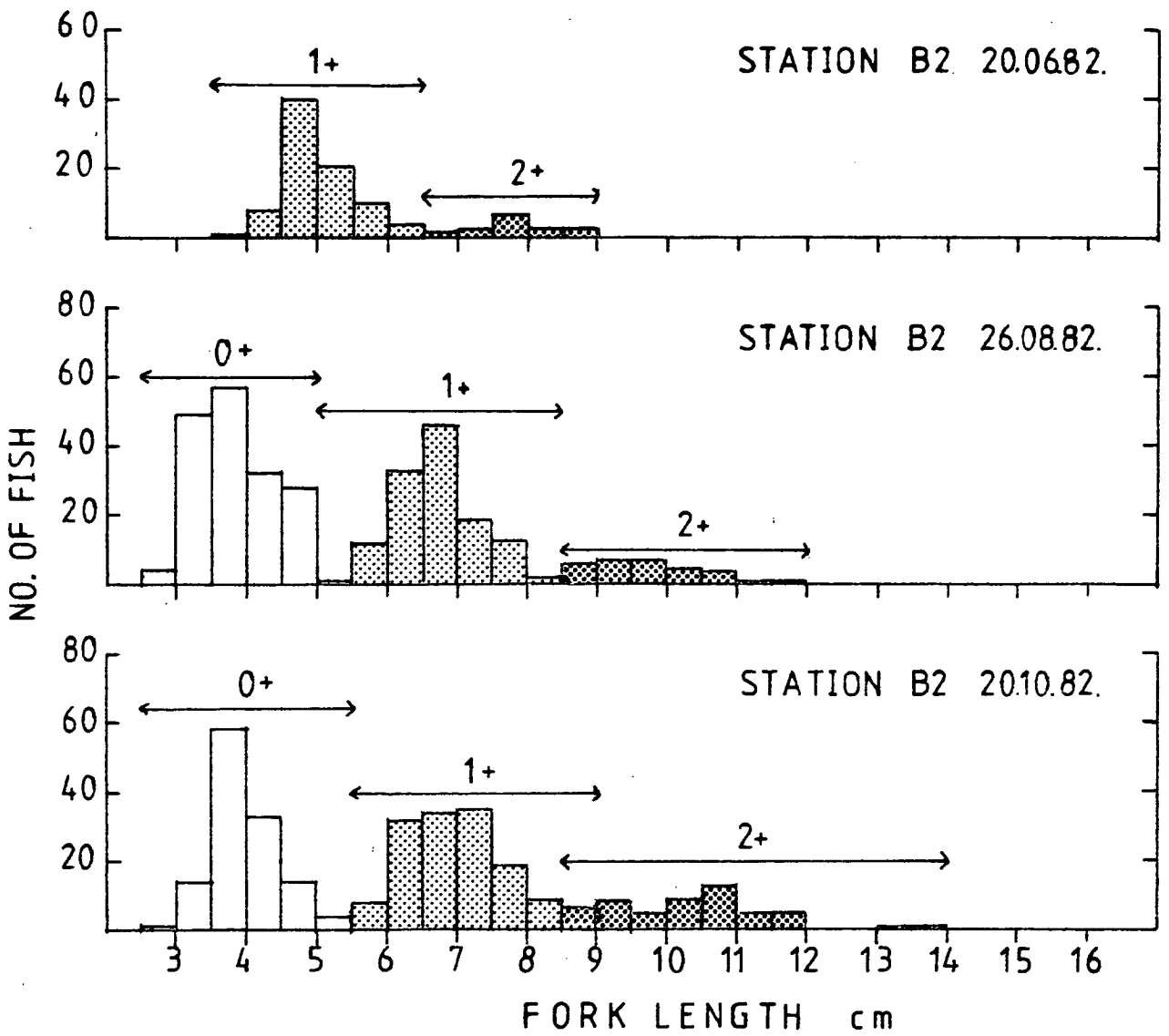


FIGURE 3.4: Length and age distribution of juvenile salmon in R. Bugda (St. B2) on three sample dates in 1982.

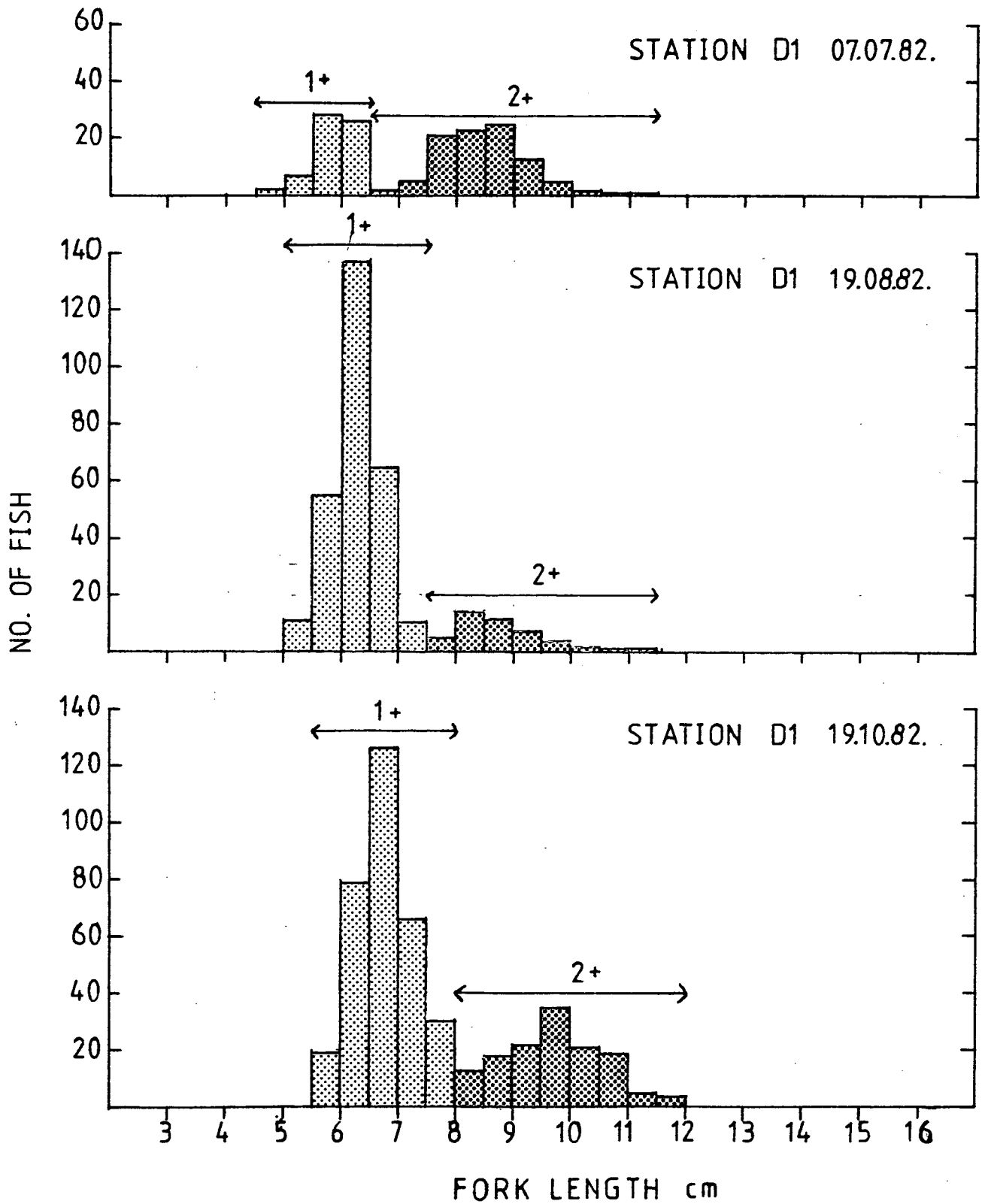


FIGURE 3.5: Length and age distribution of juvenile salmon in R. Daeliså (St. D1) on three sample dates 1982.

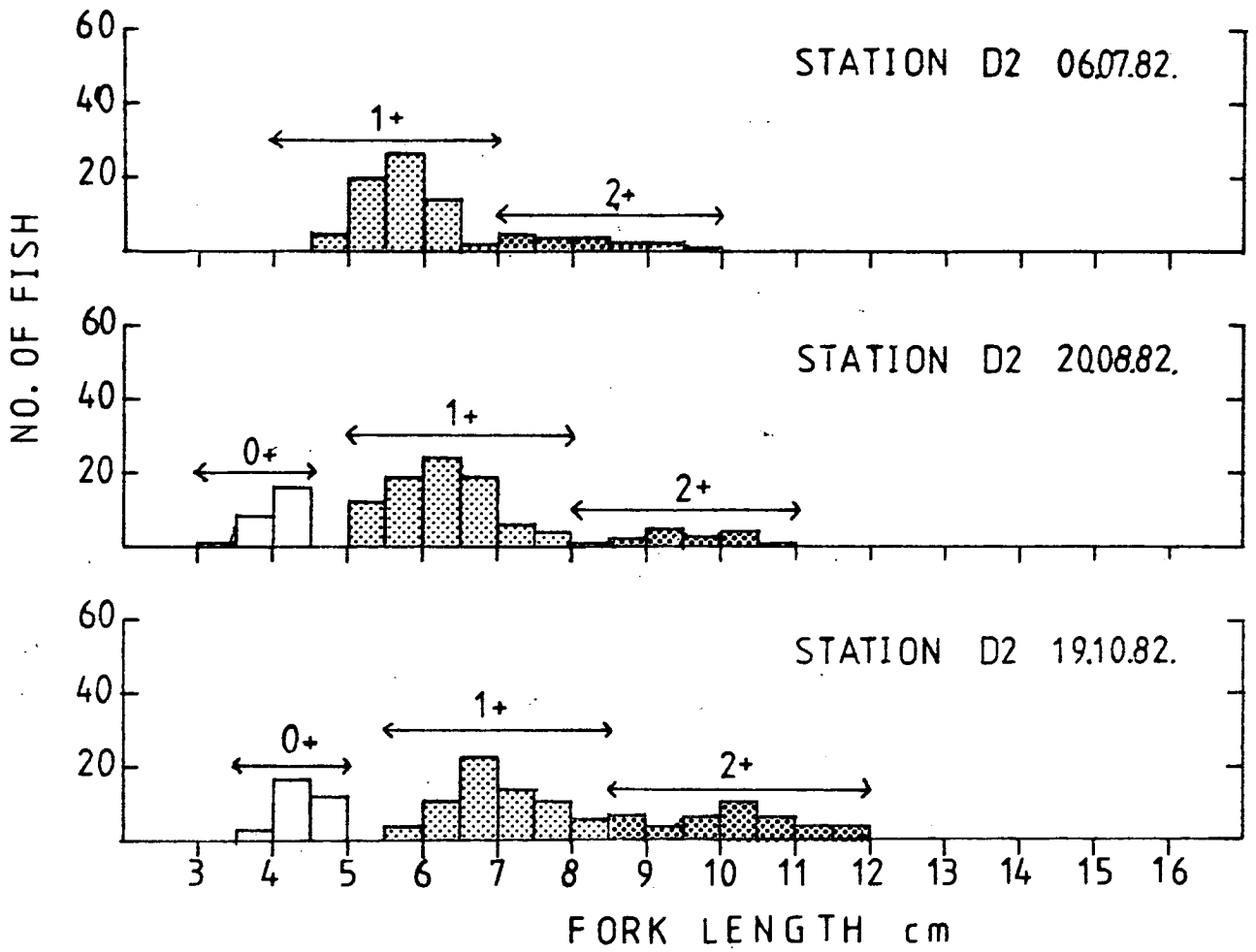


FIGURE 3.6: Length and age distribution of juvenile salmon in R. Daelisá (St. D2) on three sample dates 1982.

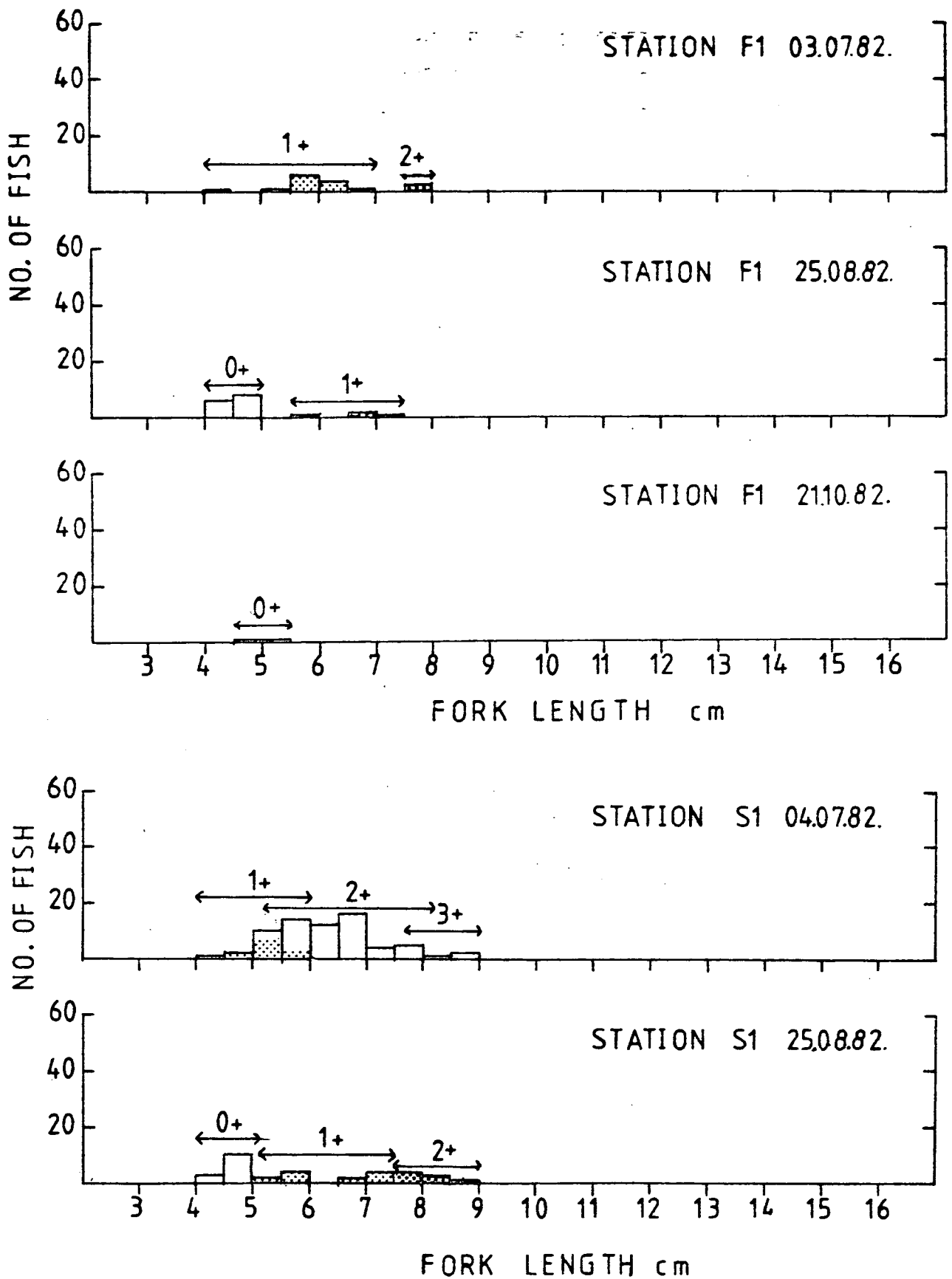


FIGURE 3.7: Length and age distribution of juvenile salmon in R. Flekkudalsá (St. F1) and R. Sandsá (St. S1) on three sample dates 1982.

On St. D1 fry were not present on any sample date and parr dominated the catches. 1+ and 2+ parr occurred in equal proportion in early July (Figure 3.5) but in August and October 1+ parr constituted the bulk of the catches. The size of 1+ parr at the end of October ranged from 5.6-8.0 cm and 2+ parr ranged from 8.3-11.9 cm. (Figure 3.5).

On St. D2 (Figure 3.6) three age classes were found (0+, 1+ and 2+). Fry first occurred in the catches at the end of August. At the end of October the size of fry ranged from 3.6-5.0 cm. Parr both 1+ and 2+ were numerous on all sample dates but 1+ parr predominated. At the end of October 1+ parr ranged in size from 5.6-8.5 cm and 2+ parr ranged from 8.6-12.0 cm.

In R. Flekkudalsá three age classes of salmon were found (Figure 3.7) both fry and parr, but catches were low compared to previous sample sites. Fry first occurred in the catches at the end of August and were also present in October but in very low numbers. In early July and at the end of August 1+ parr were present but not in October. Older parr (2+) were only present in July but neither in August nor October.

In R. Sandsá, four age classes of salmon were found (0+, 1+, 2+ and 3+) in early July and August but no fishing could be carried out in October due to dredging of the river. Fry were not present in early July but occurred in low numbers at the end of August. Salmon parr dominated the catches on both sample dates (Figure 3.7).

3.3.4 Density and standing crop of young salmon

The density ($N \times 100m^{-2}$) and standing crop ($g \times 100m^{-2}$) of young salmon on each sample site is

TABLE 3.6

Density ($N \times 100m^{-2}$) and standing crop ($g \times 100m^{-2}$) of juvenile salmon on six sample sites in the Laxá in Kjós river system in 1982
(95% confidence limits are given in parentheses)

<u>River</u>	<u>Station</u>	<u>Date</u>	<u>Age</u> <u>yr</u>	<u>Density</u>	<u>Standing crop</u>
R. Bugða	B1	19.06	0+	-	-
			1+	61.2(13.9)	152.4(34.6)
			2+	5.2(0.4)	44.0(3.4)
R. Bugða	B1	26.08	0+	1177.1(237.6)	1071.2(216.2)
			1+	102.0(51.0)	710.9(355.5)
			2+	5.8(2.7)	113.1(52.7)
R. Bugða	B1	20.10	0+	1312.8(201.9)	1470.3(226.1)
			1+	90.4(15.5)	673.5(115.6)
			2+	16.5(8.2)	306.7(127.8)
R. Bugða	B2	20.06	0+	-	-
			1+	24.6(11.8)	40.8(19.5)
			2+	3.6(0.6)	22.5(3.8)
R. Bugða	B2	26.08	0+	87.1(60.0)	56.6(39.0)
			1+	56.7(36.8)	190.5(123.6)
			2+	6.7(1.4)	72.2(15.1)
R. Bugða	B2	20.10	0+	31.2(6.5)	22.8(4.7)
			1+	27.3(1.2)	96.4(4.2)
			2+	11.5(1.4)	127.5(15.5)
R. Daelisá	D1	07.07	0+	-	-
			1+	20.1(8.4)	36.4(15.2)
			2+	21.9(2.5)	118.0(13.5)
			3+	2.3(0.8)	22.8(7.9)
R. Daelisá	D1	19.08	0+	-	-
			1+	82.4(14.3)	229.1(39.8)
			2+	10.9(1.8)	88.0(14.5)
R. Daelisá	D1	19.10	0+	-	-
			1+	123.0(25.5)	430.5(89.3)
			2+	30.2(2.2)	305.0(22.3)

<u>River</u>	<u>Station</u>	<u>Date</u>	<u>Age</u> <u>yr</u>	<u>Density</u>	<u>Standing crop</u>
R. Daelisá	D2	06.07	0+	-	-
			1+	27.1(7.4)	51.8(14.1)
			2+	6.5(1.0)	35.8(5.5)
R. Daelisá	D2	20.08	0+	7.4(0.2)	5.2(0.1)
			1+	30.6(6.3)	79.9(16.4)
			2+	5.0(0.8)	45.4(7.3)
R. Daelisá	D2	19.10	0+	10.8(2.2)	10.5(2.1)
			1+	23.8(5.3)	89.3(19.9)
			2+	15.5(2.0)	169.4(21.9)
R. Flekkudalsá	F1	03.07	0+	-	-
			1+	6.6(0.0)	13.1(0.0)
			2+	1.5(0.0)	6.6(0.0)
R. Flekkudalsá	F1	25.08	0+	7.2(0.5)	6.7(0.5)
			1+	2.0(0.0)	5.6(0.0)
			2+	-	-
R. Flekkudalsá	F1	21.10	0+	2.0	2.1
			1+	-	-
			2+	-	-
R. Sandsá	S1	04.07	0+	-	-
			1+	18.8(8.4)	27.1(12.1)
			2+	17.4(3.1)	45.8(8.2)
			3+	3.9(0.0)	22.9(0.0)
R. Sandsá	S1	25.08	0+	7.1(1.0)	8.0(1.1)
			1+	5.4(0.4)	17.7(1.3)
			2+	3.9(0.0)	18.8(0.0)
			3+	-	-

presented in Table 3.6. Results of population estimates are further given for each sample site in Appendix 3.1-3.6.

On St. B1 both density and standing crop increased from June to October (Table 3.6). The density and standing crop of fry in June was not calculated due to low fishing efficiency. The numbers of fry increased from 1177.1 in August to 1312.8 in October and standing crop of fry similarly rose from 1071.2 g to 1470.3 g in October. Parr densities were lowest in June at 66.4 and rose to 107.8 in August and 106.7 in October. The standing crop of parr was highest in October (980.2 g) but lowest in June (196.4 g).

On St. B2 both density and standing crop of fry and parr were significantly lower than calculated for St. B1 ($P > 0.05$). Numbers of fry dropped from 87.1 in August to 31.2 in October. Standing crop similarly dropped from 56.6 g in August to 22.1 g in October. Parr densities were highest in August (63.4) but lowest in June (28.2). Standing crop of parr was highest in August (162.7) and lowest in June (63.3 g).

In R. Daelisá both density and standing crop increased from July to October on both sample sites. On St. D1 numbers of parr increased from 44.3 in July to 153.2 in October and standing crop increased as well from 177.2 in July to 735.5 g in October. On St. D2 both numbers and standing crop were significantly lower than on St. B1 ($P > 0.05$). Parr densities increased a little from July to October (33.6-39.3) and standing crop of parr increased from 87.6 in July to 251.7 in October.

Both numbers and standing crop were significantly

lower in the inflowing rivers to L. Medalfellsvatn, R. Flekkudalsá and R. Sandsá compared with the other sample sites ($P>0.05$). On St. F1 in R. Flekkudalsá fry densities fell from 2.0-0.0 in the August to October period and parr densities similarly fell from 19.7 in July to 0.0 in October when no parr were present.

In R. Sandsá (St. S1) the same trend was observed. Parr densities dropped from 40.1 in July to 9.3 in August, but no fishing was carried out in October. Standing crop dropped from 98.1 g in July to 36.5 in August.

3.3.5 Growth in length

Growth in length of all salmon fry and parr sampled in the four study rivers is summarized in Table 3.7. Growth in length of salmon parr on four sample sites in R. Bugða and R. Daelisá is shown in Figure 3.8 and Figure 3.9.

In R. Bugða the mean fork lengths of fry and parr (Figure 3.8 and Figure 3.9) were highly significantly larger in St. B1 than in St. B2 ($P<0.001$) indicating that the growth rate of salmon was better on St. B1 than B2.

In R. Daelisá growth of parr both 1+ (Figure 3.8) and 2+ (Figure 3.9) was not statistically different between the two sample sites. The growth rate of parr in R. Daelisá was significantly slower than on St. B1 in R. Bugða ($P<0.001$) but was generally similar to growth of parr in St. B2 in R. Bugða ($P>0.001$).

TABLE 3.7

Mean fork lengths (cm) and mean weights (g) of juvenile salmon by age for each sample site in 1982.

(Ml=Mean fork length, w=mean weight, CI=95% confidence limits, n=number)

Date	Station	Age yr	Mean length			Mean weight	
			Ml	CI	n	w	CI
19.06	B1	0+	2.89	0.09	14	-	-
		1+	5.82	0.09	190	2.49	0.12
		2+	8.71	0.33	22	8.47	1.01
26.08	B1	0+	4.57	0.05	536	0.91	1.09
		1+	8.38	0.13	213	6.97	0.34
		2+	11.70	0.40	25	19.50	2.13
20.10	B1	0+	4.73	0.09	144	1.12	1.21
		1+	8.82	0.13	278	7.45	0.32
		2+	12.10	0.35	48	18.59	1.60
20.06	B2	0+	-	-	-	-	-
		1+	5.08	0.11	84	1.66	0.11
		2+	7.88	0.26	18	6.26	0.65
26.08	B2	0+	3.82	0.07	160	0.65	0.67
		1+	6.73	0.10	125	3.36	0.16
		2+	9.73	0.30	33	10.77	1.09
20.10	B2	0+	4.00	0.09	124	0.73	0.75
		1+	7.01	0.11	137	3.53	0.17
		2+	10.36	0.29	55	11.09	0.93

Date	Station	Age yr	Mean length			Mean weight	
			Ml	CI	n	w	CI
07.07	D1	0+	-	-	-	-	-
		1+	5.93	0.09	63	1.81	0.10
		2+	8.39	0.12	89	5.39	0.24
		3+	10.20	0.36	9	9.93	1.14
19.08	D1	0+	-	-	-	-	-
		1+	6.34	0.05	280	2.78	0.07
		2+	8.93	0.23	44	8.07	0.67
19.10	D1	0+	-	-	-	-	-
		1+	6.85	0.06	330	3.50	0.09
		2+	9.89	0.14	127	10.14	0.42
06.07	D2	0+	-	-	-	-	-
		1+	5.72	0.05	68	1.91	0.04
		2+	8.30	0.16	20	5.50	0.30
20.08	D2	0+	4.10	0.10	25	0.70	0.71
		1+	6.31	0.13	84	2.61	0.16
		2+	9.61	0.32	16	9.09	0.93
19.10	D2	0+	4.44	0.10	32	0.97	1.06
		1+	6.99	0.15	65	3.75	0.23
		2+	10.15	0.28	46	10.93	0.89
03.07	F1	0+	-	-	-	-	-
		1+	5.87	0.33	13	1.98	0.33
		2+	7.80	0.20	3	4.42	0.33
25.08	F1	0+	4.61	0.11	14	0.93	1.09
		1+	6.83	0.71	4	2.82	0.96
		2+	-	-	-	-	-



<u>Date</u>	<u>Station</u>	<u>Age</u> <u>yr</u>	<u>Mean length</u>			<u>Mean weight</u>	
			<u>ml</u>	<u>CI</u>	<u>n</u>	<u>w</u>	<u>CI</u>
21.10	F1	0+	5.10	0.39	2	1.00	-
		1+	-	-	-	-	-
		2+	-	-	-	-	-
04.07	S1	0+	-	-	-	-	-
		1+	5.25	0.18	14	1.44	0.15
		2+	6.49	0.19	43	2.63	0.23
		3+	8.63	0.13	8	5.88	0.26
25.08	S1	0+	4.71	0.13	14	1.12	1.21
		1+	7.12	0.25	6	3.28	0.36
		2+	8.09	0.24	8	4.81	0.45

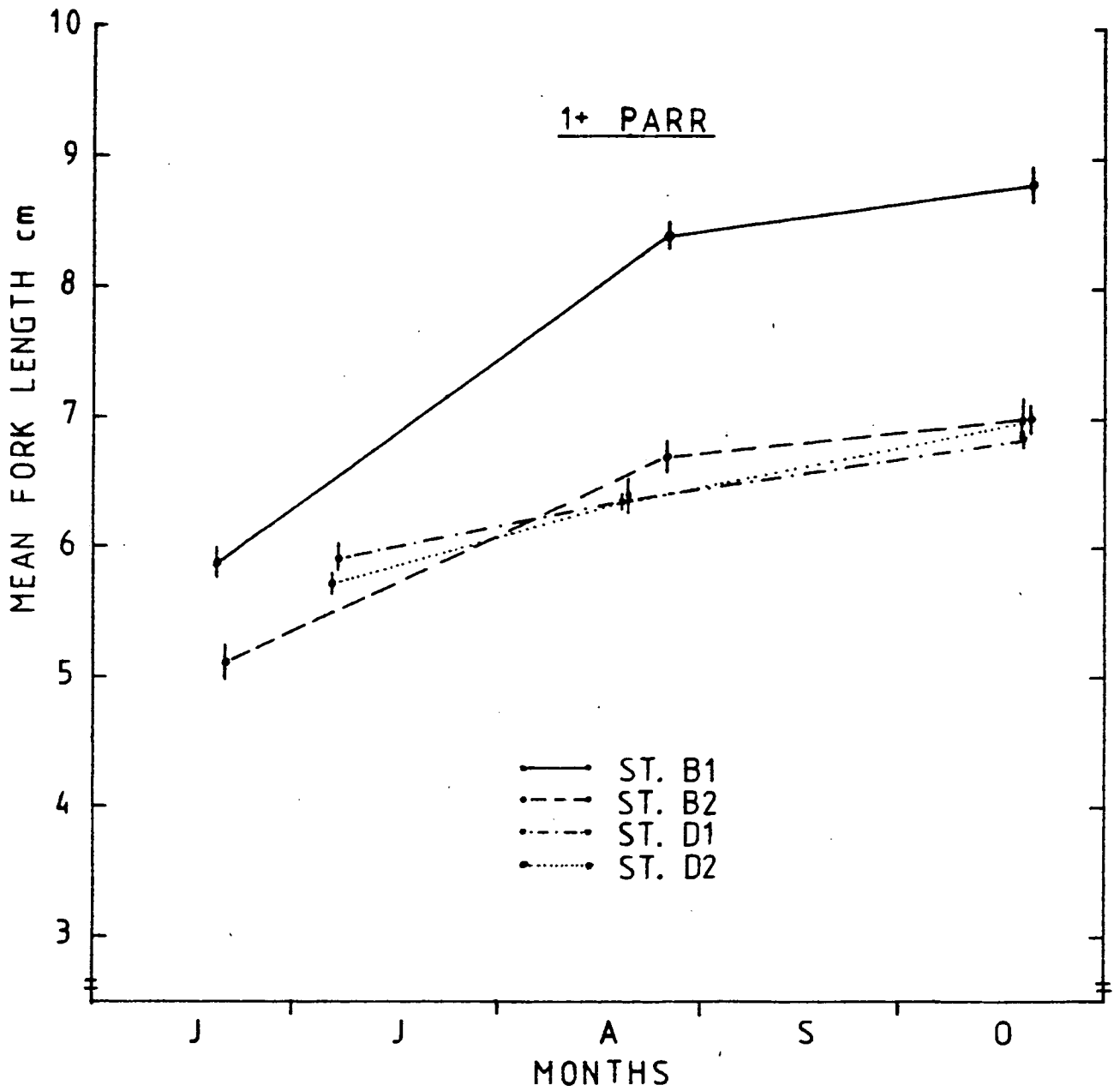


FIGURE 3.8: Comparison of the growth of 1+ salmon parr between four sample sites in R. Bugda and R. Daelisá 1982.

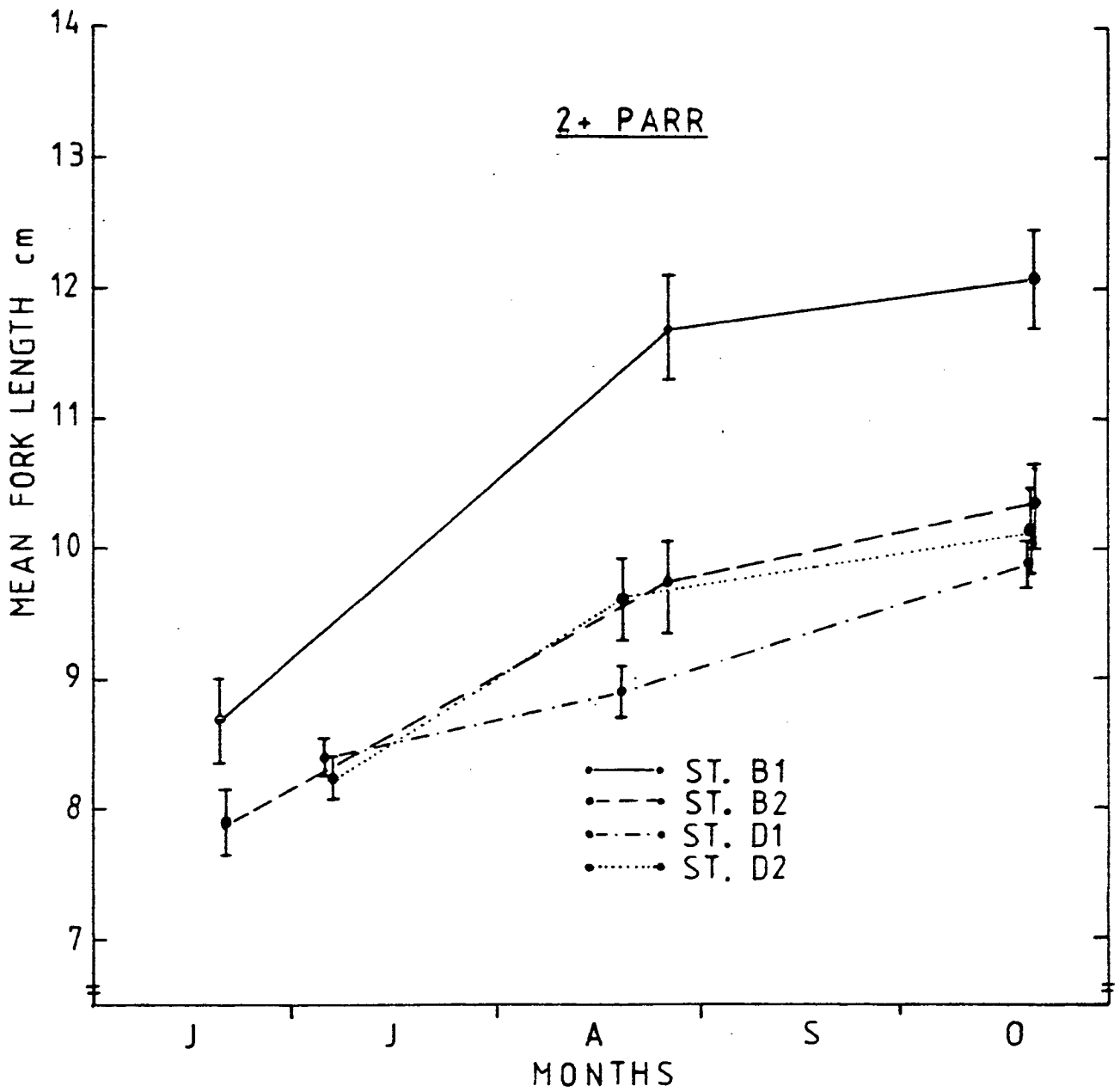


FIGURE 3.9: Comparison of the growth of 2+ salmon parr between four sample sites in R. Bugda and R. Daelisá 1982.

Growth of parr in the inlets appeared to be similar to growth of parr in R. Daelisá but this could not be tested due to small sample size in the inlets.

Most of the growth of parr on all sample sites took place from June to August (Figure 3.8 and Figure 3.9), since little or no growth took place from late August to the end of October.

3.4 DISCUSSION

3.4.1 Bottom fauna

The composition of the bottom fauna on the sample sites showed that Dipteran larvae and pupae dominated the fauna. Chironomid larvae and pupae dominated the bottom fauna except in R. Bugda below the outlet of L. Medalfellsvatn where high densities of Simuliidae replaced Chironomidae as a dominating group. These results are supported by Jóhannsson (1986) who estimated the production of blackflies (Simulium vittatum) in R. Bugda at 4 sample sites. He estimated that production of blackflies below the lake outlet was 1655 g (ww)/m²/year but close to St. B2 the production dropped to 355 g(W)/m²/year. In the lower reaches the production further dropped to 69 g(w)/m²/year. Jóhannsson (1984) obtained similar results when he surveyed the bottom fauna in R. Bugda in 1981. High densities of blackflies in other lake outlets in Iceland have been found by Gíslason (1979), Gíslason and Jóhannsson (1985) and Jóhannsson

(1986). High density of blackflies below lake outlets have also been found abroad by Illies (1956), Carlsson (1962), Ulfstrand (1968), Carlsson et.al. (1977) and Wooton (1979).

The high density of black flies below lake outlets is related to large drift of organic particles from lakes (Maciolek and Tunzi 1968) which simuliidae larvae feed on by filtration (Hynes 1970). The fine particulate organic matter consists mainly of bacteria, detritus and algae (Fredeen 1964, Wooton 1976, Carlson et.al. 1977, Gíslason and Jóhannsson 1985). The downstream drop in densities of blackflies is mostly due to a drop in drift of organic particles (Wooton 1979). Maciolek et.al. (1968) found that simuliidae larvae were capable of removing 60% of the suspended algae within a 0.4 km section of the stream studied.

The species diversity of the bottom fauna on the sample sites is very low. Diptera larvae, mainly Chironomidae and Simuliidae dominated in numbers. In Scandinavia and Britain mayflies and stoneflies are an important part of the bottom fauna (Hynes 1970) and the diet of juvenile salmon and brown trout (Frost 1950, Egglshaw 1967, Lillehammer 1973 and Williams 1981). In Iceland only one species of stoneflies, Capnia vidua has been found (Hallgrímsson 1979) in running water and only one species of mayflies Chlöeon praetextum is known. In R. Bugda these insect groups are replaced by Diptera larvae which often are found in great densities in Icelandic rivers (Tómasson 1975, Lindegaard 1979, Gíslason 1979, Jóhannsson 1984, Gíslason and Jóhannsson 1985, Jóhannsson 1986).

3.4.2 Population estimates

The methods of estimating the population size in this study are based on the survey removal method. When removal methods are used it is essential that following conditions are met (Moran 1951):

1. The influence of migration, losses caused by natural mortality and recruitment must be insignificant during the sampling period.
2. The catch per unit effort must significantly reduce the population.
3. The probability of capture remains constant during the sampling period.
4. The probability of capture is the same for all individuals in the population.
5. The population must not be so large that the catching of one individual interferes with the capture of another.

The first requirement is usually fulfilled by using stop nets to enclose the fish population. This was not possible in this study due to the physical characteristics of the sample sites. However, Karlström (1972) and Hesthagen (1978) have shown that both immigration and emigration during the fishing period is relatively small.

To fulfill the second requirement, the catch per unit effort must significantly reduce the population size. This depends mainly on gear efficiency (Cowx 1983). This is often difficult to ascertain since

physical characteristics of rivers, as conductivity, discharge, water velocity, bottom substrate and water temperature (Vibert 1967, Karlström 1976) affect gear efficiency.

The probability of capture remaining constant is difficult to justify, because the vulnerability of fish to capture declines in successive fishings (Libosvársky 1967, Mahon 1980) due to the subdued activity of previously stunned but uncaught fish.

The fourth requirement is also difficult to fulfill. It is known that large fish are caught more efficiently than small fish (Vibert 1967) and the fisherman unconsciously selects larger fish due to greater visual impact.

Finally it is difficult to show that the catching of one individual does not interfere with the catching of another. This is especially difficult when fishing is done where the density of fish is very high.

When using survey removal methods one therefore must be careful in accepting the results of the population estimates. Many authors have found that the removal method tends to underestimate the population size (Libosvársky 1967, Karlström 1976, Bohlin and Sundström 1977). Heggberget and Hesthagen (1979) found that their population estimate by removal methods on Atlantic salmon and brown trout in North Norway underestimated the population size by 50%. In the current study a high density of salmon especially fry was found in R. Bugda. The population estimates are therefore likely to be underestimates since the catchability of salmon, especially fry was very low. However the maximum weighted likelihood method of Carle and Strub (1978) used in this study has been found to give statistically reliable estimates when the quality of data is suspect (Cowx 1983).

3.4.3 Density and standing crop of salmon

In R. Bugda both density and standing crop of fry increased on St. B1 from June to October. The same trend applied to parr on St. B2. Fry densities increased from June to August but dropped again in October. Normally one would expect a decrease in both density and standing crop due to natural mortality. This increase is possibly explained by migration from other areas and/or higher fishing efficiency in autumn due to low water level. It is also likely that fry are more easily caught in autumn than early summer due to larger size. Parr could possibly have immigrated from other areas, since it is known that older salmon are not as territorial as fry (Kennedy 1981, Saltveit and Styrvold 1983) and such migration mainly occurs in autumn. On St. D1 parr densities and standing crop increased 3-4 fold from July to October but in contrast parr densities and standing crop remained constant on St. D2.

In the inlets R. Flekkudalsá and R. Sandsá both density and standing crop decreased during the summer. On St. F1 parr density fell from 8.1 per 100 m² in July to zero in October and on St. S1 parr densities fell from 40.1 in July to 9.3 in the end of August. This difference compared to the other sample site is possibly due to natural mortality and to emigration out of the area. Both sample sites are situated in the lower reaches of the rivers, close to the inlets in L.Medalfellsvatn. Both these rivers are unfavourable habitats with respect to temperature and other physical characteristics. Saunders (1983) considered that movement away from shallow water in autumn could remove fish from areas prone to freezing or low water in autumn and winter and Pepper (1976) concluded that movement of parr from stream to lakes

was caused by unfavourable conditions such as crowding and low water. It is therefore possible that juvenile salmon could to some extent migrate from the inlets into L. Medalfellsvatn which has been shown to be a favourable habitat for young salmon (Chapter 4).

The population estimates show that the highest density and standing crop occurred on St. B1 in R. Bugda below the outlet of L. Medalfellsvatn. Density on St. B1 was thus 2.4-20 times higher from June to October than on St. B2. This was mostly due to a great density of fry on St. B1. This difference between the two sample sites is probably explained by the richer food resources on St. B1 due to a high density of black fly larvae and pupae below the lake outlet. It is known that size of territories is related to food availability, since aggressiveness increases when food resource is poor (Symons 1968) thereby reducing the number of individuals that can occupy a particular stretch of river (Symons 1971). Other factors that could partly explain the difference in density especially of fry is the distance of the sample sites from the nearest nest site. Kennedy (1981) and Egglshaw and Shackley (1973) showed that over 70% of emerging fry do not move further than 200 m downstream from the nest site. St. B1 is situated close to good spawning areas below the lake outlet (Chapter 6) and the nearest spawning areas are further away from St. B2. However the richer food resource is the most likely explanation for the high density of salmon below the lake outlet. This is supported by Mason and Chapman (1965) who reported for juvenile coho salmon in two experimental stream canals, that poorer food resource in the other canal resulted in lower density of young salmon. Mills (1969) attributed an increase in fish biomass to an accidental increase in available nutrients to the loch at the head of the stream

studied. Symons (1971) found that density of juvenile salmon was positively related to the amount of available food. Stanley and Northcote (1974) report similar results in their research on rainbow trout.

3.4.4 Growth of juvenile salmon

Growth of both fry and parr was significantly better in R. Bugda below the outlet than on the other sample sites. Allen (1941), Brett et.al. (1969) and Elliot (1975) point out the importance of temperature and food for growth rate of salmonid fish. The density of bottom fauna was by far the highest below the lake outlet and is the most probable cause of better growth of juvenile salmon in the upper reaches of R. Bugda.

Temperature measurements show that (Appendix 2.1) the mean water temperature is on average 1.0°C higher on St. B1 than B2 and 3-5°C higher than in the inlets and R. Daelisá. Differences in growth rate therefore could partly be explained by higher temperature on St. B1 than on the other sample sites. The upper part of R. Bugda is also more stable in discharge than the lower part of R. Bugda and the three direct run-off rivers. Variations in discharge are known to increase drift of invertebrates such as blackfly larvae and Chironomidae resulting in lower density of invertebrates (Minshall and Winger 1968).

Many workers have found that a high population density leads to reduced growth in salmonids (Elson 1975, Egglshaw and Shackly 1977, Gee, Milner and Hensworth 1978). In this study the best growth of young salmon was found where population density was also by far highest. This is probably explained by the "lake-effect" (Muller 1955, Illies 1956) of L. Medalfellsvatn i.e. the high concentration of

blackflies below the lake outlet which supply young salmon with adequate food (Jóhannsson 1984, Jóhannsson 1986). Similar results have been found for salmon population in Canada (Gibson and Galbraith 1975) and on the brown trout population in the upper reaches of R. Laxá in North East Iceland (Kristjánsson 1978).

3.5. SUMMARY

Density, standing crop and growth of young salmon was compared in four rivers within the Laxá in Kjós river system in relation to environmental factors from June to October 1982.

Density (N per m²) of bottom fauna animals varied little between sample sites, except in R. Bugda below the lake outlet, where number of animals were 4-11 times higher than on the other sample sites. Diptera larvae and pupae dominated the bottom fauna and made up 78.4 - 99.8% of the total number of animals present both in summer and autumn. Chironomidae larvae dominated on all sample sites, except in R. Bugda below the lake outlet where black fly larvae were found in great densities and replaced Chironomidae as a dominant group.

The lowest density and standing crop of salmon was found in the two inflowing streams of L. Medalfellsvatn, R. Flekkudalsá and R. Sandsá where numbers of salmon ranged from 8.1 per 100 m² in July to 2.0 per 100m² in October (R. Flekkudalsá) and 40.1 per 100m² in July to 16.4 per 100 m² in August (R. Sandsá).

The highest density and standing crop was found in R. Bugda below the outlet of the lake. The number of salmon ranged from 66.4 per 100 m² in June to 1420 per 100 m² in October. The standing crop varied from 196.4 g per 100 m² in June to 2450 g per 100 m² in October. Further downstream in R. Bugda (St. B2) both density and standing crop of salmon were significantly lower than below the lake. Numbers of salmon varied from 28.2 per 100 m² in June to 70.0

per 100 m². The standing crop ranged from 63.3 g in June to 246.7 g in October. In R. Daelisá both density and standing crop of salmon were similar to the lower half of R. Bugda.

Growth of salmon parr was significantly better in R. Bugda below the lake outlet than in the other sample sites. Differences in growth were not found between the other sample sites.

It was concluded that the high density and standing crop and better growth of young salmon found below the lake outlet in R. Bugda could best be explained by the rich food source of black fly larvae found below the lake outlet and possibly to a higher temperature than found on the other sample sites.

APPENDIX 3.1

Results from population estimates of juvenile salmon on station B1
in R. Bugda 1982. The table also shows total catch of
other fish species (p =catchability, $M = (k-i)C_i$, T =total catch
 N_0 =original population size, SE =standard error, $CI=95\%$
confidence interval

Date	Area m ²	No. of sweeps K	Age	p	M	T	N ₀	N ₀ / 100m ²	SE/ 100m ²	CI(95%)	Other fish species		
											Trout	Charr	Stickleb
19.06.82	429	3	0+	0.37	15	14	17.7	4.1	+ 0.9	2.3- 5.9			
			1+	0.35	239	190	262.4	61.2	+ 7.1	47.2- 75.2	1	0	3
			2+	0.63	32	22	22.4	5.2	+ 0.2	4.8- 5.6			
26.08.82	429	2	0+	0.26	-	2292	5049.8	1177.1	+121.2	939.5-1414.7			
			1+	0.31	-	227	438.0	102.0	+ 26.0	51.0- 153.0	150	0	3
			2+	0.20	-	9	25.0	5.8	+ 1.4	4.4- 7.2			
20.10.82	429	3	0+	0.10	1560	1472	5632.0	1312.8	+103.0	1110.8-1514.8			
			1+	0.34	350	278	387.7	90.4	+ 7.9	74.9- 105.9	31	0	0
			2+	0.30	54	47	70.9	16.5	+ 4.2	8.3- 24.7			

APPENDIX 3.2

Results from population estimates of juvenile salmon on station B2
in R. Bugda 1982. The table also shows total catch of
other fish species (p =catchability, $M = (k-i)C_i$, T =total catch
 N_0 =original population size, SE =standard error, $CI=95\%$
confidence interval

Date	Area m ²	No. of sweeps K	Age	p	M	T	N ₀	N ₀ / 100m ²	SE/ 100m ²	CI(95%)	Other fish species			
											Trout	Charr	Stikleb	
20.06.82	520	2	0+	-	-	-	-	-	-	-	-	-	-	-
			1+	0.42	-	84	127.7	24.6	+ 6.0	12.9-	36.3	2	1	0
			2+	0.80	-	18	18.8	3.6	+ 0.3	3.1-	4.1			
26.08.82	520	3	0+	0.14	170	162	453.0	87.1	+ 30.6	27.2-	147.0			
			1+	0.17	135	126	295.0	56.7	+ 18.8	19.8-	93.6	14	7	0
			2+	0.48	41	31	35.0	6.7	+ 0.7	5.4-	8.0			
20 10.82	520	3	0+	0.38	159	124	162.0	31.2	+ 3.3	24.7-	37.7			
			1+	0.65	216	137	142.0	27.3	+ 0.6	262.0-	284.0	6	2	0
			2+	0.54	78	55	60.0	11.5	+ 0.7	10.2-	12.8			

99

APPENDIX 3.3

Results from population estimates of juvenile salmon on station D1
in R. Daelisá 1982. The table also shows total catch of
other fish species (p=catchability, $M = (k-i)C_i$, T=total catch
 N_0 =original population size, SE=standard error, CI=95%
confidence interval

Date	Area m ²	No. of sweeps K	Age	p	M	T	N ₀	N ₀ / 100m ²	SE/ 100m ²	CI(95%)	Other fish species			
											Trout	Charr	Stikleb	
07.07.82	455	3	0+	-	-	-	-	-	-	-	-	0	0	0
			1+	0.32	75	63	91.5	20.1	+ 4.3	11.7- 28.5				
			2+	0.51	126	89	99.6	21.9	+ 1.3	19.4- 24.4				
			3+	0.40	9	9	10.5	2.3	+ 0.4	1.5- 3.1				
19.08.82	455	3	0+	-	-	-	-	-	-	-	0	0	0	
			1+	0.37	359	280	374.8	82.4	+ 7.3	68.1- 96.7				
			2+	0.50	60	44	49.6	10.9	+ 0.9	9.1- 12.7				
19.10.82	455	5	0+	-	-	-	-	-	-	-	4	2	0	
			1+	0.16	771	331	559.7	123.0	+ 13.0	97.0- 149.0				
			2+	0.39	365	127	137.4	30.2	+ 1.1	28.0- 32.4				

APPENDIX 3.4

Results from population estimates of juvenile salmon on station D2
in R. Daelisá 1982. The table also shows total catch of
other fish species (p =catchability, $M = (k-i)C_i$, T =total catch
 N_0 =original population size, SE =standard error, CI =95%
confidence interval

Date	Area m ²	No. of sweeps K	Age	p	M	T	N ₀	N ₀ / 100m ²	SE/ 100m ²	CI(95%)	Other fish species			
											Trout	Charr	Stikleb	
06.07.82	339	3	0+	-	-	-	-	-	-	-				
			1+	0.35	84	68	91.9	27.1	+ 3.8	19.6-	34.6	0	0	0
			2+	0.50	26	20	22.0	6.5	+ 0.5	5.5-	7.5			
20.08.82	339	3	0+	0.67	38	25	25.1	7.4	+ 0.1	7.2-	7.6			
			1+	0.42	110	84	103.7	30.6	+ 3.2	24.2-	37.0	11	0	0
			2+	0.54	21	16	16.9	5.0	+ 0.4	4.2-	5.8			
19.10.82	339	3	0+	0.47	42	32	36.7	10.8	+ 1.1	8.6-	13.0			
			1+	0.41	84	65	80.7	23.8	+ 2.7	18.5-	29.1	7	2	0
			2+	0.54	68	48	52.4	15.5	+ 1.0	13.5-	17.5			

APPENDIX 3.5

Results from population estimates of juvenile salmon on station F1
in R. Flekkudalsá 1982. The table also shows total catch of
other fish species (p=catchability, $M = (k-i)C_i$, T=total catch
 N_0 =original population size, SE=standard error, CI=95%
confidence interval

Date	Area m ²	No. of sweeps K	Age	p	M	T	N ₀	N ₀ / 100m ²	SE/ 100m ²	CI(95%)	<u>Other fish species</u>			
											Trout	Charr	Stikleb	
03.07.82	198	3	0+	-	-	-	-	-	-	-	-	-	-	-
			1+	1.00	21	13	13.0	6.6	+ 0.0	0	3	71	0	
			2+	1.00	5	3	3.0	1.5	+ 0.0	0	-	-	-	
25.08.82	198	3	0+	0.59	19	14	14.2	7.2	+ 0.25	6.7- 7.7	-	-	-	
			1+	1.00	6	4	4.0	2.0	+ 0.0	0	12	46	0	
			2+	-	-	-	-	-	-	-	-	-	-	
21.10.82	198	2	0+	-	-	2	2.0 ¹⁾	1.0	-	-	-	-	-	
			1+	-	-	-	-	-	-	-	5	20	0	
			2+	-	-	-	-	-	-	-	-	-	-	

1) Total catch since density could not be calculated.

APPENDIX 3.6

Results from population estimates of juvenile salmon on station S1
in R. Sandsá 1982. The table also shows total catch of
other fish species (p =catchability, $M = (k-i)C_i$, T =total catch
 N_0 =original population size, SE =standard error, CI =95%
confidence interval

Date	Area m ²	No. of sweeps K	Age	p	M	T	N ₀	N ₀ / 100m ²	SE/ 100m ²	CI(95%)	Other fish species				
											Trout	Charr	Stikleb		
04.07.82	206	3	0+	-	-	-	-	-	-	-	-	-	-	-	-
			1+	0.31	30	27	38.8	18.8	+ 4.3	16.3-	21.3	3	34	0	
			2+	0.50	43	32	35.8	17.4	+ 1.6	14.3-	20.5				
			3+	1.00	11	8	8.0	3.9	+ 0.0						
25.08.82	206	3	0+	0.54	18	14	14.7	7.1	+ 0.5	6.1-	8.1				
			1+	0.57	14	11	11.1	5.4	+ 0.2	5.0-	5.8	6	14	0	
			2+	0.57	10	8	8.0	3.9	+ 0.0		0				

APPENDIX 3.7

Length weight relationships of salmon parr on
sample sites 1982.

(r=regression coefficient, n=no. of fish measured)

<u>Date</u>	<u>Station</u>	<u>Log w = a + b (Log l)</u>	<u>n</u>	<u>r</u>
19.06	B1	Log w = -1.92+3.03 (Log l)	15	0.98
26.08	B1	Log w = -2.00+3.08 (Log l)	29	0.97
20.10	B1	Log w = -1.86+2.89 (Log l)	21	1.00
20.06	B2	Log w = -1.92+3.03 (Log l)	18	0.97
26.08	B2	Log w = -2.09+3.16 (Log l)	17	0.99
20.10	B2	Log w = -1.93+2.93 (Log l)	34	0.98
07.07	D1	Log w = -2.16+3.13 (Log l)	13	1.00
19.08	D1	Log w = -2.05+3.11 (Log l)	20	0.99
19.10	D1	Log w = -1.88+2.90 (Log l)	39	0.99
06.07	D2	Log w = -1.87+2.84 (Log l)	12	0.88
20.08	D2	Log w = -1.96+2.97 (Log l)	16	0.99
19.10	D2	Log w = -1.85+2.87 (Log l)	32	0.99
03.07	F1	Log w = -1.87+2.82 (Log l)	20	0.93
25.08	F1	Log w = -2.02+2.96 (Log l)	8	0.99
04.07	S1	Log w = -1.87+2.82 (Log l)	20	0.93
25.08	S1	Log w = -2.05+3.01 (Log l)	12	0.98

CHAPTER 4

LAKE USE BY A WILD STOCK OF ANADROMOUS ATLANTIC SALMON

4.1 INTRODUCTION

In this chapter I examine the use of L. Medalfellsvatn as a rearing habitat for juvenile Atlantic salmon. The aims of the study were to obtain preliminary information on the distribution, age structure and habitat preferences of juvenile salmon in the lake. Information from this study is believed to contribute to our general knowledge about the importance of lakes for the production of juvenile salmon and it is hoped that the information will be useful to those investigators involved in the enhancement of salmon populations through stocking programmes and lake habitat modifications.

Generally the carrying capacity or rearing habitat of a particular stream or river for juvenile Atlantic salmon is considered to be the ultimate factor limiting population size in most Atlantic salmon populations (Symons 1979). The most important single factor controlling and affecting the survival, distribution and production of juvenile salmonids, is the existence of territorial behaviour (Lindroth 1955, Kalleberg 1958, Keenleyside and Yamamoto 1962, Symons and Heland 1978)). The number of territories within a river or stream is finite. Therefore the potential freshwater production of Atlantic salmon is usually estimated by the amount of fluvial habitat available to salmon parr (Elson 1975). The habitat requirements of juvenile Atlantic salmon within a river are well documented (Keenleyside 1962, Elson 1967, Symons and Heland 1978). Typically juvenile

salmon are most numerous in shallow fast flowing riffles during the summer and prefer slightly deeper riffles during the winter. Salmon fry generally prefer shallow riffles (10-15 cm deep), but with parr the preference changes for deeper riffles (>30 cm deep) containing boulders. Juvenile salmon are better adapted to fast water current than any other species, by using their large pectoral fins to keep themselves firmly attached to the bottom surface (Kalleberg 1958).

However, there is evidence that juvenile salmon are produced in atypical areas as well. Atlantic salmon parr are commonly found in the lacustrine habitat in Newfoundland (Pepper 1976) and Chadwick and Green (1985) estimated that as much as 67% of the smolt production in Western Arm Brook occurred in the lacustrine habitat. Elsewhere, Gravem and Haraldstadt (1982) reported that salmon parr are found in Lake Vangsvatnet in Norway.

In Iceland, lakes are an important component of stream drainage basins and commonly the most productive salmon rivers per unit area, originate in lakes or contain lakes in their watershed. In some cases the production of Atlantic salmon, as revealed by catch statistics, is so high that either these river systems are unusually productive or their rearing habitat has been seriously underestimated. Where lakes are an important component of watersheds, it is therefore necessary to know if the lake habitat is used by juvenile salmon. The importance of lakes to Atlantic salmon production is poorly researched in Iceland. Kristjánsson (1973) found that salmon parr inhabited L. Medalfellsvatn and Jónsson (1981) similarly reported that salmon parr were found in Lake Eyrarvatn.

Lake Medalfellsvatn

1: 10000

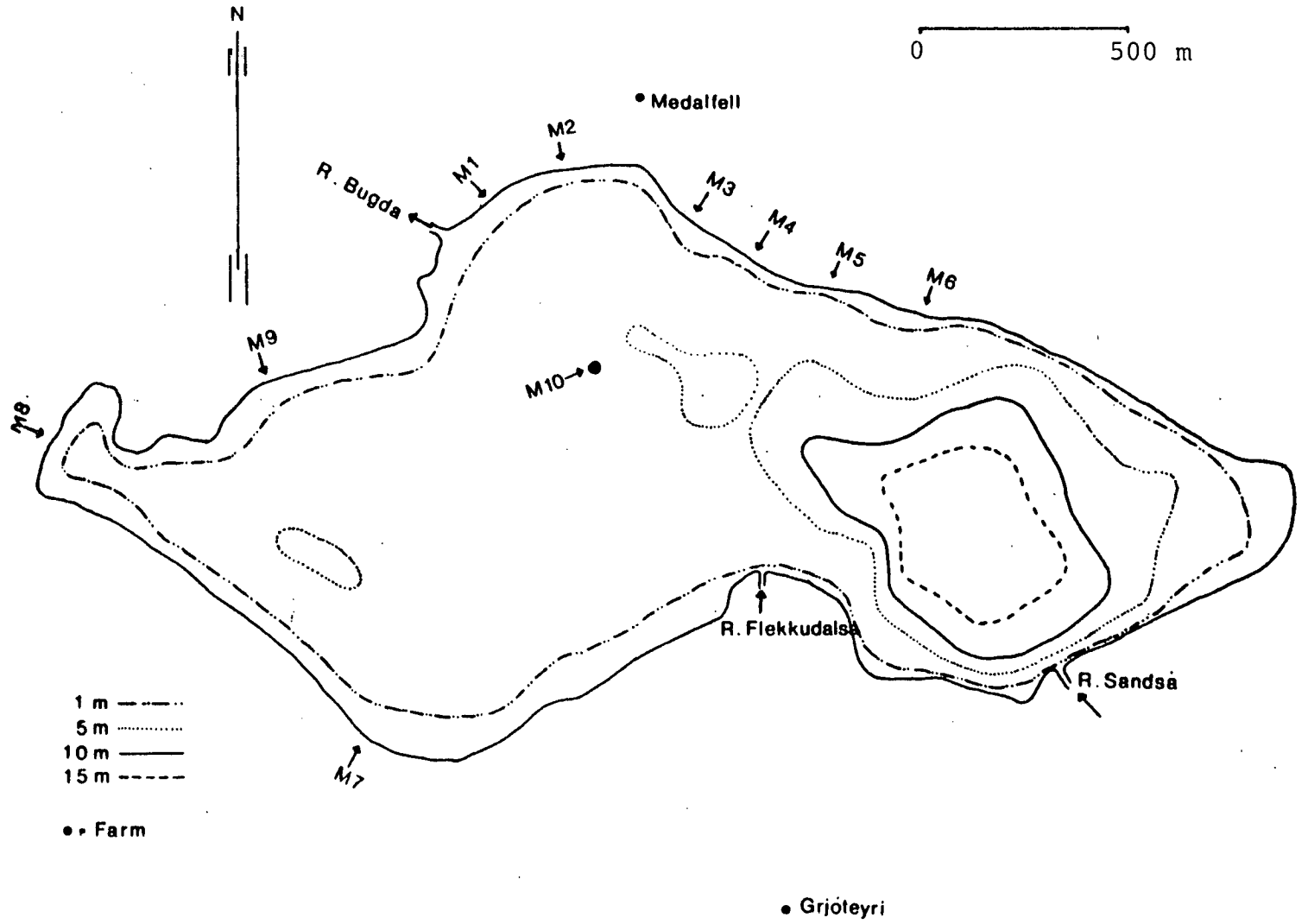


FIGURE 4.1: Location of the electrofishing stations in L. Medalfellsvatn 1982-1983.

4.2 METHODS

4.2.1 Sample sites

L. Medalfellsvatn (Figure 4.1, Plate 4.1), has a surface area of 2.03 km² or 200 ha (Stefánsson 1952) which is 70.2% of the total surface area available for production of juvenile Atlantic salmon in the Laxá in Kjós river system (Table 4.1).

The lake is shallow with a mean depth of 4.5 m. The eastern part of the lake is relatively deep (5-18 m), but the western part is shallow (2-4 m). 62.2% of the total surface area of the lake is found within the 1-5 m depth contours (Table 4.2, Figure 4.1). In the western part of the lake the shores are composed of gravel interspersed with rubble or boulders (Plate 4.2), but in the eastern part sand or silt dominate the bottom substrate. A more detailed description of the study area is given in chapter 2.

The location of the sample sites is shown in figure 4.1. The sites were chosen to represent different habitats within the lake. Most of the sites were situated along the shoreline of the lake except one which was located along the shoreline of the only island in the lake. The characteristics of each station are presented in table 4.3.

4.2.2 Capture methods

All sampling of fish in the lake was carried out by electrofishing. It is a perennial problem for fish biologists that most fish capture methods are selective with respect to species, size of individuals and often sex as well (Lagler 1968). Electrofishing is considered to be one of the least



PLATE 4.1: View from east to west of Lake Medalfellsvatn
(Photo by Dr Derek H Mills, August 1982).



PLATE 4.2: The outlet area of Lake Medalfellsvatn
(Photo by Dr Derek H Mills, August 1982).

TABLE 4.1

The surface area (ha) of different parts of the
Laxá in Kjós river system

	Surface area <u>ha</u>	Surface area <u>%</u>
R. Sandsá	2.46	0.86
R. Flekkudalsá	0.69	0.24
L. Medalfellsvatn	200.00	70.20
R. Bugða	6.44	2.26
R. Daelisá	2.20	0.77
R. Thverá	0.90	0.32
R. Selá	0.28	0.10
R. Hálsá	0.75	0.26
R. Svínadalsá	0.70	0.25
R. Laxá	<u>70.50</u>	<u>24.74</u>
Total	284.92	100.00

TABLE 4.2

The surface area of L. Medalfellsvatn
according to depth classes

<u>Depth interval</u>	<u>Surface area</u> <u>ha</u>	<u>Surface area</u> <u>%</u>
0- 1	28.9	14.5
1- 5	124.7	62.2
5-10	22.5	11.3
10-15	12.6	6.3
<u>> 15</u>	<u>11.3</u>	<u>5.7</u>
Total	200.0	100.0

TABLE 4.3

Physical characteristics of each sample site
in L. Medalfellsvatn 1982-1983

<u>Station</u>	<u>Depth</u> <u>m</u>	<u>Bottom composition</u>
M1	0-1	Gravel
M2	0-1	Gravel, rubble
M3	0-1	Sand, silt
M4	0-1	Gravel
M5	0-1	Gravel, rubble
M6	0-1	Gravel, rubble, boulders
M7	0-1	Sand, silt
M8	0-1	Gravel, rubble, boulders
M9	0-1	Boulders, gravel
M10	0-1	Gravel, boulders, rubble

selective of all methods of fishing although it is most suitable for sampling rivers (Lagler 1968). However since the objective of this study was to capture small individuals electrofishing was chosen, since conventional capture methods in lakes (i.e. gill netting) often fail to catch small individuals efficiently.

The electrofishing gear used was a light, highly portable set composed of a petrol driven transportable generator (Honda Ex 500), a transformer and two electrodes (cathode (-) and anode(+)). The transformer is connected to the generator (440w, 220V AC) and converts the current from alternating current (A.C.) to direct current(D.C.). With water of conductivity in the range 40-60 μ s) the transformer yields an output current of 0.3-0.5 w and a voltage of 300 V. The anode is composed of a 2 m long glassfiber rod with a 25 cm diameter aluminium ring at the end. The anode is connected to the transformer by a 50 m long cable. The cathode is composed of 1 mm thick copper plate (20x20 cm) and is connected to the transformer by a 3 m long cable. In operating the gear, the generator and the transformer are kept on land, and the cathode lies in the water close to the set. The operator holds the anode with one hand and a small mesh hand net is held in the other hand. The method requires another person, to collect the stunned fish in a handbucket, partially filled with water, and who also makes sure that the cable is free from obstruction during the fishing period.

Normally when electrofishing in rivers, one fishes upstream in a zig-zag fashion. In lakes the circumstances are different since no water current is present. Fishing was carried out by wading out at

right angles to the shoreline and back again to shore until the fishing area had been covered. Fishing in the lake was only carried out on calm days, since on windy days the lake surface was disturbed so much that the fish became hard to see and the fishing became inefficient.

The size of the fishing area varied between stations but most of the areas fished were between 200-500 m². The sampling dates for each station are given in table 4.4.

Sampling in the lake was carried out on four occasions in August and October of each year of the study. Two stations were fished on all dates, but in 1983 sampling was extended to various parts of the lake.

All fish caught in each station were anaesthetized with Ms 222 after capture in order to make handling easier. All length of the anaesthetized fish were measured from the tip of the jaws to the fork of the tail to the nearest mm. In 1982 scale samples were taken from fish of intermediate lengths for ageing purposes, but in 1983 scale samples were taken from the majority of fish caught.

After measuring the fish were returned to holding boxes and returned to each section after a recovery period. Egglshaw (1970) claimed that neither density nor growth of juvenile salmon and trout were affected by electrofishing or subsequent handling of the fish.

4.2.3 Calculation of relative density

It was not the objective of this study to obtain precise population estimates of juvenile salmon

TABLE 4.4

Sampling dates in each station in L. Medalfellsvatn during the study period.

(- = Not fished)

Station	1982		1983	
	<u>August</u>	<u>October</u>	<u>August</u>	<u>October</u>
M1	25.08	21.10	03.08	22.10
M2	-	21.10	-	-
M3	25.08	-	03.08	22.10
M4	25.08	-	03.08	22.10
M5	-	-	03.08	22.10
M6	25.08	21.10	03.08	25.10
M7	-	-	03.08	-
M8	-	-	03.08	-
M9	-	-	03.08	22.10
M10	-	-	03.08	-

occupying the lake. Such study involves both manpower and time consuming methods such as mark-recapture estimates which were beyond the scope of this survey.

To be able to compare relative fish density between stations and sample dates a semi-quantitative method was used. On each sample date, each sample site was only fished once and relative fish density was calculated using the following equation:

$$(4.1) \quad N^* = (C \times 100) / A$$

where: C = No fish taken in one sweep in each station

A = Fishing area (m²)

N* = Density of fish taken in one sweep
expressed as no. per 100 m²

4.2.4 Calculation of growth

The mean length of each age class was calculated with 95% confidence intervals (Elliot 1977) for each station on each sample date and differences in mean lengths tested with students t-test (Elliot 1977).

4.3 RESULTS

4.3.1 Distribution of juvenile salmon

Juvenile salmon were found to be widely distributed along the shore line of the lake. Juveniles were found at eight of the ten sample sites (Figure 4.1, Table 4.6). Since the sample sites were all located within the one metre depth contour line they only represent the distribution of salmon in that particular area of the lake amounting to 28.9 ha or 14.5% of the total surface area of the lake (Table 4.2).

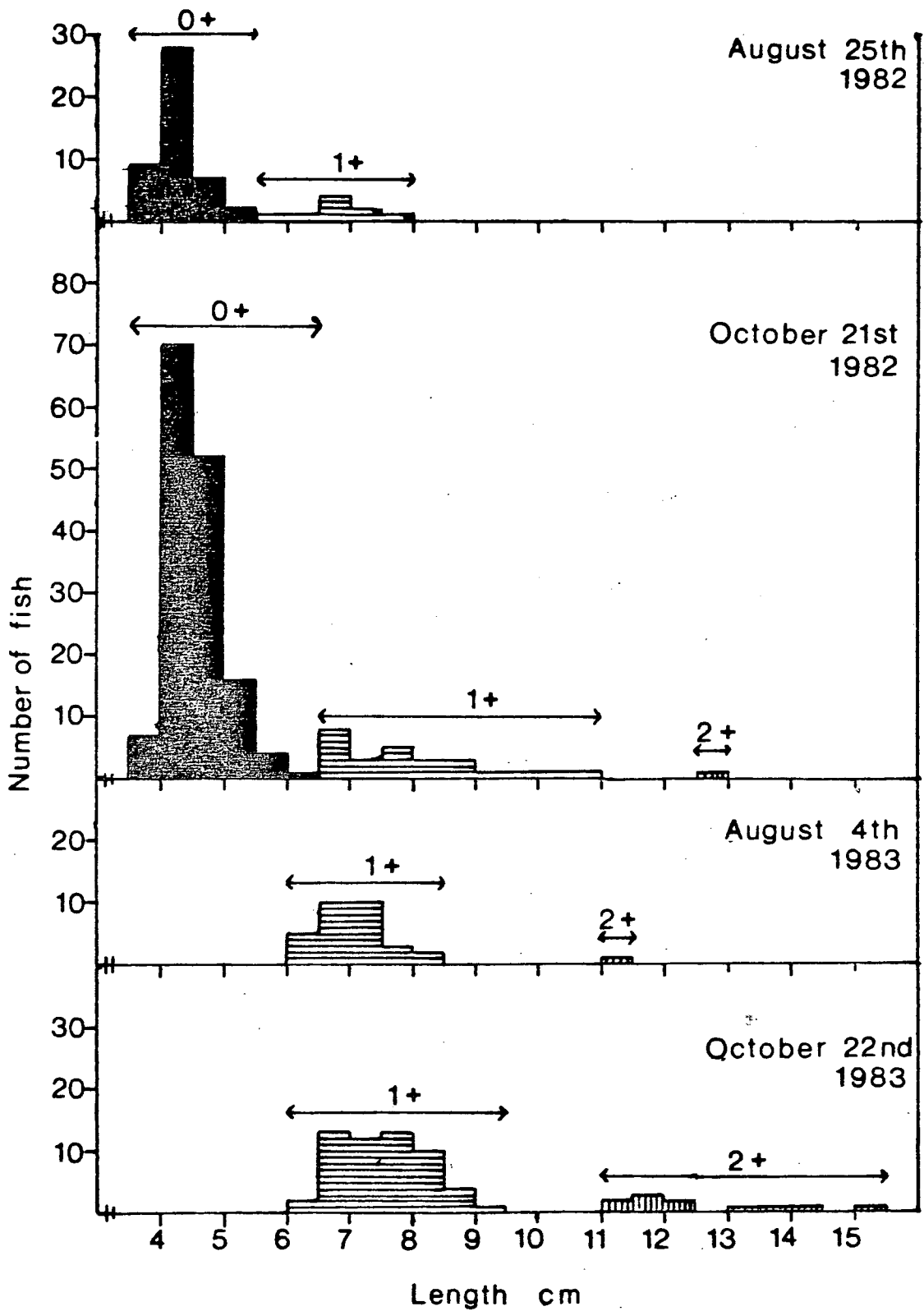


FIGURE 4.2: Length distribution and age of juvenile Atlantic salmon in L. Medalfellsvatn in 1982-1983.

TABLE 4.5

Total number of fish of each species caught during
the study period

<u>Species</u>	<u>No. caught</u> <u>n</u>	<u>% caught</u>
Salmon	373	93.0
Arctic charr	2	0.5
Brown trout	9	2.2
<u>Sticklebacks</u>	<u>17</u>	<u>4.3</u>
Total	401	100.0

TABLE 4.6

Densities (No./100 m²) of juvenile salmon in
L. Medalfellsvatn by station and date.
Total catch of other fish species is also shown.

S	Date	Area Catch		N ^x /100m ²				C	T	S
		m ²		0+	1+	2+	Total			
M1	25.08.82	720	39	4.4	1.0	0.0	5.4	1	0	0
M3	"	250	0	0.0	0.0	0.0	0.0	0	0	0
M4	"	250	2	0.4	0.4	0.4	0.8	0	0	0
M6	"	432	13	2.8	0.2	0.0	3.0	0	0	3
M1	21.10.82	253	115	43.5	1.6	0.0	45.1	0	0	0
M2	"	152	61	32.2	7.2	0.7	40.1	0	0	0
M6	"	189	45	18.0	5.8	0.0	23.8	0	0	6
M1	03.08.83	600	5	0.0	0.8	0.0	0.8	1	0	1
M3	"	150	0	0.0	0.0	0.0	0.0	0	0	0
M4	"	500	6	0.0	1.2	0.0	1.2	0	0	0
M5	"	270	3	0.0	1.1	0.0	1.1	0	0	0
M6	"	400	11	0.0	2.5	0.3	2.8	0	0	4
M7	"	100	1	0.0	1.0	0.0	1.0	0	0	0
M8	"	280	3	0.0	1.1	0.0	1.1	0	0	0
M9	"	200	2	0.0	1.0	0.0	1.0	0	0	0
M10	"	150	0	0.0	0.0	0.0	0.0	0	0	1
M1	22.10.83	500	21	0.0	4.2	0.0	4.2	0	0	1
M3	"	200	0	0.0	0.0	0.0	0.0	0	0	0
M4	"	350	5	0.0	1.4	0.0	1.4	0	0	0
M5	"	456	5	0.0	1.1	0.0	1.1	0	2	1
M6	25.10.83	300	29	0.0	6.7	2.7	9.4	0	7	0
M9	22.10.83	350	7	0.0	1.1	0.9	2.0	0	0	0

S = Station, C = Charr, T = Trout, S = Stickleback

The composition of the bottom substrate clearly affected the distribution of salmon. Generally the largest number of juveniles was caught on a rocky bottom (gravel, rubble, boulders) while salmon were absent or in low number where the substrate had little or no cover (Station M3, M7) (Table 4.6). It was clear that both salmon fry and parr used gravel, rubble and boulders as cover and were always caught hiding within this type of cover and were never found to be very far from the bottom substrate.

Salmon fry were numerous in the catches in 1982 but did not occur in 1983. The distribution and occurrence of fry was particularly interesting. In 1982 they were found as far as 1200 m from the outlet R. Bugda and 1700 m from the nearest inlet (R. Sandsá).

4.3.2 Catch by species

A total of 401 fish were caught by electrofishing on four sampling dates in 1982-83. Juvenile salmon dominated the catches and represented 93% of the total catch (Table 4.5). Other species encountered were the three spined stickleback, arctic charr and brown trout together making up 7% of the total number of fish caught.

4.3.3 Length and age distribution of salmon

The total number of salmon caught according to 0.5 cm length classes is shown in Figure 4.2 for each sample date. All stations fished on each sample date were combined since length distribution for separate catches revealed little about the population. The range in size for each age class is also given. It was found that the length distribution was a valid

method of separating age classes and there was generally no overlap in length between different age classes.

Three age classes of salmon were found in the lake and included fry (0+) and parr (1+ and 2+). Parr older than 2+ were not found in the catches.

In 1982 salmon fry dominated the catches and were found at three out of four stations in both August and October (Table 4.6). Salmon parr were also numerous, especially 1+ parr. Two year old parr were scarce and were not present in the August catch and only one occurred in the October catch.

In 1983 no salmon fry were found in the lake and one year old parr (1+) dominated the catches in both August and October. Older parr (2+) also occurred in low numbers and were mainly found in the October survey.

4.3.4 Relative density

The relative density of fry (Table 4.6) varied from 0-4.4 fry per 100 m² in August to 18-43.5 in October 1982. On average fry densities increased approximately thirty fold from late August to October (Table 4.7). The differences in densities between August and October were highly significant (P>0.01). Parr density were much lower than calculated for fry and ranged from 0-1.0 per 100 m² in August to 1.6-7.2 per 100 m² in October. On average parr densities increased approximately twelvefold from August to September from 0.4-5.1 per 100 m². The difference was highly significant (P>0.02) between the two sampling dates.

TABLE 4.7

Mean densities (N /100 m²) of salmon, fry and parr in
L. Medalfellsvatn by date

<u>Date</u>	<u>Age</u>	<u>N*/100 m²</u>	<u>No. of stations</u>
25.08.82	Fry	1.9	4
	Parr	0.4	4
	Total	2.3	4
21.10.82	Fry	31.2	3
	Parr	5.1	3
	Total	36.3	3
03.08.83	Fry	0.0	9
	Parr	1.0	9
	Total	1.0	9
22.10.83	Fry	0.0	6
	Parr	3.0	6
	Total	3.0	6

TABLE 4.8

Mean fork lengths (mm) standard deviation and 95% confidence limits of each ageclass in L. Medalfellsvatn on four sample dates 1982-1983

<u>Year</u>	<u>Date</u>	<u>Age</u>	<u>Me</u>	<u>Sd</u>	<u>C.I. (95%)</u>	<u>N</u>
1982	25.08	0+	43.4	3.9	42.2- 44.6	46
"	"	1+	68.8	6.2	64.6- 73.0	9
1982	21.10	0+	45.7	4.3	45.0- 46.4	150
"	"	1+	79.5	11.4	74.9- 84.1	26
"	"	2+	130.0	-	-	1
1983	04.08	1+	70.8	4.9	69.0- 72.6	30
"	"	2+	114.0	-	-	1
1983	22.10	1+	75.8	6.6	74.0- 77.6	55
"	"	2+	126.5	13.5	118.2-134.8	11

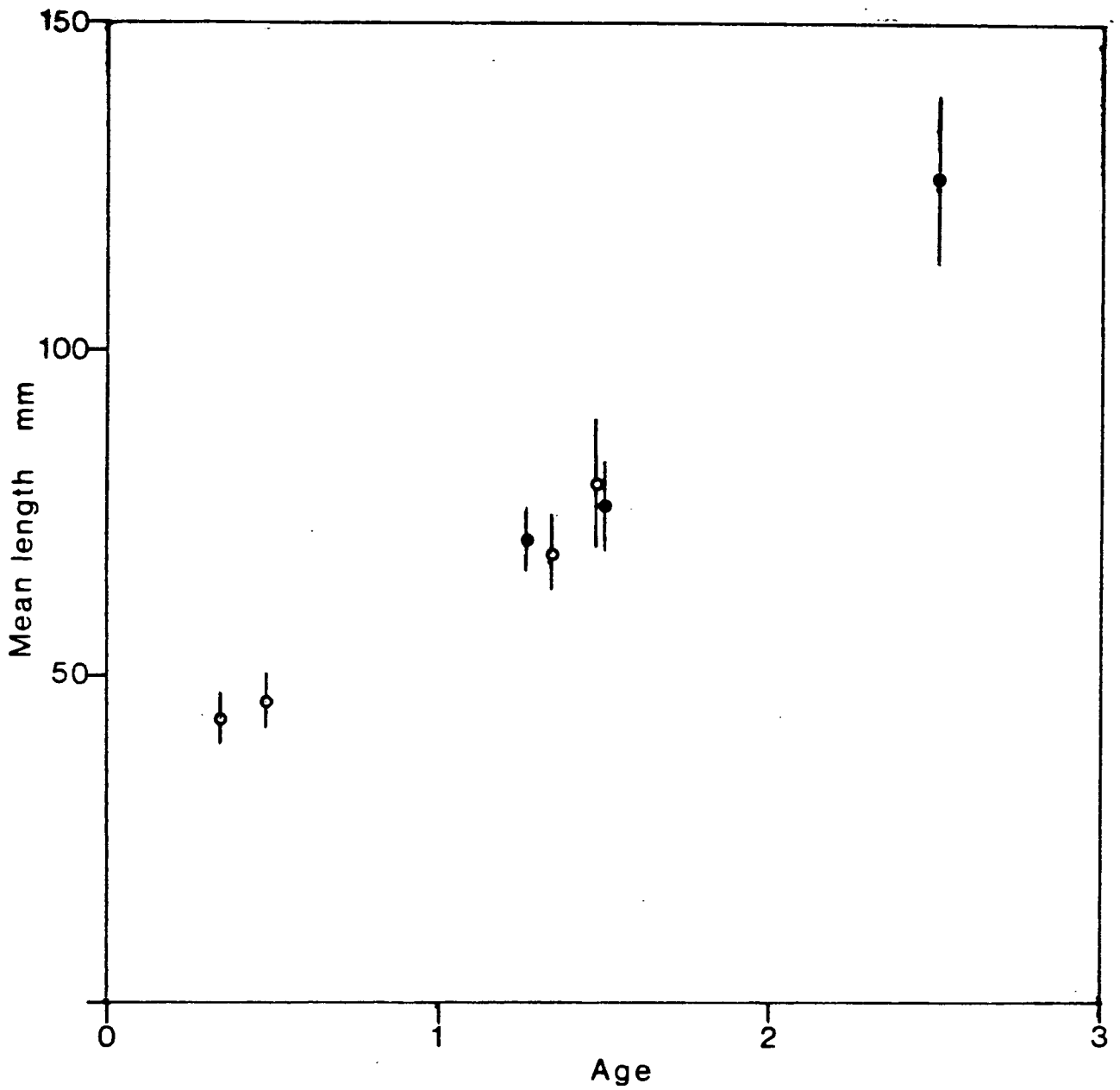


FIGURE 4.3: Growth of juvenile salmon in L. Medalfellsvatn. Circles represent mean lengths of an age class and vertical lines the standard deviation of the mean. Open circles represent samples from 1982 and the closed circles samples from 1983.

In 1983 no fry were found on either sampling date. Parr densities in the lake ranged from 0-1.0 in August to 1.0-3.0 in October. On average the density increased threefold during the period, but the difference was not statistically different ($P>0.05$) for this period.

4.3.5 Growth in length

Growth of all salmon fry and parr sampled in L. Medalfellsvatn during the study period is presented in Figure 4.3 and the data are summarized in Table 4.8.

Data from all stations fished within the lake on each sample date were pooled due to small sample size and where the sample size was sufficient there were no significant differences ($P<0.05$) in mean lengths between age classes in different sample sites.

Growth of both fry and parr (Table 4.8) was very slow from August to October in both years. Mean lengths of fry in 1982 increased only from 43.4-45.7 mm from August to October. This was also seen for salmon parr. Their mean lengths increased from 68.8-79.5 mm in 1982 and from 70.8-75.8 mm in 1983.

Changes in growth both for fry and parr were not significantly different ($P<0.05$) between August and October. This is indicative of the short growing season for salmon in Iceland. Most of the growth takes place from June to August.

4.4 DISCUSSION

4.4.1 Lake use by wild stocks of juvenile salmon

The naturally occurring use of lake habitat by wild stocks of juvenile Atlantic salmon appears to be rather uncommon. In Iceland Kristjánsson (1973) reported that salmon parr were found inhabiting L. Medalfellsvatn and Jónsson (1981) reported the occurrence of parr in L. Eyrarvatn, a source of the salmon river Laxá in Leirársveit. Elsewhere, Gravem and Haraldstadt (1982) reported that salmon parr were found in L. Vangsvatnet in Norway. In Newfoundland, Canada, wild Atlantic salmon are common inhabitants of lakes and Pepper (1976) concluded that the movement of parr from streams to lakes was mediated by unfavorable conditions such as crowding and low water in the streams. Chadwick and Green (1985) compared the smolt production of the Western Arm Brook river system to the smolt production in fluvial habitat and estimated that as much as 67% of the smolt production occurred in lakes and steadies which constituted 98.5% of the available habitat for salmon production. Chadwick and Green suggested that a greater proportion of parr would move into ponds as stock density increased. Elsewhere in eastern Canada Huntsman (1945) reported that young salmon inhabited lakes for varying periods. Saunders (1960) found that an artificially created 2 ha pond served as a summer rearing area for some Atlantic salmon parr and that some parr moved into the pond prior to their spring smoltification. Saunders and Gee (1964) showed that pools were useful habitat for young Atlantic salmon under conditions of low stream flow and that the fish moved to pools and deep riffles in autumn.

4.4.2 Distribution of juvenile salmon within L. Medalfellsvatn

The results from this study show that juvenile salmon had a widespread distribution in the littoral area of L. Medalfellsvatn and were mainly found on shallow rocky bottom. These results are supported by Pepper (1976) who similarly found that shallow, rocky ponds in Newfoundland were extensively used by salmon parr. However, the technique used for sampling fish in L. Medalfellsvatn, is restricted to shallow littoral areas and different sampling techniques are needed to investigate the occurrence of salmon in deeper areas of the lake. Recent findings, however have shown that salmon parr are never caught very far from the shore in the lake (S.M. Einarsson and V. Jóhannsson 1985, unpublished data) and nearly always the salmon are caught on a rocky substrate.

Juvenile salmon appeared to dominate the littoral area of the lake. Beside salmon, arctic charr, brown trout, eels and sticklebacks occur in the lake. The lake holds dense populations of arctic charr and brown trout and the fishing yields of these species ranges from 2.9-5.1 kg/ha/year (Gudjónsson 1954, Kristjánsson 1973). The sampling technique used is only efficient in catching small fish (>10 cm). Larger fish probably easily avoid the fisherman due to limited range of the fishing gear. The catches therefore only represent the relative number of young fish that occupy the littoral area. Arctic charr exclusively use the shallow littoral areas in the lake for spawning grounds. Recent findings show that charr fry are present in June in the littoral area but later in the season they disappear indicating that fry migrate to deeper areas of the lake early in the summer (S.M. Einarsson and V. Jóhannsson 1985,

unpublished data). The absence of trout possibly indicates that juvenile trout are not present in the lake at this stage or prefer deeper areas of the lake. Gravem and Haraldstadt (1982) found that in L. Vangsvatnet juvenile trout dominated the littoral area at depths 0-5 m and salmon parr were found in deeper areas close to the bottom at depth 5-15 m. Arctic charr mainly utilized pelagic areas in the lake. These authors suggested that the segregation of the species was due to competition and the depth distribution of salmon parr was affected by the trout and charr populations. They explained the segregation by differences in aggression of the species the trout being the most aggressive of the three and salmon being more aggressive than charr.

4.4.3 Movement of juvenile salmon to lake environment

The results from this study indicate that the lake is utilized by juvenile salmon as early as the fry stage and juveniles remain in the lake environment until smolting. This is the first study that finds salmon fry occupying a lake environment, since so far only parr have been reported to inhabit lakes (Pepper 1976, Gravem and Haraldstadt 1982, Kristjánsson 1973, Jónsson 1981, Huntsman 1945). Fry were found in the lake in considerable numbers in 1982, but not in 1983. Recently fry were found in the lake as early as the middle of July (S.M. Einarsson and V. Jóhannsson 1985, unpublished data).

Generally, following emergence the fry of salmoniid fishes typically disperse from their gravel nest site and move varying distances depending on the species and the population, to their initial juvenile feeding habitat (Northcote 1978), which for Atlantic salmon and several other species means an upstream or

downstream dispersal within a river habitat. Other salmoniid species have a different dispersal mechanism from parental reproductive habitat into a nursery lake. Such migration is achieved by upstream or downstream movement from the nest site. Species illustrating this dispersal pattern, include sockeye salmon, rainbow trout and cutthroat trout (Northcote 1978). Dispersal pattern of this type is not known to occur for Atlantic salmon fry. Studies on Atlantic salmon fry dispersal have furthermore shown that dispersal of emerging fry is mostly in the downstream direction (Mills 1969, Egglshaw and Shackley 1973). The dispersal of fry is also limited to the first few months of life. Studies by Egglshaw and Shackley (1973) and Kennedy (1982) suggested that over 70% of emerging fry do not move further than 200 m downstream from the nest site. No fry were captured 400 m below the stocking point, and very few fry moved upstream and not very far.

Atlantic salmon fry were found in the present study as far as 1200 m upstream from the outlet river and 1700 m downstream of the nearest inflowing stream. To account for the presence of fry in the lake, three factors could possibly explain this phenomenon.

1. Upstream migration of fry from outlet into lake.
2. Downstream migration from inflowing streams.
3. Spawning of Atlantic salmon within the lake.

The results of this study suggest that recruitment of juvenile Atlantic salmon is achieved at least in part by upstream migration from the outlet of L. Medalfellsvatn. This is supported by spawning observations (Chapter 6) where it was found that the major spawning areas of lake dwelling salmon

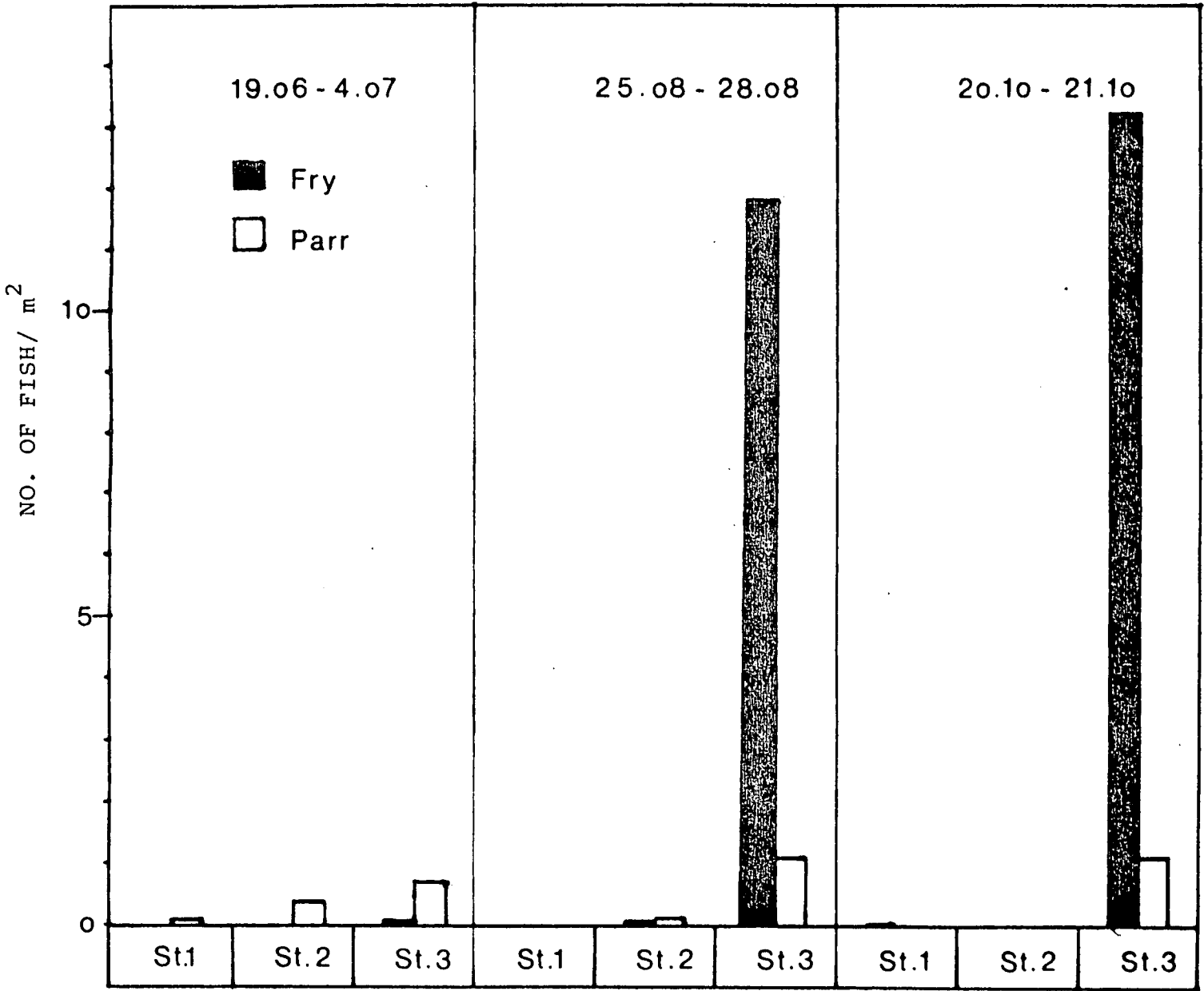


FIGURE 4.4: Density of salmon in R. Flekkudalsá (St. 1), R. Sandsá (St. 2) and in the R. Bugða (St. 3) during the summer in 1982.

are located in the outlet of the lake and there is high population density of juvenile salmon in the outlet compared to the inflowing streams (Figure 4.4). Population density of fry in August to September 1982 was 170-200 fold higher in the outlet compared to the inflowing streams and during the period August to October 1982 density of fry increased approximately thirtyfold. Upstream migration of this kind could be either genetically or environmentally controlled (Northcote 1969). Pepper (1976) concluded that movement of parr from streams to lakes was mediated by unfavourable conditions such as crowding and low water and Chadwick and Green (1985) suggested that production in lakes could increase as more fish moved into lakes at higher stock densities. Rimmer et. al. (1983) considered that movement away from shallow water in autumn could remove fish from areas prone to freezing or low water in autumn and winter. Certainly the high population density in the outlet of the lake and severe winter conditions in Iceland could be the factors that induce migration into the lake, but genetical controlling factors can not be excluded. While migration control mechanisms in different population of salmon may differ to a large extent (Chapman and Björn 1969, Northcote 1969) the results of these studies and the present one indicate that the use of standing water by young salmon probably depends on their availability and physical characteristics of watersheds, such as suitable spawning areas close to lakes, and tend to increase at higher stock densities.

Finally, however, the possibility that the presence of fry and parr in the lake to some extent could be explained by spawning of adult salmon in the lake must be mentioned.

On the northern side of the lake there are a number of small springs that upwell close to the shore. Close to these springs salmon fry have been found. It is a possibility that salmon could possibly make use of these springs to some extent for spawning which would ensure sufficient supply of oxygen for successful development of eggs. What especially favours this hypothesis is that fry have been found as far as 1200 m from the most likely spawning areas. The swimming capacities of fry are small compared to older parr and a migration of this scale is unheard of for salmon fry. This hypothesis however remains a field for further studies.

4.5 Summary

1. Juvenile salmon have a widespread distribution in the shallow littoral areas of L. Medalfellsvatn especially on a rocky substrate.
2. Juvenile salmon spend most of their lifecycle in the lake environment and have been found as early as at the fry stage in the lake.
3. Recruitment to the lake is most likely achieved by upstream migration from lake outlet spawning grounds, but lake spawning can not to be excluded.

CHAPTER 5

THE SMOLT MIGRATION FROM LAKE MEDALFELLSVATN

5.1 INTRODUCTION

In the Laxá in Kjós river system in Iceland a total area of 284.9 ha is available for production of juvenile salmon. Of the total area available for Atlantic salmon production in the river system L. Medalfellsvatn represents 70% of the total rearing habitat. Usually the potential freshwater production of Atlantic salmon is estimated by the amount of fluvial habitat available to parr (Elson 1975). Parr have been found in the lake environment in Iceland (Kristjánsson 1973, Jónsson 1981), Newfoundland (Pepper 1976) and in Norway (Gravem and Haraldstadt 1982). Since L. Medalfellsvatn is a dominant feature of the Laxá in Kjós river system it is necessary to assess the importance of the lake to Atlantic salmon production. Lakes are known to be very important to the overall production of Atlantic salmon in Newfoundland (Chadwick and Green 1985, Ryan 1986).

The aim of this chapter is to assess the smolt production in an Icelandic lake and to document some of the biological characteristics of the smolt migration. This study is believed to contribute to a general knowledge of the importance of lakes to Atlantic salmon production. It is also of interest to investigators involved in the management of Atlantic salmon, particularly in Iceland.

5.2 METHODS

5.2.1 Sampling gear and sampling sites

The smolt migration from L. Medalfellsvatn was sampled in the R. Bugda below the outlet of the lake. In 1982 the sample site was located 15 m below the outlet where the river flows in a shallow riffle with a deeper channel close to the bank on the northern side. At the sample site the river was 18 m wide with a mean depth of 25 cm. The substrate consisted mainly of gravel interspersed with rubble and boulders. The sampling gear consisted of a weir fence with attached fyke net and a floating live box, as described in detail by Poe (1975).

In 1983 a permanent fish counting fence designed for catching both upstream and downstream migrants was installed during April and May. The counting fence was situated in the R. Bugda 50 m below the lake outlet (Plate 5.1). At the sample site the river was 15 m wide. The bottom substrate consisted mainly of rubble and boulders interspersed with gravel. The trap was based on the Wolf trap principle which has been shown to be the most effective for sampling migratory fish (Mills 1971). The base of the trap was made of concrete. The vertical part of the trap consisted of several iron poles which are inserted in the concrete base. The sides of the poles were U-shaped and timber planks were used to dam the river to a height of 60 cm. The horizontal framework consisted of aluminium frames covered with screens made of steel bars spaced 10 mm apart. Figure 5.1 gives details of the trap. The trap operates by water flowing through the horizontal screens sieving downstream migrants from the water and the fish are channelled into a trough leading to the live box.



PLATE 5.1: The counting fence for downstream and upstream migrants in R. Bugða (Photos by V. Jóhannsson).

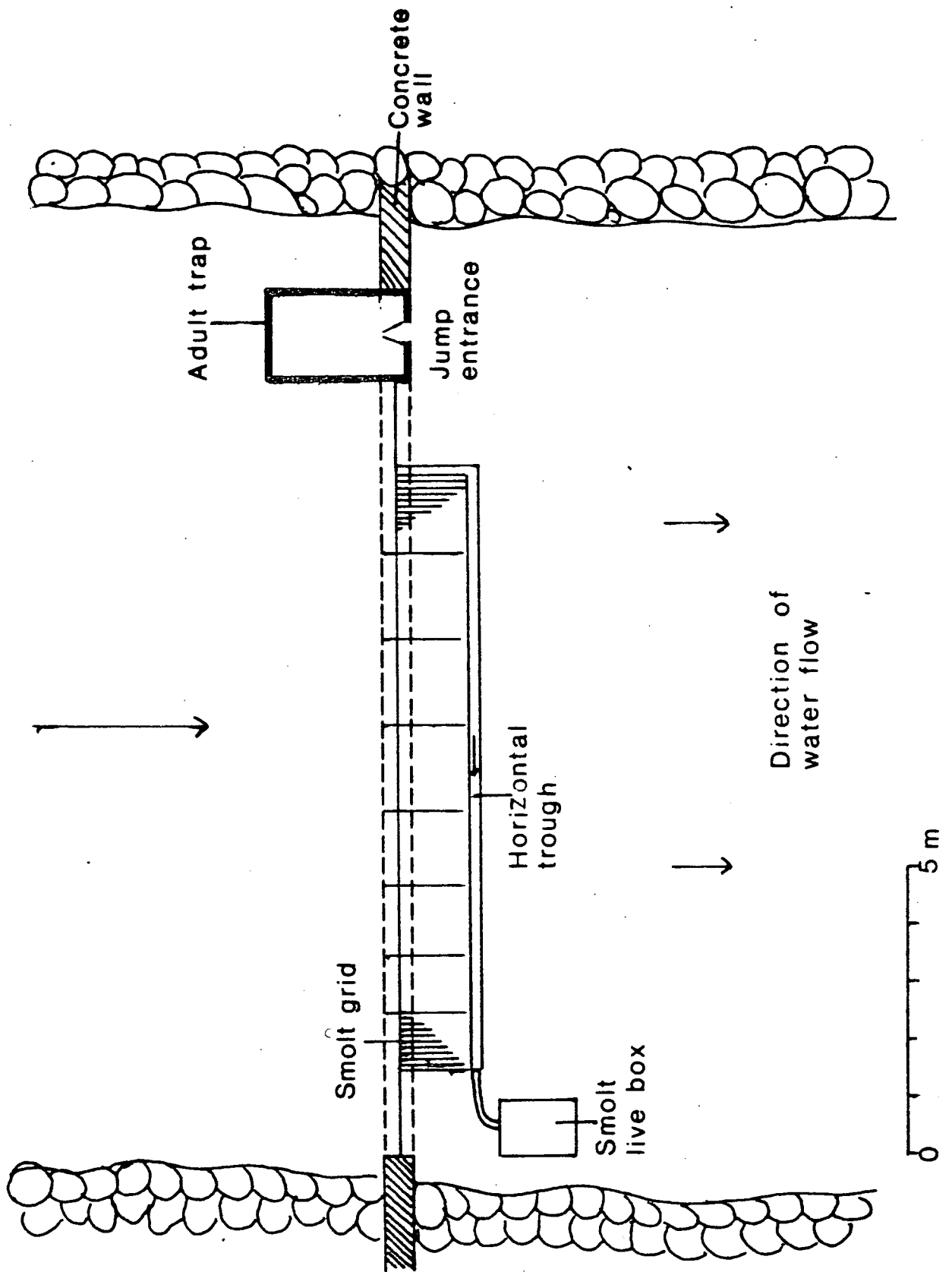


FIGURE 5.1. Diagram of the Wolf grid-type trap for upstream and downstream migrants in R. Bugda.

The fence is easily removable and is kept on land during the winter to avoid damage.

5.2.2 Sampling procedures

The traps were installed in May each year, except for 1984 when no sampling was carried out. Trap operation started during the first week of May in 1982 and 1985 and during the last week of May in 1983. The smolt traps were removed at the end of the smolt migration. The trap was removed at the end of June in 1982, but in mid-July in 1983 and 1985.

The majority of the smolt run was enumerated in 1982 and 1985 except for five days in June 1982 when the trap was inoperable due to floods. In 1983 the count was incomplete due to severe floods for long periods. The part of the run that was missed in 1982 was estimated by assuming that the smolt run approached a normal distribution pattern and that a similar number of smolts migrated during the missing period as in the week after the run reached its peak. It was thus estimated that 600 smolts had been missed during that period or 23% of the total migration. This however is in no way a precise estimate and must not be considered as such.

The traps were efficient in catching all downstream migrating fish greater than 9 cm in length except at times of flood. This included the full range of smolt sizes. Other fish caught included salmon parr, brown trout and sticklebacks.

The traps were checked several times daily and nightly when necessary. Catches of fish were either

counted and then quickly released and allowed to continue their migration, or transferred to a nearby holding box for sampling purposes.

Length and weight measurements of smolts were made several times throughout the sampling period each year. Prior to handling, fish were anaesthetized using MS-222 (Tricaine Methane Sulfonate) and after handling allowed to recover in freshwater before being released. Fish were measured from the tip of the nose to the fork of the tail (fork length) to the nearest mm and weighed to the nearest gram using 50 gr Pesula spring balances..

Fish were aged from scale samples taken from the region between the lateral line, and the dorsal fin. In the laboratory impressions of the scales were made by rolling on acetate strips. The scales were aged at 55x magnification with a Microps microprojector, and annuli were discerned by standard criteria (Harvey 1959).

The sex ratio of migrating smolts was determined by gross examination of the gonads of smolts from the 1983 migration.

Condition factor (CF) was calculated using the equation:

$$(5.1) \quad CF = (W/FL^3) \times 100$$

where: W = weight (g)
 FL = fork length (cm)

Several biological characteristics of the smolt runs were estimated indirectly. These included standing crop of the smolt migrations, production of smolts from L. Medalfellsvatn and back-calculated growth of smolts.

The standing crop in kilograms (kg) of smolt migrations was calculated from the equation:

$$(5.2) \quad SC = N_i \times W_i$$

where: N_i = number of smolts in a migration of year_i
 W_i = mean weight of smolts taken in year_i

The production of smolts migrating from L. Medalfellsvatn was expressed in g/m² and was calculated from the equation:

$$(5.3) \quad P = SC(g) / A(m^2)$$

where: SC = standing crop of a smolt migration in year, i
A = Surface area of L. Medalfellsvatn.

The fork length of smolts at time of annulus formation was back-calculated from scale samples taken in 1982 and 1983. Scale growth and the growth of the fish were considered to be isometric (Harvey 1959). The distances between scale annuli were measured from the focus along the longest oral radius (Tesch 1968). Linear relationship between total scale radius and fork length was then determined by using samples of both smolt, fry and parr taken during sampling in 1982 and 1983 by using regression analysis. Lengths were then back-calculated by the traditional Lee method (Carlander 1981) using the equation:

$$(5.4) \quad L_i = a + (L_C - a/S_C)S_i$$

where: L_C = Fork length of fish at capture
 S_C = Total scale radius
 a = Intercept of the body-scale regression
 s_i = Scale measurements to each annulus
 L_i = Back-calculated length of each annulus

5.2.3 Statistical analysis

The effect of environmental factors (day, water temperature, air temperature and rainfall) on the number of smolts migrating during the smolt period was tested for the 1982 and 1983 smolt migrations by using least squares analyses of variance which estimates how much of the variation in the dependent variable (N and Log N of smolts) is explained by independent variables (Campbell 1975). The test was carried out using Harveys statistical program on the computer in the Agricultural Research Institute in Iceland.

Variation in fork length, weight and smolt condition were compared between years. Size differences between smolt ages and sexes were also tested. Differences between means were done with students t-test (Elliot 1977) by comparing, t_s to tabulated values of t.

$$(5.5) \quad t_s = (Y_1 - Y_2) / ((S_1^2 - N_2) + (S_2^2 - N_1))$$

where Y_1 = Means of sample i
 S_i^2 = variance of sample i
 N_i = Number of sample i

5.3 RESULTS

5.3.1 Magnitude of the smolt migration

Atlantic salmon smolts formed the greatest part of the catch in the trap (Table 5.1) and constituted 97.6-99.2% of the total number of fish caught during operation of the trap in 1982-1985.

A total of 2607 smolts were estimated to have migrated through the smolt trap in 1982. Of these, 2027 were caught in the trap but the rest (23%) were estimated to have migrated during a 5 day interval when the trap was out of operation due to floods. The number of smolts caught in 1983 and 1985 was 413 and 663 respectively. The number taken in 1983 was certainly an underestimate since the trap was only partly operable for long periods of time due to severe floods. In 1985 all smolts migrating were caught, but a large number of smolts did not migrate that year possibly due to drought and stayed on in the lake (S.M. Einarsson and V. Jóhannsson, unpublished data).

Salmon parr also occurred in small numbers (Table 5.1). Other species encountered were brown trout parr and a few resident arctic charr. The counts of both salmon and trout parr are underestimates due to floods and the inefficiency of the traps to capture small fish.

5.3.2 The timing of the smolt migration

The duration of the smolt run in 1982 was 32 days with the first smolts migrating on 26 May and the last on 27 June (Table 5.1). The peak of the migration (Figure 5.2) occurred during the second

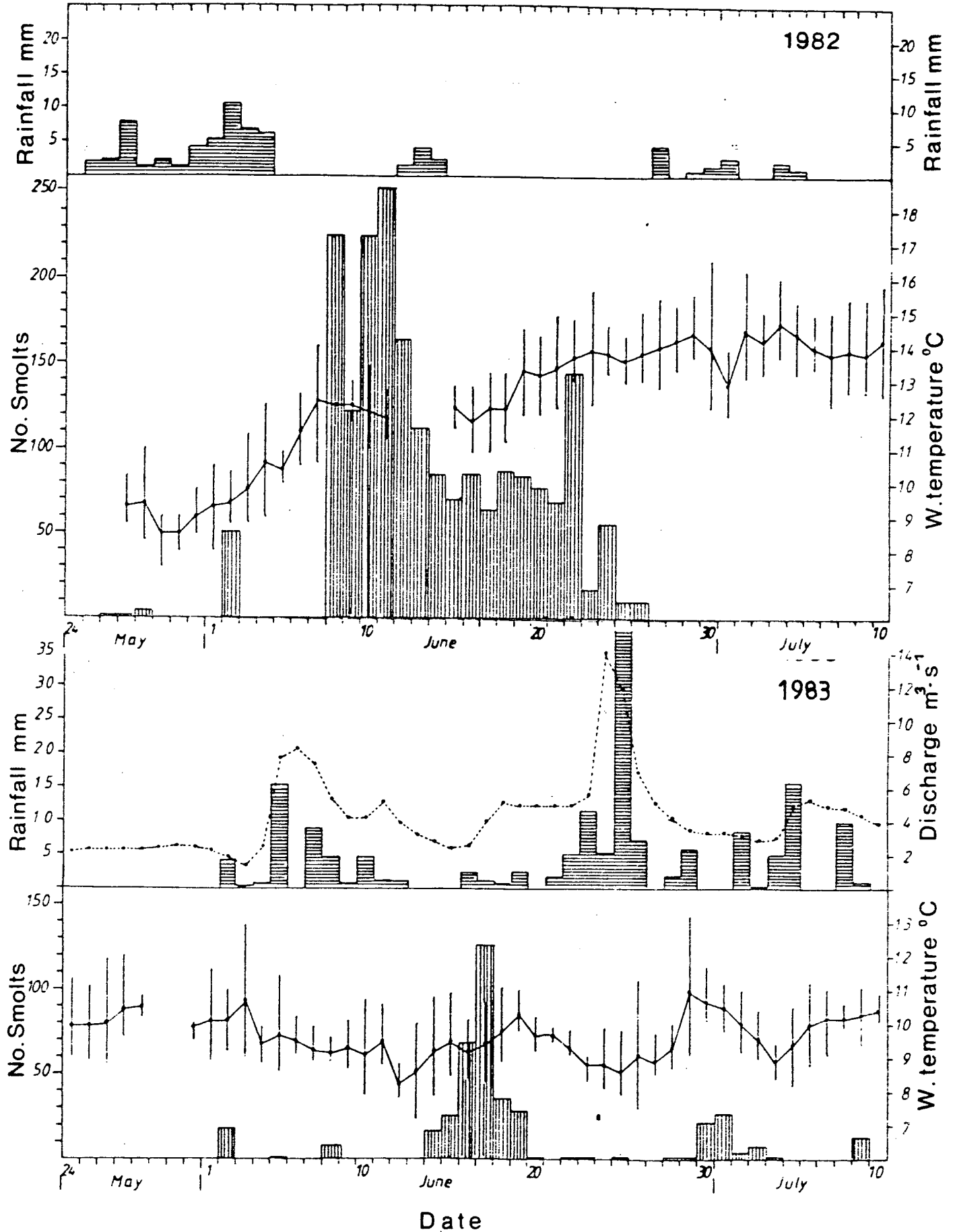


FIGURE 5.2. Daily totals of smolts (▨) caught in the R. Bugda smolt trap in 1982-1983. Mean, maximum and minimum water temperature (†) and discharge (---) of R. Bugda and rainfall (▨) at the Medalfell farm is also shown.

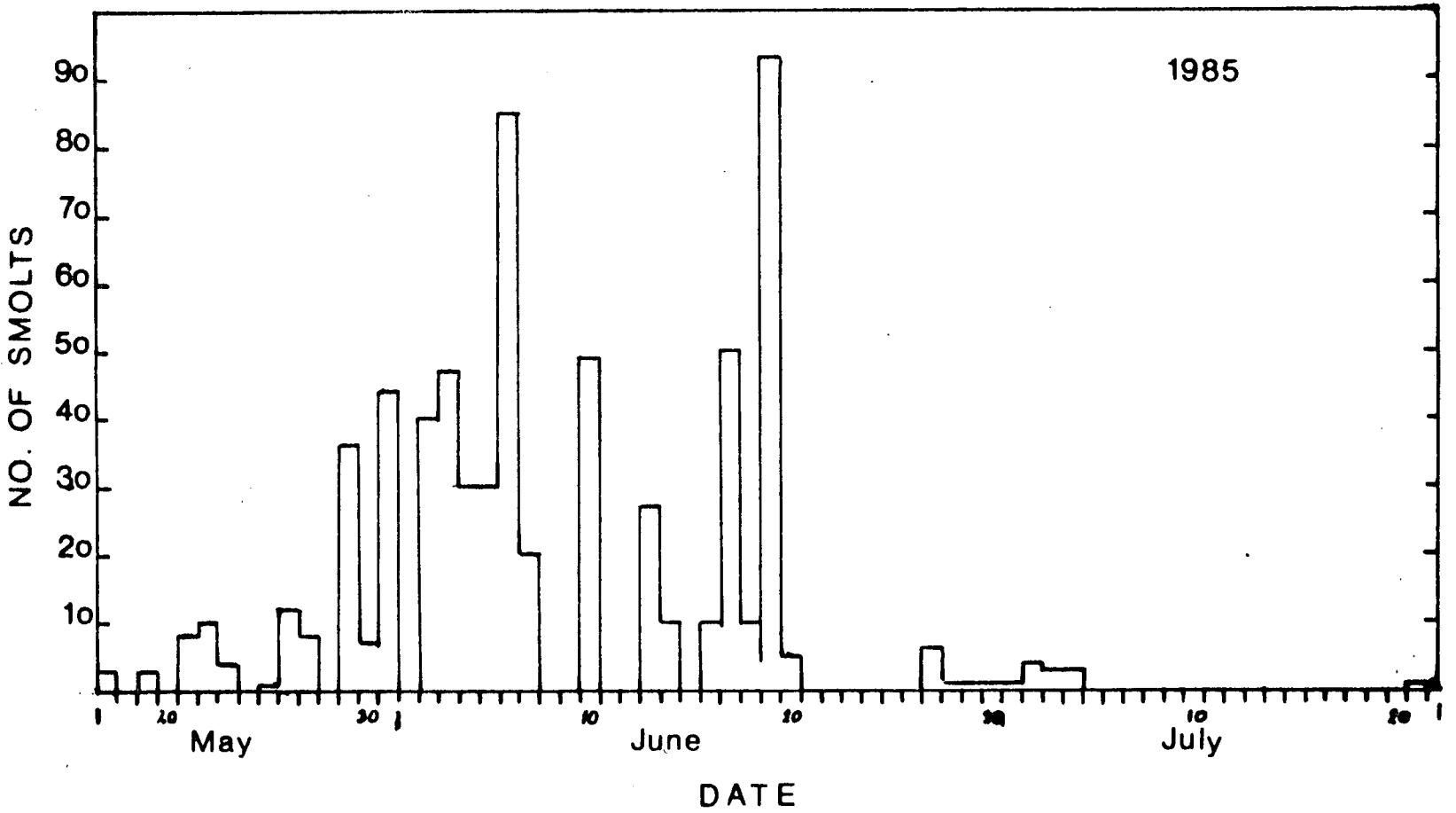


FIGURE 5.3. Daily totals of salmon smolts during 1985 observations on R. Bugda.

TABLE 5.1

Daily catches of downstream migrating fish during
the smolt trap operation in R. Bugda 1982-1985
by species and date.

The trap was not operated in 1984.

(S=Smolt, P=Parr, A=Adults)

Date	1982				1983				1985			
	Salmon		Tr.	Ch.	Salmon		Tr.	Ch.	Salmon		Tr.	Ch.
	S	P	P	A	S	P	P	A	S	P	P	A
11/5	0	0	0	0					0	0	0	0
12	0	0	0	0		T			0	0	0	0
13	0	0	1	0		R			0	0	0	0
14	0	0	0	0		A			0	0	0	0
15	0	0	0	0		P			0	0	0	0
16	0	0	2	0					0	0	0	0
17	0	0	0	0		N			3	0	1	0
18	0	0	2	2		O			0	0	0	0
19	0	0	0	0		T			3	0	2	0
20	0	0	0	1					0	0	0	0
21	0	0	0	0		O			8	0	0	0
22	0	0	0	0		P			10	0	0	0
23	0	0	0	0		E			4	0	0	2
24	0	0	0	0		R			0	0	0	0
25	0	0	0	0		A			1	0	0	0
26	1	3	0	0		T			12	0	0	0
27	1	0	0	1		E			8	0	0	0
28	4	0	0	0		D			0	0	0	0
29	0	0	0	0					36	0	0	0
30	0	0	2	0					7	0	0	0
31	0	0	0	0	0	0	0	0	44	0	0	0
1/6	0	0	0	0	0	0	0	0	0	0	0	0
2	51	0	0	0	18	0	0	0	40	0	0	0
3	TRAP NOT				0	0	0	0	47	0	0	0
4	OPERATED DUE				0	0	0	0	30	0	0	0
5	TO FLOODS				1	0	0	0	30	0	0	0

Date	1982				1983				1985			
	Salmon		Tr.	Ch.	Salmon		Tr.	Ch.	Salmon		Tr.	Ch.
	S	P	P	A	S	P	P	A	S	P	P	A
6					0	0	0	0	85	0	0	0
7					0	0	0	1	20	0	0	0
8	225	0	0	0	8	0	0	0	0	0	0	0
9	133	3	0	1	0	0	0	1	0	0	0	0
10	225	0	0	0	0	0	0	0	49	0	0	0
11	251	1	0	0	0	0	0	0	0	0	0	0
12	164	0	0	0	0	0	0	0	0	0	0	0
13	112	0	0	0	0	0	0	0	27	0	0	0
14	85	0	0	0	17	0	0	0	10	0	0	0
15	70	0	0	0	26	1	0	0	0	0	0	0
16	87	0	0	0	69	0	0	0	10	0	0	0
17	64	0	0	0	127	0	2	0	50	0	0	0
18	87	0	0	0	36	0	0	0	10	0	0	0
19	84	5	0	0	29	1	0	0	93	0	0	0
20	77	0	0	0	1	0	0	0	5	0	0	0
21	69	0	0	0	0	0	0	0	0	0	0	0
22	144	26	0	0	1	0	0	0	0	0	0	0
23	17	0	0	0	1	0	0	0	0	0	0	2
24	56	0	0	0	0	0	0	0	0	0	0	0
25	10	0	0	0	1	0	0	0	0	0	0	0
26	10	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	1	0	0	0	6	0	0	0
28	0	0	0	0	1	0	0	0	1	0	0	0
29	0	0	0	0	1	0	0	0	1	0	0	0
30	0	0	0	0	23	0	0	0	1	0	0	0
1/7					27	0	0	0	1	0	0	0
2		T			4	2	0	0	4	0	0	0
3		R			8	0	0	0	3	0	0	0
4		A			1	0	0	0	3	0	0	0
5		P			0	0	0	0	0	0	0	0
6					0	0	0	0	0	0	0	0
7		N			0	0	0	0	0	0	0	0
8		O			0	0	0	0	0	0	0	0
9		T			13	0	0	0	0	0	0	0

Date	<u>1982</u>				<u>1983</u>				<u>1985</u>			
	<u>Salmon</u>		<u>Tr.</u>	<u>Ch.</u>	<u>Salmon</u>		<u>Tr.</u>	<u>Ch.</u>	<u>Salmon</u>		<u>Tr.</u>	<u>Ch.</u>
	<u>S</u>	<u>P</u>	<u>P</u>	<u>A</u>	<u>S</u>	<u>P</u>	<u>P</u>	<u>A</u>	<u>S</u>	<u>P</u>	<u>P</u>	<u>A</u>
10					0	2	0	0	0	0	0	0
11			O		0	0	0	0	0	0	0	0
12			P						0	0	0	0
13			E						0	0	0	0
14			R						0	0	0	0
15			A				TRAP NOT		0	0	0	0
16			T				OPERATED		0	0	0	0
17			E						0	0	0	0
18			D						0	0	0	0
19									1	0	0	0
<hr/>												
Total number												
	2027	38	7	5	413	6	2	2	663	0	3	2
<hr/>												
Percent number												
	97.6	1.9	0.3	0.2	97.6	1.4	0.5	0.5	99.2	0	0.4	0.4
<hr/>												

week of June. In 1983 the pattern of the smolt-migration was markedly different from the previous year (Figure 5.2). The run started on 2 June and the duration of the run was 39 days with the last smolts caught on 10 July. The spring and summer of 1983 were abnormally cold and water temperatures seldom rose above 10°C. June and July were wet and due to a heavy snowfall the previous winter, the discharge of R. Bugda was four times greater than the normal. The severe environmental conditions caused great difficulties in operating the trap due to floods, but the trap always functioned partly and it is believed that the number of smolts caught was indicative of the pattern of the run although it was not possible to estimate the total run. Most of the smolts were caught in two periods of time from 14 June to 19 June and 29 June to 3 July. In 1985 the pattern of the run was different from previous years. The first smolts migrated on 17 May and the last smolt was caught on 19 July (Table 5.1). Most of the smolts were caught in two distinct peaks (Figure 5.3) in June, but the smolts migrated irregularly and over an extended period of 64 days. Most of the run however was caught within a 49 days interval. Temperatures were normal in 1985 but the summer of 1985 was very dry with little rain until autumn. Further studies in the lake showed that large number of smolts stayed on in the lake and did not migrate, possibly lacking a stimulus to migrate (S.M. Einarsson and V. Jóhannsson, unpublished data).

The number of smolts caught in 1982 and 1983 was highly influenced by water temperature and for both years the initiation of the smolt run correlated with water temperatures above 9.0°C. When daily catch figures were tested against environmental factors (day, water temperature, air temperature and

TABLE 5.2

A

Regression analysis of the correlation between the independent variables, day, water temperature and rainfall. The value of $r = 1$ shows that the relationship is a straight line and $r = 0$ shows no relationship of linearity.

<u>Variables</u>	<u>Correlation (r)</u>
Day - Water temperature	0.4783
Day - Air temperature	0.2354
Day - Rainfall	0.0415
Water temperature - Air temperature	0.5701
Water temperature - Rainfall	-0.1766
Air temperature - Rainfall	-0.1913

B

Least squares analysis of variance when number of smolts (N and LogN) caught in the R. Bugda smolt trap are designated as dependent variables and day, water temperature, air temperature and rainfall are independent variables.

<u>Independent variables</u>	<u>Dependent variables</u>			
	<u>N</u>		<u>Log N</u>	
	<u>F</u>	<u>P</u>	<u>F</u>	<u>P</u>
Day	1.987		2.408	
Water temperature	11.536**	P>0.1	26.273***	P>0.01
Air temperature	2.668		1.142	
Rainfall	0.099		0.356	

rainfall) both number of smolts and the transformed number of smolts ($\log N$) showed highly significant relationships with water temperature ($P < 0.1$, and 0.01 respectively), but no significant relationships with the other independent variables (Table 5.2).

5.3.3 Size composition

A total of 1087 smolts were measured during the operation of the smolt trap in 1982-1985 (Table 5.3). The length distribution for all smolts measured approached a normal distribution (Table 5.3) with a mean length of 14.23 cm. The mean lengths of smolts were not significantly different in 1982 and 1983 ($P > 0.1$), but in 1985 smolts were on average 2 cm larger than in 1982 and 1983 (Figure 5.4) and variation in mean length between 1985 and 1982 and 1983 was highly significant ($P < 0.001$). Smolts ranged in size from 10.1-18.8 cm in 1982-1983, but in 1985 very large smolts occurred in small numbers with the largest being 36.5 cm (Table 5.3).

There were generally significant size differences between smolt ages 2+ and 3+ (Table 5.4) for smolts sampled in 1982 and 1983. Fish of smolt age 2+ were significantly smaller than those of smolt age 3+ in 1982 ($P < 0.05$) and in 1983 ($P < 0.1$). Fish of smolt age 3+ were not significantly smaller than fish of smolt age 4+ either in 1982 or 1983 ($P > 0.05$). Fish of smolt age 5+ could not be tested against any other age group because of the small sample size. Fish of smolt age 4+ were significantly larger than 2+ smolts both in 1982 and 1983 ($P < 0.05$).

Analysis of sex composition, smolt age and smolt size (Table 5.5) showed that there were no significant size differences ($P > 0.05$) between sexes for the two smolt ages 2+ and 3+.

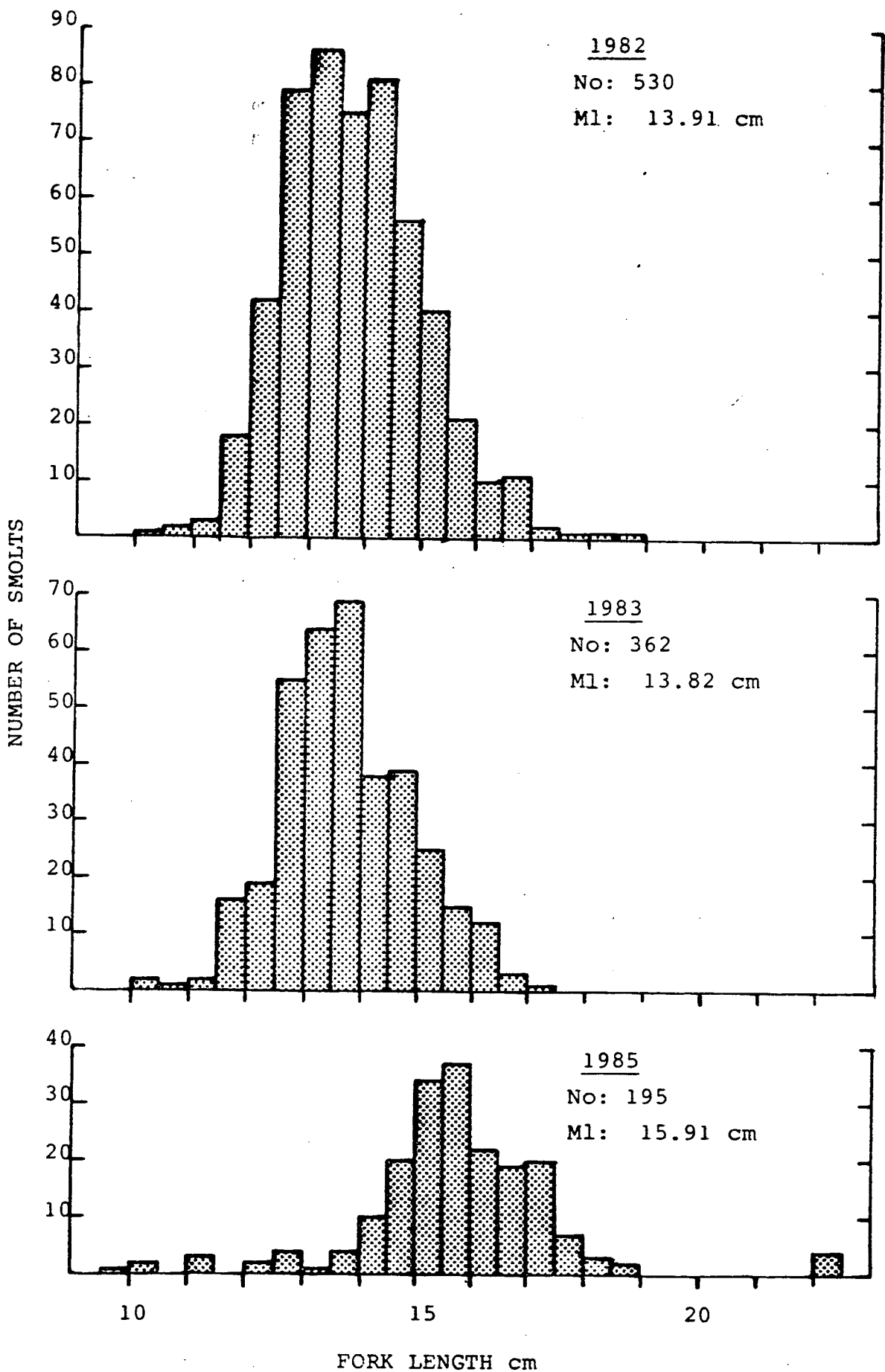


FIGURE 5.4. Length distribution of smolts measured during the smolt trap operation in R. Bugda 1982-1985.

TABLE 5.3

Length distribution of smolts (fork length) according to 0.5 cm length classes caught in the R. Bugda smolt trap in 1982-1985. The smolt trap was not operated in 1984.

Length interval cm	1982 n	1983 n	1985 n	Total N
9.6-10.0	0	0	1	1
10.1-10.5	1	2	2	5
10.6-11.0	2	1	0	3
11.1-11.5	3	2	3	8
11.6-12.0	18	16	0	34
12.1-12.5	42	19	2	63
12.6-13.0	79	55	4	138
13.1-13.5	86	64	1	151
13.6-14.0	75	69	4	148
14.1-14.5	81	38	10	129
14.6-15.0	56	39	20	115
15.1-15.5	40	25	34	99
15.6-16.0	21	15	37	73
16.1-16.5	10	12	22	44
16.6-17.0	11	3	19	33
17.1-17.5	2	1	20	23
17.6-18.0	1	1	7	9
18.1-18.5	1	0	3	4
18.6-19.0	1	0	2	3
19.1-19.5	0	0	0	0
19.6-20.0	0	0	0	0
20.1-20.5	0	0	0	0
20.6-21.0	0	0	0	0
21.1-21.5	0	0	0	0
21.6-22.0	0	0	0	0
22.1-22.5	0	0	1	1
22.6-23.0	0	0	1	1
>23	0	0	2	2
Total (N)	530	362	195	1087
Range (cm)	10.1-18.8	10.2-18.0	10-36.5	10-36.5
Mean length(cm)	13.91	13.82	15.91	14.23

TABLE 5.4

Smolt fork length at 4 smolt ages sampled during
the smolt trap operation in R. Bugda 1982-1983
(L=Mean fork length, SD=Standard deviation,
N=Number)

Age yr	1982			1983			Overall mean		
	L	SD	N	L	SD	N	L	SD	N
2+	12.9	0.95	21	13.2	1.07	43	13.1	0.21	2
3+	14.2	1.69	11	14.5	1.43	45	14.4	0.21	2
4+	14.4	1.40	3	15.6	1.20	2	14.5	0.14	2
5+	14.7	-	1	-	-	-	-	-	-
Total	13.4	1.43	35	13.7	0.35	91	13.7	0.35	2

The subtotals for age groups 2, 3, 4 and 5 do not necessarily add up to equal total N, as all fish could not be aged.

TABLE 5.5

Sex composition and mean fork length (cm) at two river ages for the 1983 smolt run migration. Sample size and standard deviation is also shown (M=Male smolt, F=Female smolt).

	<u>2+</u>		<u>3+</u>	
	<u>M</u>	<u>F</u>	<u>M</u>	<u>F</u>
Mean fork length	13.4	13.5	15.3	14.5
Standard deviation	0.6	0.9	2.2	1.1
Sample size	11	15	13	9

5.3.4 Age composition

The smolts migrating from L. Medalfellsvatn were predominantly 2+ and 3+ year old (Table 5.6, Figure 5.5). These two smolt ages constituted 91.4% and 96.8% of the smolt runs in 1982 and 1983 respectively (Table 5.6). In 1982 2+ smolts constituted 60% of the total smolt run but in 1983 2+ and 3+ smolts occurred in approximately equal proportions. The high proportion of 2+ smolts in 1982 is possibly a result of the small sample size.

The mean age of smolts was 2.49 years in 1982 and 2.57 years in 1983. The difference in mean age of smolts between years was not significant ($P > 0.05$).

5.3.5 Sex composition

During the 1983 smolt run the sex composition of migrating smolts was investigated from trap mortalities (Table 5.7). The total sex ratio of smolts was 49% males and 51% females. When broken up according to freshwater age 2+ smolts were predominantly females but 3+ smolts were predominantly males (table 5.7). The results could possibly be biased because of small sample size. No precocious males were found in the samples.

5.3.6 Smolt condition, weight and standing crop

The mean condition factor of smolts ranged from 0.89 in 1983 and 1985 to 0.90 in 1982 (Table 5.8). No annual difference in smolt condition could be detected ($P > 0.05$).

Mean weight of smolts was 26.9 g, 24.8 g and 35.9 g in 1982, 1983 and 1985 respectively (Table 5.9). The mean weight between 1982 and 1983 was not

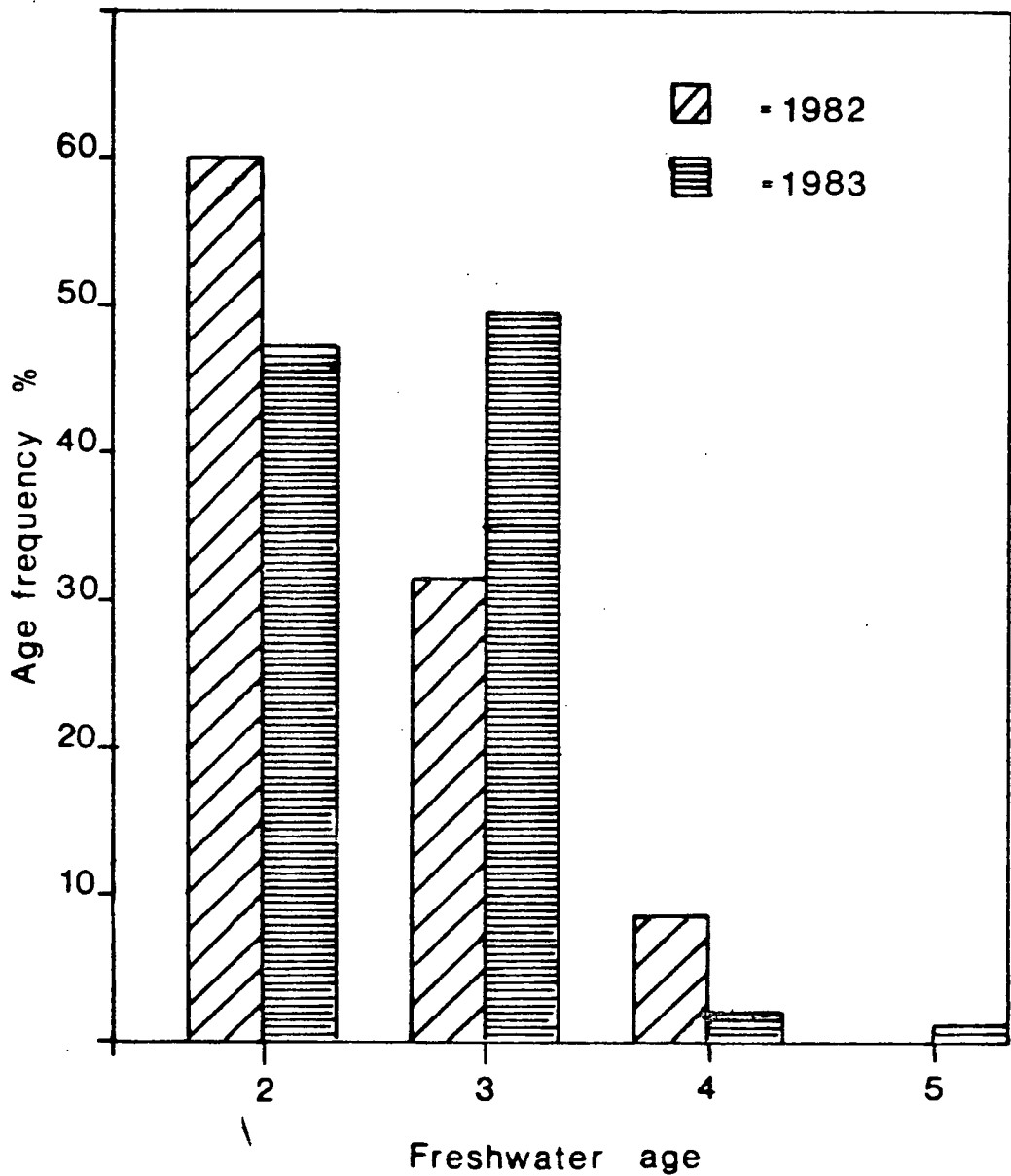


FIGURE 5.5. Age composition of salmon smolts sampled during the smolt trap operation in R. Bugda 1982-1983.

TABLE 5.6

Age composition of Atlantic salmon smolts samples in the R. Bugda smolt trap 1982-1983.

Mean age, standard deviation and sample size is also given for each year.

Freshwater age	1982		1983	
	N	%	N	%
2+	21	60.0	43	47.2
3+	11	31.4	45	49.5
4+	3	8.6	2	2.2
5+			1	1.1
Total	35	100.0	91	100.0
Mean age (yr)	2.49		2.57	
S. deviation	0.66		0.60	

TABLE 5.7

Sex composition of smolts by freshwater age and total for the ages combined for smolts sampled for sex determination in 1983

Sex	<u>Freshwater age</u>				<u>Total</u>	
	<u>2+</u>		<u>3+</u>		<u>M</u>	<u>F</u>
	<u>M</u>	<u>F</u>	<u>M</u>	<u>F</u>		
Number (n)	11	15	10	7	21	22
Percent (%)	42.3	57.7	58.8	41.2	48.8	51.2

TABLE 5.8

Smolt condition factor ($W/l^3 * 100$) for samples taken in 1982-1985 from migrating smolts in the R. Bugda smolt trap (C=Condition factor, SD=Standard deviation, N=Number of fish).

The smolt trap was not operated in 1984.

<u>Year</u>	<u>C</u>	<u>SD (g)</u>	<u>N</u>
1982	0.90	0.0574	52
1983	0.89	0.0626	179
1985	0.89	0.1001	144

TABLE 5.9

Mean weight (g) and standing crop (kg) of the smolt migration by years. (Standard deviation and number of fish is given in parentheses).

<u>Year</u>	<u>Mean weight (g)</u>	<u>Standing crop (kg)</u>
1982	26.9 (SD = 7.05) (N = 52)	70.1
1983	24.8 (SD = 6.90) (N = 79)	10.2*
1985	35.9 (SD = 16.63) (N = 144)	23.8

* Underestimate since the total smolt run could not be estimated.

significantly different, but in 1985 the mean weight was significantly greater than in 1982 and 1983 ($P < 0.001$). The standing crop of the total number of smolts migrating from L. Medalfellsvatn ranged from 10.2 kg in 1983 to 70.1 kg in 1982. In 1985 the standing crop was 23.8 kg. The estimate of the standing crop for the 1983 smolt migration is an underestimate, as previously mentioned.

5.3.7 Lake production of smolts

Production of salmon smolts for the three years ranged from 0.005 to 0.035 $g \times m^{-2} \times yr^{-1}$. Production was highest in 1982, but lowest in 1983 (Table 5.10). Production figures for the 1983 smolt migrations are underestimates for the reasons previously described. The estimates for the 1985 migration are biased, although the whole migration was counted, since a large number of smolts did not emigrate (S.M. Einarsson and V. Jóhannsson unpublished data) but stayed on in the lake.

5.3.8 Back-calculated growth

The equation calculated and used to examine the relationship between fork length of fish and scale radius was $FL = 28.0 + 2.14 SR$ where FL is fork length (mm) and SR is scale radius (mm). There was a good correlation between scale radius and fork length of juvenile salmon ($r^2 = 0.93$) (Figure 5.6).

Back-calculated growth of smolts (Table 5.11) is tabulated separately for smolts sampled in 1982 and 1983 respectively.

There were no significant annual differences in mean lengths at back-calculated annuli for different smolt ages between 1982 and 1983 ($P > 0.05$).

TABLE 5.10

Production ($\text{g} \times \text{m}^{-2} \times \text{yr}^{-1}$) of smolts migrating from L. Medalfellsvatn in 1982-1985. No production estimates are available for 1984, when the smolt trap was not operated.

<u>Year</u>	<u>Area</u> <u>(ha)</u>	<u>No.of smolts</u> <u>(n)</u>	<u>Mean</u> <u>weight(g)</u>	<u>Production</u> <u>($\text{gxm}^{-2}\text{xy}^{-1}$)</u>
1982	200	2607	26.9	0.035
1983	"	413	24.8	0.005*
1985	"	663	35.9	0.012

* Production is an underestimate since the total smolt run could not be estimated.

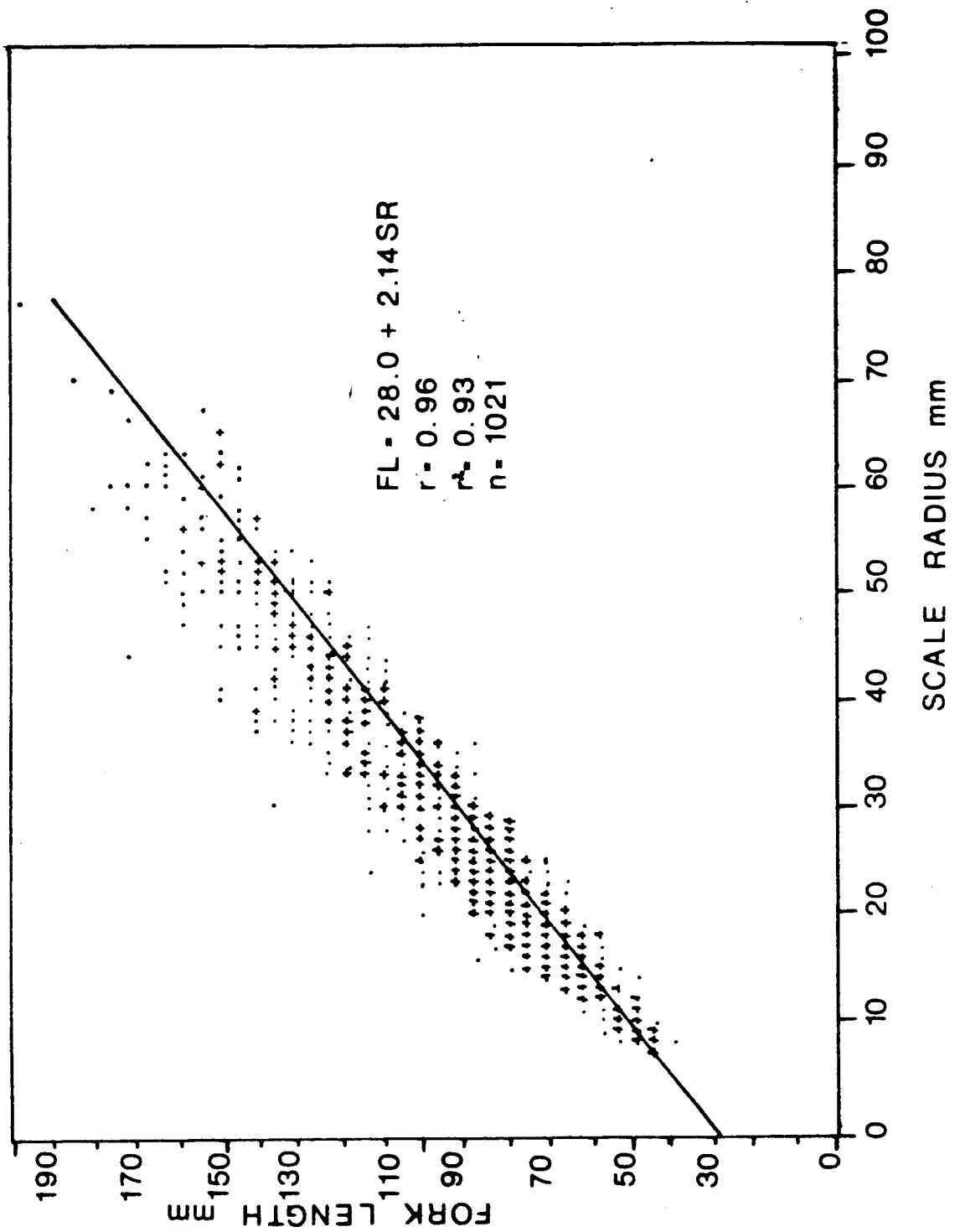


FIGURE 5.6. Relationship between fork length of juvenile salmon and total scale radius (mm x 55).

TABLE 5.11

Back-calculated fork lengths (cm) of smolts by year class and smolt age (A=Samples from the 1982 smolt migration, B=Samples from the 1983 smolt migration). Standard deviation of means is given in parentheses.

A

Year- class	Smolt age	Sample size	Mean length (cm)	Length at annulus				
				L ₁	L ₂	L ₃	L ₄	L ₅
1980	2+	25	12.86 (0.96)	5.84 (0.35)	11.22 (1.39)			
1979	3+	15	14.29 (2.80)	5.49 (0.21)	9.08 (0.40)	12.89 (3.59)		
1978	4+	3	14.44 (1.96)	4.70 (0.31)	6.90 (0.63)	9.66 (0.85)	13.00 (1.03)	

B

Year- class	Smolt age	Sample size	Mean length (cm)	Length at annulus				
				L ₁	L ₂	L ₃	L ₄	L ₅
1981	2+	43	13.19 (1.18)	5.92 (0.26)	11.74 (0.98)			
1980	3+	49	14.76 (3.01)	5.48 (0.41)	8.82 (1.96)	13.26 (3.31)		
1979	4+	2	15.55 (1.45)	4.77 (0.33)	7.79 (1.63)	10.16 (1.09)	13.64 (1.21)	
1978	5+	1	14.70	4.71	6.44	9.05	11.44	13.40

There was an inverse relationship between back-calculated lengths at the end of the first year growth (l_1) and smolt age (Table 5.11, Figure 5.7). Smolts that smoltified at age 2 grew significantly larger in their first year than smolts that smoltified at age 3 ($P < 0.001$) and similarly smolts that smoltified at age 3 grew significantly larger than smolts of age 4 ($P < 0.01$). The same trend applied to back-calculated lengths of older ages (l_2 etc), suggesting that the faster growth seen in the larger l_1 continued throughout freshwater life (Figure 5.7). Length at smoltification increased slightly with smolt age (Figure 5.7). Smolts migrating at age 3 were significantly larger than smolts of age 2, both in 1982 ($P < 0.05$) and 1983 ($P < 0.1$), but fish of smolt age 4+ were not significantly larger than fish of smolt age 3+, in either 1982 or 1983

5.4 DISCUSSION

5.4.1 The timing and magnitude of the smolt migration

The Atlantic salmon in Iceland is approaching the northern extreme of its range. A detailed knowledge of the effect of environmental factors on the downstream migration of smolts is therefore more important than in most other Atlantic salmon producing countries, especially if extreme environmental conditions seriously affect smolt runs.

Ruggles (1980) in his review of the downstream migration of Atlantic salmon smolts summarizes "... the natural downstream migration of smolts depends upon a gradual physiological development of migrating

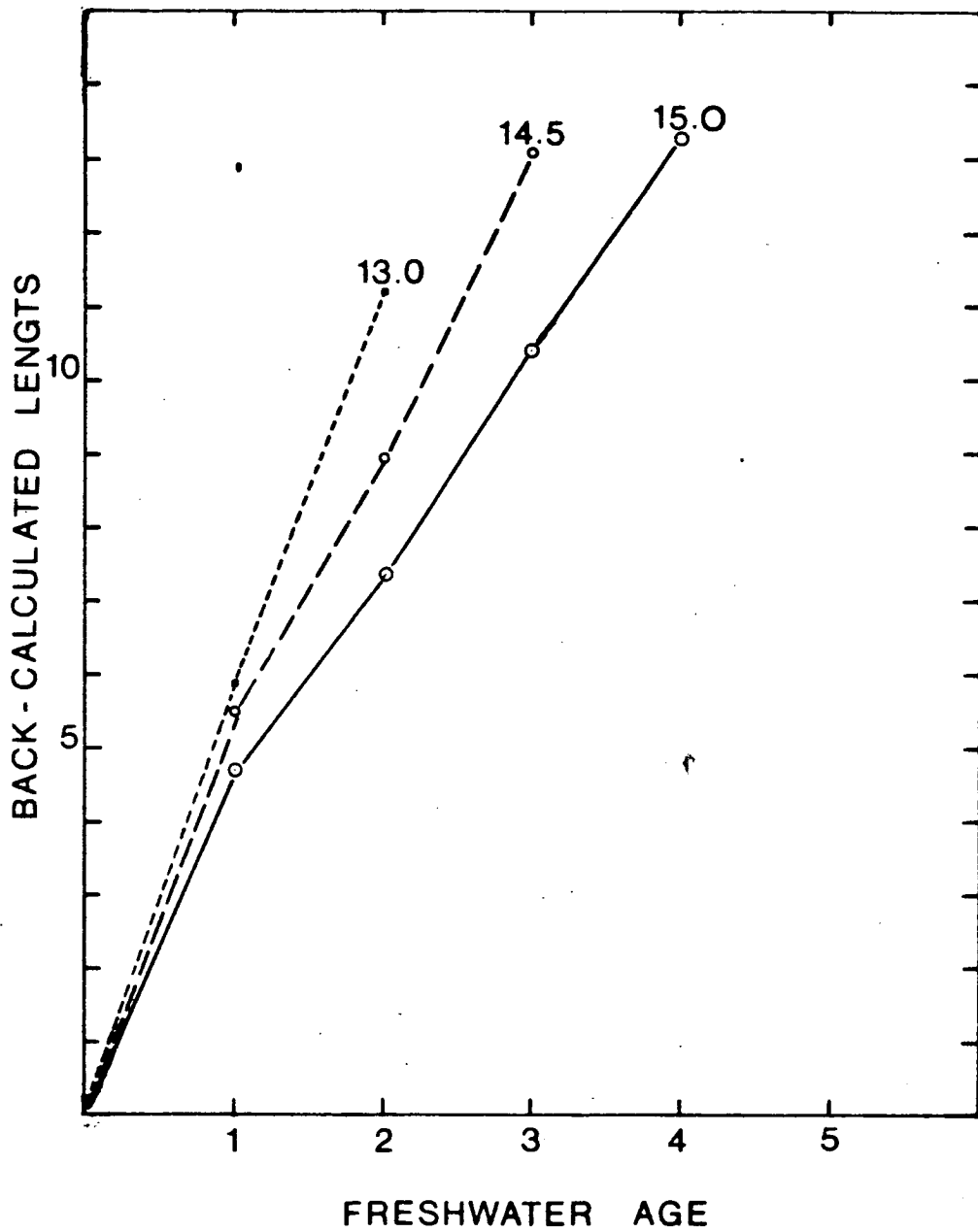


FIGURE 5.7. Back-calculated lengths for the three types of smolts at all river ages (years). Mean size at each age at smoltification is shown at the top of the graph.

readiness, involving hormonal, behavioral and morphological changes, and an increasing salinity tolerance. After the transformation from parr to smolt, some environmental stimulus triggers the migration, the nature of stimulus often appearing to differ in different rivers ..."

A number of environmental factors have been correlated with the timing of the yearly descent of Atlantic salmon smolts such as photoperiod, temperature, rainfall and discharge, cloud cover and lunar cycle. (Ruggles 1980) Huntsman (1952) and Hoar (1954) suggested that downstream migration of smolts occurred as a result of failure of the rheotactic response and this failure is believed to be triggered by some environmental mechanism (Hoar suggested photoperiod).

Most of the earlier studies on smolt migrations in Atlantic salmon concluded that migration of smolts was associated with increases in water level following rain and took mainly place at night (Allen 1944, Berry 1932, Berry 1933, Bull 1931, Pyefinch and Mills 1963, White and Huntsman 1938). Generally the role of water temperature was considered to be important to the extent that large scale migrations did not occur until water temperature reached 10°C, but temperature was not considered as a key triggering stimulus.

Often however, a rise in water temperature is cited as the key environmental stimulus triggering seaward migration of Atlantic salmon smolts with peak migrations occurring at 10°C or higher (White 1939, Elson 1962, Jessop 1975, Baglinere 1976, Solomon 1978 and Chadwick 1981). Mills (1964) in his studies on River Bran concluded that movements were partly due

to rainfall and partly to water temperature, the major part of the run entering the traps after the water temperature had risen fairly consistently above 10°C. Recently Solomon (1982) in his studies on River Piddle in England suggested that the role of high water temperature is in greatly enhancing the physiological readiness via the endocrine system to the extent that no specific environmental trigger is required for the fish to migrate.

In Sweden, Österdahl (1969) observed a change in diel timing of the migration from predominantly night-time during the early part of the run, to predominantly day-time later in the run. Night-time activity had a weak correlation with water level, cloudiness, air and water temperature in one year out of three in each case. Day-time migration was correlated with solar radiation but only weakly with water temperature. In Norway Jónsson and Ruud-Hansen (1985) tested if water temperature, water flow, cloudiness and lunar cycle were significantly correlated with the timing of yearly descent of Atlantic salmon smolts in the Imsa river. Of these environmental factors water temperature explained 91, 95 and 83% of the yearly variation in the date of 25, 50 and 75% cumulative smolt descent respectively. These authors concluded that the start of the smolt run was not triggered by a specific water temperature or degree days but was controlled by a combination of increase in temperature and temperature level in the river during spring. The authors found no significant correlation between smolt descent and any of the other environmental variables tested.

Smolt migrations from lakes are reported to be somewhat different from river migrations. When stocking lakes with juvenile salmon, it has been

reported that smolts are reluctant to migrate from nursery lakes (Munro 1965, Berg 1967, Korn and Smith 1970, Frantsi et.al. 1972) and that Atlantic salmon smolts are delayed when descending through lakes with a small water through flow. Hansen et.al. (1984) found that lake released smolts in the river Imsa in Norway were considerably delayed in their downstream migration compared to river released smolts and suggested that this was mainly due to the small water through flow in the lakes. Thorpe, Ross, Struthers and Walts (1981) showed that the direction and speed of the smolt movements through Loch Voil, Scotland was approximately the same as that of surface water. Their results suggested that the downstream displacement could be explained by passive displacement of smolts and that the active component required to ensure passage through a loch is very small.

In Iceland few studies of smolt migrations have been made. Poe (1975) concluded that the cold spring in 1975 affected the timing of the Ellidaár smolt migrations and previous studies of the smolt migration in the river Úlfarsá over a period of 23 years showed that the peak migrations occurred in late May and early June during years with normal spring conditions, but in cold years the run was delayed (T. Gudjónsson, personal communication).

In Iceland two abnormally cold years have occurred in the last decade. The spring of 1979 was the coldest of this century, and in 1983 the mean monthly temperatures were below average, with the exception of February. The summer of 1983 was the coldest since 1886 and both July and August were the coldest on record. Do these cold years affect the smolt runs and subsequent survival in the sea? The catch

records in Iceland show that in the years 1961-1979 the average percent age of grilse in the rod catch was 54.6% with a minimum value of 49.8% and a maximum value of 64.5%. In 1980 the grilse catch fell drastically to 28% of the total catch. The 1984 grilse catch was also below average (46% of the total catch). Scarnecchia (1984) investigated the effects of variations in climate, weather, and ocean conditions on yields of Atlantic salmon to anglers from 15 Icelandic rivers. He found highly significant relationships between mean June-July sea temperatures and yield of grilse the following year from several rivers in northern Iceland. This suggests that extreme environmental conditions during the time that smolts migrate to the sea result in low survival of grilse the following year. A precise timing of the smolt migration could be a critical factor in determining survival of both wild and hatchery smolts. It is known that the change from parr to smolt occurs over a relatively short period of time and some workers have observed a marked decrease in resistance to sea water if smolts are delayed from entering sea water (Europeitseva 1962), a phenomenon called desmoltification or regression of smolt characteristics. Cross and Piggins (1982) reported that the smolt runs of Atlantic salmon and sea trout in the Burrishoole river system in Ireland, in 1980 were delayed until early June by low water conditions and the following year the return of grilse to the traps on the Burrishoole system was much lower than in the previous eleven years. The authors assumed that the recorded decrease in grilse numbers was largely due to delayed smolt migration, caused by low water conditions.

Conditions affecting productivity of food organisms in the sea at the time of smolt entry also possibly affect smolt survival, although this is poorly researched area.

It seems likely that under extreme environmental conditions such as low water temperatures and drought that coordination of the many factors that influence or govern smoltification and downstream migration are in some way imperfect and could subsequently lead to poor survival of a smolt yearclass.

5.4.2 Length distribution

The mean size of smolts migrating from L. Medalfellsvatn was significantly different between 1985 and 1982 and 1983 respectively but not between 1982 and 1983. Since data for 1985 are preliminary it is not known whether the large smolt size in 1985 was due to changes in the age composition or differences in growth rate. Usually smolt size within a particular riversystem is a comparatively fixed characteristic (Chadwick 1981).

Comparison with other smolt studies in Iceland indicates that the smolts which migrated from L. Medalfellsvatn were larger than smolts produced in rivers. Gudjónsson (1978) found that the average length of smolts in the R. Úlfarsá ranged from 11-13.3 cm, but was most often between 12.2-12.9 cm. Poe (1975) in his study of the Ellidaár river (southwest Iceland) found that the smolts ranged in size from 8.8-18.8 cm with a frequency mode at 12.47 cm. Jóhannsson (1978) back-calculated the smolt length in the R. Ölfusá (south Iceland) from scale samples of adult fish and found that the average smolt size ranged from 12-12.5 cm. Helgason (personal communication) found in his studies on the R. Vesturdalsá in the northeastern part of Iceland in 1984, that of 1269 smolts measured the size range was between 9.5-18.5 cm with a mean length of 12.6 cm. Teitsson (1983) studied the smolt migration from

several hill lochs in northern Iceland, which had previously been stocked with salmon fingerlings. Unfortunately he gives no information on mean lengths of smolts, but smolts ranged in size from 14-20 cm in Lake Ljósavatn, 11-20 cm in Lake Kálfborgarvatn and 15-23 in Lake Másvatn.

The larger smolt size of lake-produced salmon can probably be attributed to faster growth rate of lake-produced salmon and that smolts originating in lakes have a tendency to migrate later in the year and over a longer period of time than smolts produced in rivers (Munro 1965, Berg 1967, Hansen and Senstad 1982 and Hansen, Jónsson and Doving 1984).

5.4.3 Age composition

Generally age at smoltification for Icelandic salmon varies from 1-5 years (Gudjónsson 1978). In south and southwestern Iceland most of the salmon spend three years in freshwater before migrating to the sea. Age at smoltification generally increases towards the north and northwest of Iceland where the duration of river life is commonly 3-5 years, reflecting less favorable environmental conditions for the growth of salmon. Many other authors have also observed smolt age to increase with latitude (Dahl 1916, Sedgewick 1953, Shearer 1966, Symons 1979, Power 1982). Most of the authors have speculated that smolt ages are greater at higher latitudes due to slower growth in cold northern climates.

The mean age at smoltification from smolts migrating from lake Medalfellsvatn is the lowest that has so far been reported for Icelandic smolts (2.49 years). Poe (1975) determined the mean smolt age to be 2.8

years in the Ellidaár river and Helgason (personal communication) found the mean duration of river life to be 3.9 year in R. Vesturdalsá in northeastern Iceland, with 70% of the smolts migrating as 4 years old. Although data on smolt age of salmon in Iceland is sparse it is clear that compared to other Icelandic river systems, lake-produced salmon in L. Medalfellsvatn shows excellent growth.

5.4.4 Sex composition

There is little information available on the sex ratio of smolts in Iceland. Helgason (personal communication) found that the sex ratio of smolts during the 1984 smolt migration in the R. Vesturdalsá was 40% males and 60% females. He found that the youngest smolts (3+) had approximately 50:50 sex ratio but in older smolts females dominated. Abroad several workers have found a preponderance of females in the smolt run (Pyefinch and Mills 1963, Österdahl 1969 and Chadwick 1978). The high ratio of females in the smolt runs is because of the tendency of male parr to become sexually mature as parr and take part in the spawning of adult fish. The proportion of male Atlantic salmon maturing as parr is increasing in some populations, possibly as a result of increased fishing pressure (Gibson 1978, Myers 1983). Such increases are alarming since in some commercial fisheries, the mortality associated with parr maturation is reported to lead to a loss of 60-70% of the male production (Myers 1984). Recently Myers and Hutchings (1985) showed that sexually mature male parr will successfully fertilize eggs of female anadromous Atlantic salmon, in the absence of anadromous males. However in Iceland no evidence of an increase in the percentage of maturation in male parr has been reported.

5.4.5 Lake production

This study is the first attempt to obtain quantitative estimates of production of wild Atlantic salmon in Icelandic standing waters. It must be stressed that the estimates so far obtained are preliminary and are underestimates, especially for the 1983 smolt migration.

There have been few studies of Atlantic salmon production and only in two cases have attempts been made to measure lake production of salmon. Chadwick and Green (1985) estimated lacustrine salmon production in the Western Arm Brook river system in Newfoundland Canada. Their estimate was based on the difference between total river system production and production in the fluvial habitat. These authors estimated that the majority of smolt production within the Western Arm Brook watershed took place in standing waters and slow flowing areas in the rivers. They estimated that the production in the lacustrine habitat was $0.07 \text{ gxm}^{-2}\text{yr}^{-1}$. The authors stressed that this estimate was very preliminary and probably an overestimate due to an underestimate of production in stream habitats. Recently, Ryan (1986) estimated the production of salmon in two lakes at the headwaters of the Gander River, Newfoundland. He was unable to obtain a precise estimate of salmon production in lake environments due to the long time between censuses and the previous stream habitation of the fish censused in the lakes but calculated that the average annual spring emigration from the study lakes corresponded to 0.06 gxm^{-2} .

The production values for smolts in L. Medalfellsvatn are lower than calculated by Chadwick and Green (1985) and Ryan (1986) for Newfoundland lakes.

However it is difficult to compare the values obtained for L. Medalfellsvatn to the Newfoundland studies due to the different methods used, and the different physical characteristics of the study sites. Preliminary results from L. Medalfellsvatn (Chapter 4) indicated that juvenile salmon only used rocky, shallow littoral areas as a rearing habitat, and salmon production in standing waters is dependent on the physical characteristic of lake systems. The results of this study show that although production per unit area is relatively low in L. Medalfellsvatn, the contribution of lake-produced salmon can be important to overall production of salmon, especially where lakes account for a large population of the total rearing area. Brayshaw (1972) indicated that if the productivity of one acre of smolt rearing lake was the same as that of a typical nursery stream this could represent the addition of 3.5 miles of stream of 4 m in width to the smolt producing area of a river.

5.5 SUMMARY

1. Atlantic salmon smolts constituted 97.6-99.2% of the total number of downstream migrants from L. Medalfellsvatn in 1982-1985.
2. Water temperature highly influenced the smolt runs both in 1982 and 1983, but no significant relationships were found with other environmental factors tested. In both years the migration commenced when water temperature reached 9.0 °C.
3. The length distribution of smolts measured during the study period approached a normal distribution with a mean length of 14.23 cm. Mean lengths of smolts were not significantly different between 1982 and 1983, but in 1985 smolts were significantly larger than in 1982 and 1983 and were on average 2 cm larger than in previous years.
4. Mean weight of smolts was significantly higher in 1985 than in 1982 and 1983. The standing crop of smolts migrating from L. Medalfellsvatn ranged from 10.2 kg in 1983 to 70.1 kg in 1982. In 1985 the standing crop was 23.1 kg.
5. Mean age of smolts varied between 2.49 yr in 1982 and 2.57 yr in 1983 but were not significantly different between years. The smolts were predominantly 2 and 3 years old.
6. Sex ratio of smolts in 1983 was 49% males and 51% females. No precocious males were found.
7. No annual difference in mean condition of smolts were found between years. The mean condition of smolts (CF) ranged from 0.89-0.90.

8. Production of smolts from L. Medalfellsvatn in 1982-1985 ranged from 0.005 to 0.035 g/m²/yr.

9. Length at smoltification increased with smolt age. Smolts at age 3 were significantly larger than smolts at age 2 both in 1982 and 1983. There was an inverse relationship between back-calculated lengths at the end of the first year growth and smolt age. Smolts at age 2 grew significantly better in the first year than older smolts suggesting that the faster growth seen in the first year continued throughout freshwater life.

MOVEMENTS OF SPAWNERS BETWEEN LAKE AND RIVERS

6.1 INTRODUCTION

The salmon ascend the rivers in Iceland from May to October with the largest number entering in July (Gudjónsson 1978). Spawning time varies within the country and takes place at low temperatures. Spawning starts in early September into October in the colder rivers in north and northeastern Iceland but in the warmer parts of the country in western and southern Iceland, spawning time extends from late September into November (Gudjónsson 1978).

The salmon generally spawns in rivers at depths ranging from 15-120 cm (Jones 1959). Typically though spawning takes place in shallow riffles where the flow is accelerating over gravel. Such a situation is usually conducive to the intra-gravel flow of water essential for survival of eggs.

A substantial number of adult salmon move into L. Medalfellsvatn each year. Recently the run into the lake was counted at a fish counting fence just below the outlet. In 1985 373 salmon entered the lake of which only 40 were caught by the rod fishery (S.M. Einarsson and V. Jóhannsson, unpublished data). The lake is an important producer of juvenile Atlantic salmon and within the lake all yearclasses of juveniles, including fry, have been found (this study). It is of biological interest to know how recruitment of juveniles to the lake occurs. Such information is crucial to the understanding of lake-use by wild anadromous Atlantic salmon and is

believed to be of use to those investigators involved in the enhancement of salmon populations through stocking programmes and lake habitat modification.

The purpose of this chapter is to examine the movements of adult salmon within the lake and the inflowing streams and outflowing river and to locate the main spawning grounds of salmon that enter the lake during the summer.

This chapter presents data collected at spawning time in October 1983.

6.2 METHODS

6.2.1 Sample sites

The sample sites chosen for this part of the study were located in the inflowing streams of the lake, i.e. the R. Sandsá and R. Flekkudalsá, the outlet R. Bugda and within the lake itself. A detailed description of this river system is given in chapter 2.

Two sites were located in the inlets (Figure 6.1). Spawning habitat is limited in both inlets and is mainly confined to the lower reaches. There are no good holding pools for adult salmon in either river. Both sample sites involved stretches of river area 150-300 m upstream of the inlets and were chosen to represent available spawning habitat and the most likely places to hold adult salmon.

One sample site was chosen in the outlet river R. Bugda, which is a good spawning river for Atlantic salmon and has three adequate holding pools in its upper reaches. The pool closest to the lake (Bakkahylur) was chosen for its proximity to the lake and suitable spawning gravel in the vicinity of the pool.

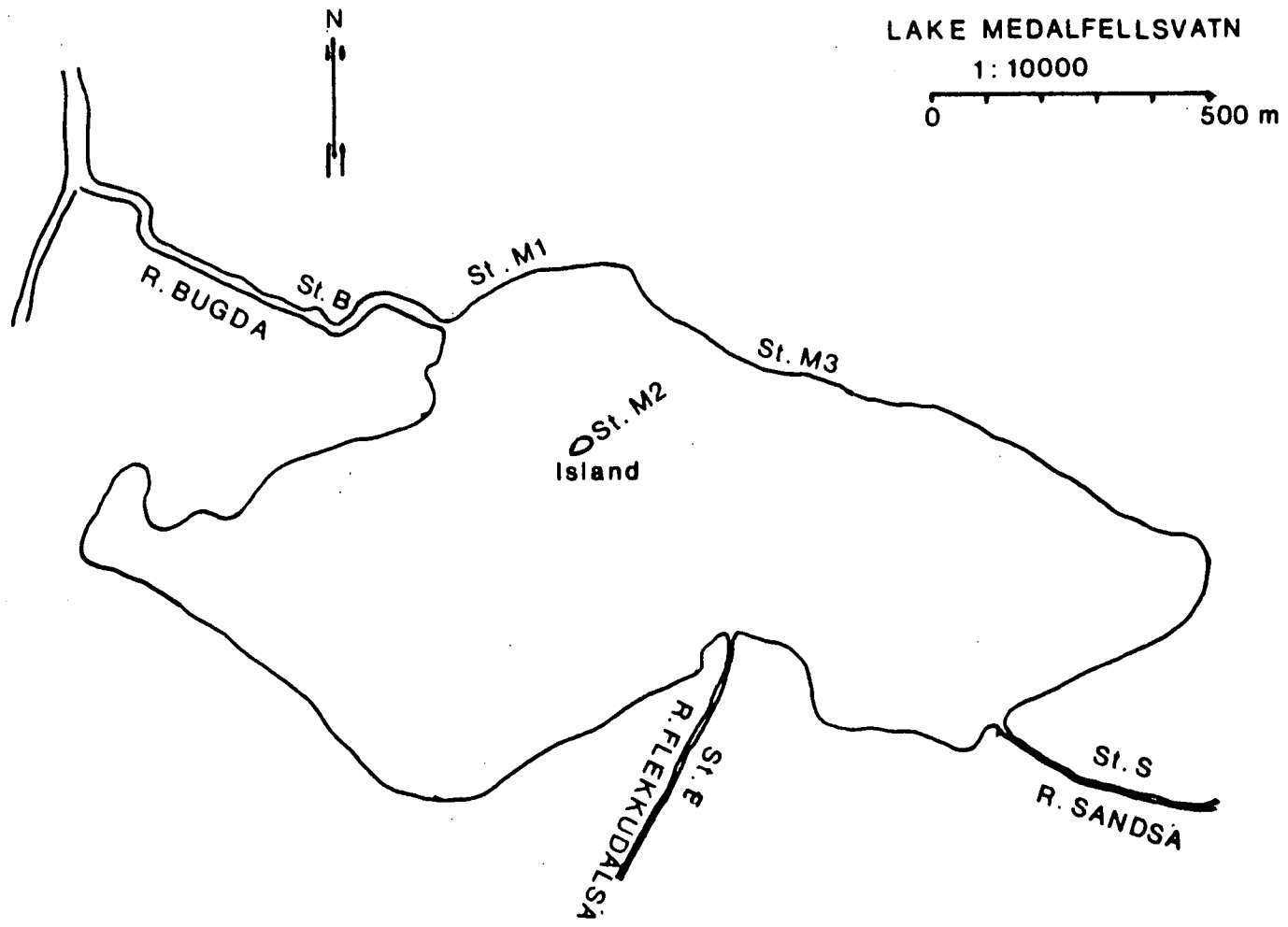


FIGURE 6.1: The location of the sample sites during the tagging

Three sites were chosen within the lake (Station M1-M3). The first site was located in the outlet area of the lake 50-150 m northeast of R. Bugda (M1). The second was situated near the only island in the lake (M2) and the third on the northern part of the lake (M3). Figure 6.1 shows the location of the study sites.

6.2.2 Capture methods

Two methods were used for capturing adult salmon, i.e. seine netting and gill netting, reflecting the need for different capture methods in a lake habitat and a river habitat. In the rivers a small seine net (52 mm knot to knot mesh size) was used in a conventional way, but in the lake gill nets of various mesh sizes (32-45 mm) were used. The nets were usually set at right angles to the shore line across depth contours of 1-4 m of water. The use of smaller mesh sizes than usually required for salmon was deliberate since experience gained at the Institute of Freshwater Fisheries in Iceland has shown that the use of larger mesh sizes often results in serious damage or death of fish especially if nets are left unattended for long periods of time. By using smaller mesh sizes salmon do not become as badly entangled and therefore suffer less damage and reduced mortality.

After capture, the sex and sea age of salmon were noted. Sex was determined by external examination of the lower jaw. Fish with a small kype were considered to be males. Sea age was also determined by gross exterior examination of size. Fish less than 65-70 cm were considered to be one seawinter fish. Larger salmon were considered to be multi seawinter (Scarneccia 1983).



PLATE 6.1: Tagging with spaghetti tags. Note the insertion of the needle below the dorsal fin. The photo was taken in July 1984 at the counting fence in R. Bugda.

6.2.3 Tagging of salmon

The objectives of marking fish are to enable their numbers to be estimated indirectly, or to follow the fate of the labelled individuals. In this study the main objective was to study the movements and migration of the spawners and this also gave the opportunity to estimate the numbers of the spawning population in part of the study area.

All tagging was carried out between 3-4 October. Immediately after capture and exterior examination the salmon were tagged by individually numbered spaghetti tags (Plate 6.1), which were inserted directly below the dorsal fin and then the salmon were quickly liberated. No salmon were tagged that appeared to be physically affected by the capture methods.

The size of the spawning population was estimated for the number of salmon concentrated in the outlet area of the lake by using an adjusted Petersen estimate (Ricker 1975):

$$(6.1.) \quad N^* = (M+1)(C+1)/(R+1)$$

where: N^* = Population size
M = No. of salmon marked
C = Catch taken for census
R = No. of recaptured tags in the sample

Approximate 95% confidence limits were obtained by using charts approximate to the binomical or Poisson distribution as described by Ricker (1975).

6.2.4 Location of spawning grounds

During the course of spawning the female cuts redds in the spawning gravel (Jones 1959) where the eggs are later deposited. Redd size is related to the size of the female cutting the redd (Ottoway 1981). Redds often cover a large area. For instance Jones (1959) observed that female salmon could spawn up to eight times, cutting a length of about 16 feet. Redds are therefore a good measure of locating spawning grounds and can easily be located by visual inspection of possible spawning areas. This method was used in October 1983 in order to locate the main spawning areas of the lake salmon.

6.3 RESULTS

6.3.1 Capture and tagging of salmon

A total of 40 salmon were caught, (Table 6.1) tagged with numbered spaghetti tags and subsequently liberated (Table 6.1). The bulk of the fish were caught within L. Medalfellsvatn (30 fish) and 10 salmon were caught in the outlet river, R. Bugda in the Bakkahylur pool (Figure 6.2). Within the lake the majority of fish were caught in the outlet area (Station M1). No salmon were seen or caught in the inlets R. Flekkudalsá and R. Sandsá.

Most of the salmon in the lake were concentrated in the outlet area. The majority of the catches in that area came at dusk (17⁰⁰-19⁰⁰). Few fishes were caught during daylight hours. The salmon seemed to stay in deeper areas of the lake during the day but at dusk they moved towards the outlet.

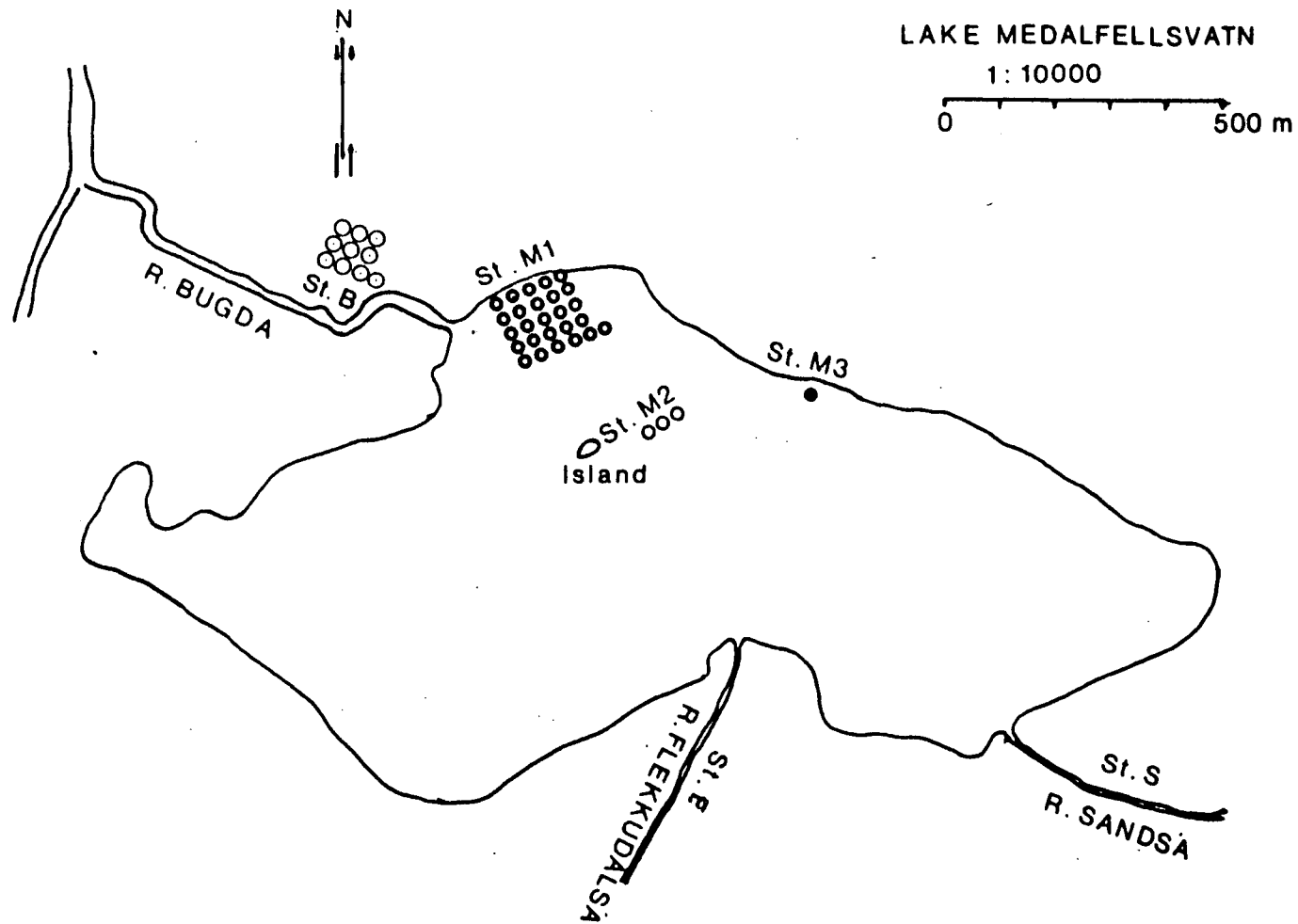


FIGURE 6.2: Number of fish tagged at each study site October 3-4th.
Each circle represent one fish.

- : Fish tagged at St.B
- : Fish tagged at St.M1
- ⊙ : Fish tagged at St.M2
- : Fish tagged at St,M3

TABLE 6.1

Number of adult Atlantic salmon caught and subsequently tagged in each sample site on 3-4 October 1983.

(F=R. Flekkudalsá, S=R. Sandsá, M=L. Medalfellsvatn, B=R. Bugda)

<u>Station</u>	<u>Date</u>	<u>No. of fish</u> <u>n</u>	<u>% fish</u>
F	4/10	0	0.0
S	4/10	0	0.0
M1	3-4/10	26	65.0
M2	4/10	3	7.5
M3	4/10	1	2.5
<u>B</u>	<u>4/10</u>	<u>10</u>	<u>25.0</u>
Total n		40	100.0

6.3.2 Age frequency and sex of salmon

The majority (92.5%) of the tagged salmon were one seawinter fish (Table 6.2). This is in accordance with the age composition of rod caught salmon from R. Bugda where 80-90% of rod caught fish are grilse (Institute of Freshwater Fisheries, catch records).

80% of the total number of salmon tagged in this study were males (Table 6.2). Differences in sex ratio were highly significant ($P < 0.001$) between salmon caught in L. Medalfellsvatn and in R. Bugda (Table 6.2). Thus 60% of the fish tagged in R. Bugda were males while the corresponding figure in the lake was 86.6% males. The sex ratio of the rod catch in the R. Bugda was 51% males during the fishing season of 1983. The dominance of males in the net catches in October may be attributed to two factors:

- (a) physical net selection favoring the capture of male fish
- (b) behavioural differences between male and female salmon

I believe there is a strong case for physical net selection in this case. Capture of fish in R. Bugda was carried out with a conventional seine net, but gill nets of small mesh sizes were used in the lake. Using nets with small mesh sizes probably favored males in the catch rather than females, since I often observed that the males became entangled by their protruding kype. It is also possible that behavioural differences could have affected the capture process since the males may have been more active than the females, i.e. defending territories or in active search of a female mate.

TABLE 6.2

Numbers of tagged adult salmon by sea age and sex
in each station, during 3-4 October 1983.

(M=Male, F=Female)

Station	1. seawinter		2. seawinter		Total	
	<u>M</u>	<u>F</u>	<u>M</u>	<u>F</u>	<u>M</u>	<u>F</u>
F	0	0	0	0	0	0
S	0	0	0	0	0	0
M1	22	2	1	1	23	3
M2	2	1	0	0	2	1
M3	1	0	0	0	1	0
<u>B</u>	<u>6</u>	<u>3</u>	<u>0</u>	<u>1</u>	<u>6</u>	<u>4</u>
Total n	31	6	1	2	32	8
% No.	77.5	15.0	2.5	5.0	80.0	20.0
Chi-square	8.44		0.17		7.2	

TABLE 6.3

A

Catch taken for census at station M1 in
L. Medalfellsvatn on 10 October by sea age and sex
of salmon.

1. seawinter		2. seawinter		Total	
<u>MA</u>	<u>F</u>	<u>M</u>	<u>F</u>	<u>M</u>	<u>F</u>
<u>18</u>	<u>1</u>	<u>4</u>	<u>0</u>	<u>22</u>	<u>1</u>

B

A mark-recapture estimate of the number of adult
salmon in the lake outlet area of L. Medalfellsvatn

No. of marked fish	Catch taken for census	Number of recaptured tags	Population number
<u>C</u>	<u>C</u>	<u>R</u>	<u>N*</u>
<u>26</u>	<u>23</u>	<u>5</u>	<u>108</u>
<u>Limits of 95% confidence</u>			<u>51-249</u>

$$N^* = \frac{(M+1)(C+1)}{R+1}$$

6.3.3 Population size of spawners in the outlet

During the tagging period it was evident that a large number of salmon were concentrated in the outlet area. This provided an opportunity to estimate the number of salmon occupying this area of the lake.

On 10 October a catch was taken for census in the outlet area (Station M1). The results are shown in Table 6.3. The population number was estimated to be 108 salmon with 95% confidence limits of 58-249.

6.3.4 Movements of adults

Data concerning capture of salmon, their tagging, release and recapture are summarized in Figure 6.3, Table 6.4 and Appendix 6.1. Of 40 fish tagged in early October 20 have so far been recaptured. Most of the recaptures were recorded throughout October 1983 by the author, but some recaptures came from two fish farms which took fish from R. Bugda and L. Medalfellsvatn for brood stock. Two recaptures came from the rod fishery in July 1984.

Of the 26 salmon tagged in the outlet area of the lake 15 fish (57.7%) were recaptured. Most of those were recaptured where they were originally tagged and released (Figure 6.3). Five fish were recaptured in R. Bugda and had thus moved down from the lake into the outlet river. Four of those fish were recorded in the Bakkahylur pool 200 m downstream of the lake outlet and one was recaptured in the Bugavad pool 400 m downstream of the lake outlet. One salmon (a male) was recaptured twice. It was originally tagged on 4 October in L. Medalfellsvatn (Station M1), recaptured first on 10 October in R. Bugda

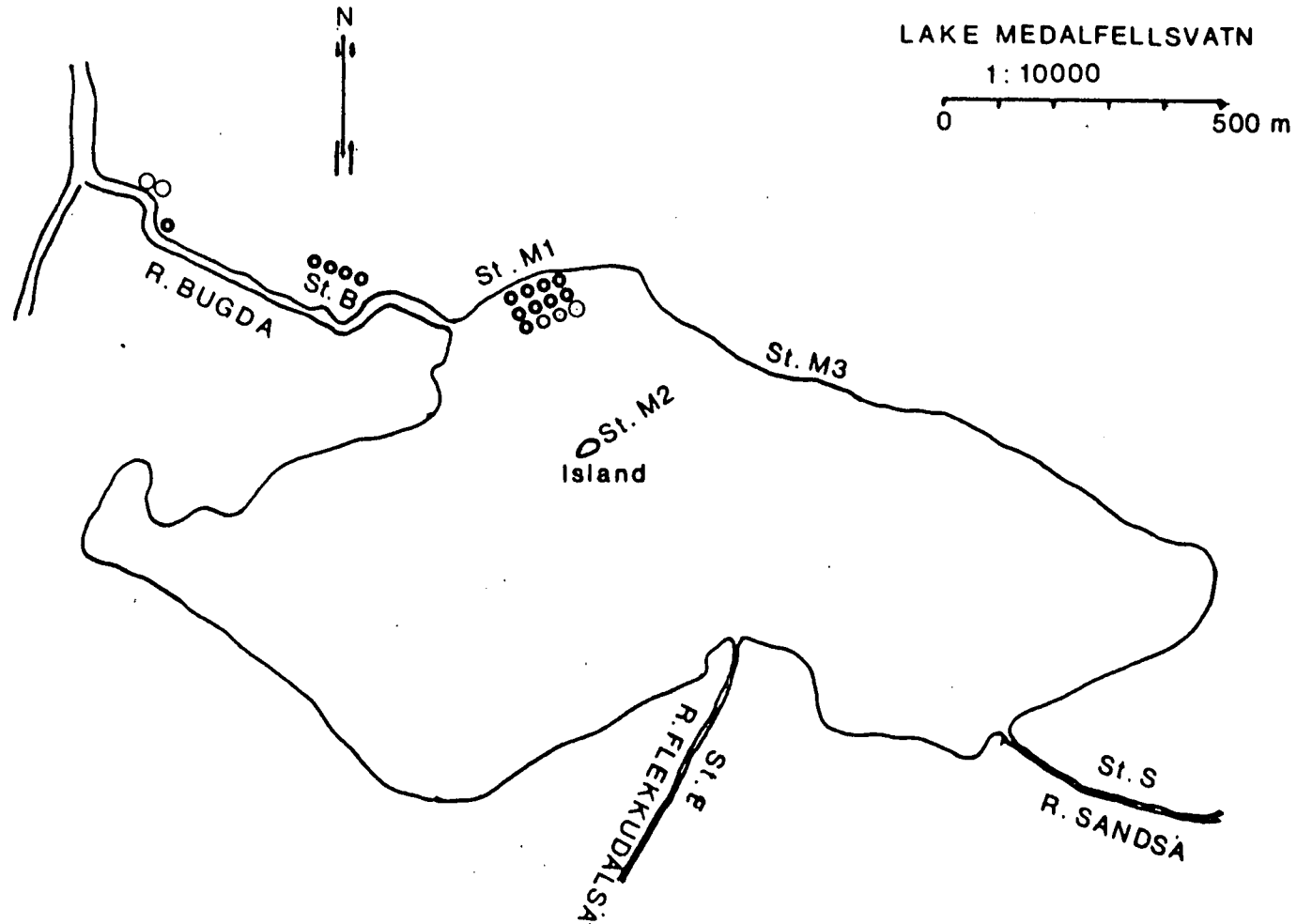


FIGURE 6.3: Recaptures of salmon tagged October 3-4th during October 1983. Fish recaptured twice are not included here. Each circle represents one fish recaptured. The circles show where the fish were originally tagged:

- : Tagged at St.M1
- ⊙ : Tagged at St.M2
- ⊖ : Tagged at St.B

TABLE 6.4

Movements of adult Atlantic salmon tagged and liberated on four study sites in the Laxá in Kjós river system on 3-4 October 1983.

These data are for 20 recaptures of 40 salmon tagged.

Data for salmon which were not recaptured is not included here.

Tag number	Capture and liberation data		Recapture data	
	Date	Place	Date	Place
007750	03.10.83	L.MFV.(M1)	10.10.83	L.MFV.(M1)
007748	03.10.83	L.MFV.(M1)	01.07.84	R.LAXÁ(FOSSBR.POOL)
007746	03.10.83	L.MFV.(M1)	27.10.83	L.MFV.(M1)
007744	03.10.83	L.MFV.(M1)	09.10.83	R.BUGDA(BAKKAHYLUR)
007742	03.10.83	L.MFV.(M1)	26.10.83	R.BUGDA(BAKKAHYLUR)
007739	03.10.83	L.MFV.(M1)	28.10.83	L.MFV.(M1)
007737	03.10.83	L.MFV.(M1)	28.10.83	L.MFV.(M1)
007735	03.10.83	L.MFV.(M1)	27.10.83	L.MFV.(M1)
007734	03.10.83	L.MFV.(M1)	28.10.83	L.MFV.(M1)
001613	04.10.83	L.MFV.(M1)	10.10.83	L.MFV.(M1)
001614	04.10.83	L.MFV.(M1)	10.10.83	R.BUGDA(BAKKAHYLUR)
"	"	"	27.10.83	L.MFV.(M1)
007713	04.10.83	L.MFV.(M1)	09.10.83	R.BUGDA(BUGDAVAD)
007714	04.10.83	L.MFV.(M1)	10.10.83	L.MFV.(M1)
"	"	"	07.07.84	L.MFV.
007716	04.10.83	L.MFV.(M1)	10.10.84	L.MFV.(M1)
007717	04.10.83	L.MFV.(M1)	26.10.84	R.BUGDA(BAKKAHYLUR)
007730	04.10.83	L.MFV.(M2)	10.10.83	L.MFV.(M1)
007728	04.10.83	L.MFV.(M2)	27.10.83	L.MFV.(M1)
007726	04.10.83	R.BUGDA(B)	10.10.83	R.BUGDA(FOSS POOL)
007706	04.10.83	R.BUGDA(B)	10.10.83	R:BUGDA(FOSSHYLUR POOL)
007712	04.10.83	R.BUGDA(B)	28.10.83	L.MFV.(M1)

(Bakkahylur) and recaptured the second time in L. Medalfellsvatn in the outlet area (Station M1). The fish had thus moved downstream from the lake into R. Bugda and was again found in the lake after moving upstream.

Two salmon originally tagged in the lake (Station M1) were recaptured in July 1984 by the rod fishery. One of them was captured in R. Laxá close to the estuary on 1 July, and the other was caught in L. Medalfellsvatn on 7 July. Scale analyses of the latter fish showed that it had returned to the sea sometime in the winter or spring and spent a short time in the sea before returning to the lake.

Two salmon originally tagged in the lake at station M2 (Figure 5.3) were recaptured in the outlet of the lake (Station M1) on the 10 and on the 27 of October 1983 respectively. Both of these fish had moved from the middle of the lake towards the outlet area of the lake.

Of the 10 fish tagged in R. Bugda (Station B) three fish were recaptured. Two were recaptured in R. Bugda 400 m downstream of the Bakkahylur pool (Station B) and one fish was recaptured in the lake outlet (Station M1) and had thus moved upstream into the lake.

6.3.5 Spawning survey

During October the inlet rivers R. Sandsá and R. Flekkudalsá were investigated twice on the 14 and on the 23 of October respectively. On neither occasion were redds found and no salmon was seen in the rivers.

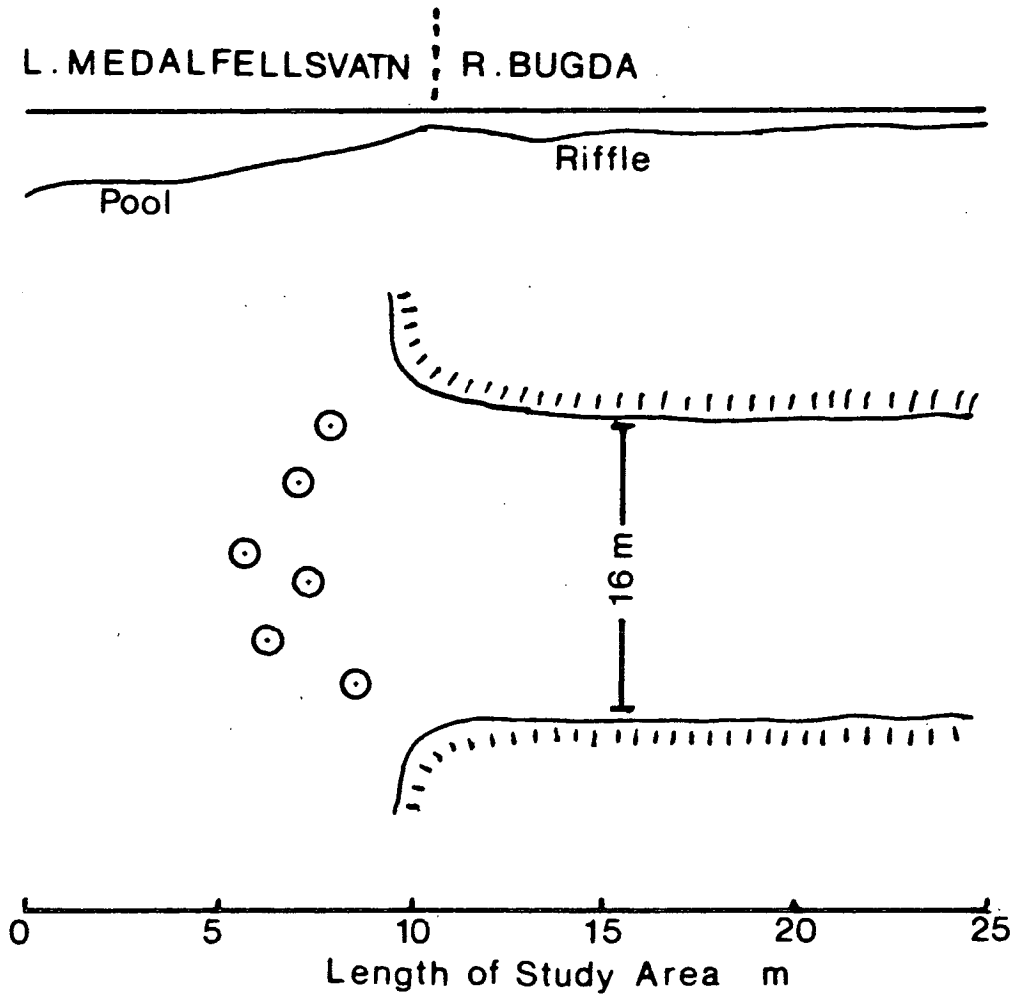


FIGURE 6.4: The location of salmon redds in the outlet of L.Medalfellsvatn. Each circle (O) represents one redd. Note location of pool and riffles as indicated along top of figure

On the other hand a large number of salmon was seen in the outlet area. At midnight on 9 October the outlet of L. Medalfellsvatn was inspected using handlights. A shoal of salmon, estimated to be between 20-30 in number was observed in the outlet and several females were seen cutting beds. The morning after 6 redds were counted in this area (Figure 6.4). They were all located 2-5 m within the lake where it tails off into a riffle where R. Bugda starts flowing. The water depth at the sites ranged from 30-60 cm. This area is an ideal spawning place for salmon and is similar to places in rivers where tail ends of pools merge into riffles. Several redds were also noted in R. Bugda around the Bakkahylur pool, 200 m downstream from the lake outlet.

6.4 DISCUSSION

6.4.1 Population estimate

The criteria for estimating population densities by mark and recapture are that: the marked fish suffer the same natural mortality as unmarked ones, that marked fish are as vulnerable to the fishing as unmarked, that marked fish do not lose their mark, that marked fish become randomly mixed with the unmarked fish, that all marks are recognized and reported on recovery and that there is a negligible amount of recruitment during the time that recoveries are made (Ricker 1975). During the tagging and recapture period of this study most of these requirements are believed to have been met. The estimate was made within a week of the tagging and only a negligible amount of recruitment should have occurred within that time period, especially since most of the Icelandic salmon stocks have already

entered the rivers in September (Gudjónsson 1978). Care was taken in inspecting every fish for the external spaghetti tags which are easily seen. To date 50% of the tags have been recovered and therefore it is unlikely that many fish had lost their tags. Fish were also recaptured in various places and therefore should have been randomly mixed with the rest of the population.

The greatest bias in the estimate however lies in the unequal catches of sexes. Thus originally 88.6% of the salmon tagged were males and in the catch taken for census 96.5% of the salmon were males. In 1983 the sex ratio of salmon in the rod fishery was almost equal so the high ratio of males in the catches is either due to physical net selection or behavioural differences as previously mentioned. The estimate therefore should only be considered reliable for males. If one assumes an equal sex ratio in the population, the population number could be twice as high or close to 200 fish during the mark-recapture period. The estimate however expresses adequately the high number of salmon that were occupying the outlet area of the lake during the tagging and recapture period.

6.4.2 Movement of spawners and spawning areas

The results indicate that the major spawning grounds for salmon that dwell in the lake are in the lake outlet and perhaps in the upper reaches of the outlet river, R. Bugða, rather than in the inlets R. Sandsá and R. Flekkudalsá. This is suggested by the number of salmon occupying the outlet area, the movements of the tagged individuals and observation of spawning behaviour and location of redds in the outlet.

This is perhaps not surprising, since physically the outlet is very suitable for spawners, having ample spawning gravel, and a relatively stable substrate. It also provides an ideal nursery area for fry and parr. Lake outlets in Iceland are generally very productive compared to other parts of the rivers (Gíslason and Jóhannsson 1985) due to the high density of the species of blackfly Simulium vittatum which dominates the invertebrate fauna of loch outlets in Iceland. Recently Jóhannsson (1986) estimated the production of blackfly larvae to be 1.655 kg (ww)/m²/year in the R. Bugda outlet. This is reflected in the high density of juvenile salmon in this area with numbers of fry ranging from 11.8-13.1 per m² and parr densities of 0.7-1.1 m² during the summer of 1982 (this study).

The inlets on the other hand are physically not very suitable, neither as spawning areas nor as nursery areas for juvenile salmon. Both of the inlets are short, steep and cold rivers with unstable substrate, and they frequently change their course. This is well reflected in the low population density of salmon in the inlets. The maximum number of fry in these rivers during 1982-1983 was 0.07/m² and 0.05/m² of parr (this study).

Generally little information is available on lake use by wild stocks of Atlantic salmon. Beside this study lakes have been identified as salmon habitat in Newfoundland (Pepper 1976, Dalley et.al. 1983, Ryan 1984, Chadwick and Green 1985), but these authors have concentrated on lake use by the juvenile salmon and little information is available about spawning areas of lake dwelling salmon. Other salmonids, e.g. brown trout and rainbow trout populations make use of lake outlets, as well as inlets as spawning

areas (Northcote 1969) and the lakes can become populated either by upstream migration from the outlets or by downstream dispersal from inlets.

6.5 SUMMARY

At spawning time in October 1983 a large number of salmon were concentrated in the outlet area of L. Medalfellsvatn but no salmon were found in the two inlet rivers. The results of the present study suggest that the major spawning grounds of salmon that move into the lake are in the outlet of the lake and perhaps in the upper reaches of the outlet river R. Bugda rather than in the inlet rivers. It was found that salmon spawned in the outlet and there was considerable movement of tagged individuals between the lake and the outlet river R. Bugda.

APPENDIX 6.1

Details of tagging experiments of adult Atlantic salmon in
L. Medalfellsvatn 3-4th October 1984 and details of tag recaptures

St.	Date	Time	Tag No.	Sex	Sea age	Recaptures
M1	03.10.83	18 ³⁰ -19 ³⁰	7750	M	1	Recapt. in L.Mfv. on St.M1, 10.10.83
M1	"	"	7748	M	1	Recapt. in R.Laxá (Fossbr) 01.07.84
M1	"	"	7746	M	1	Recapt. in L.Mfv. on St.M1, 27.10.83
M1	"	"	7744	M	1	Recapt. in R.Bugda (Bakkah) 09.10.83
M1	"	"	7743	M	1	
M1	"	"	7742	M	1	Recapt. in R.Bugda, St.B1, 26.10.83
M1	"	"	7741	M	1	
M1	"	"	7740	M	1	
M1	"	"	7739	M	1	Recapt. in L.Mfv. on St.M1, 28.10.83
M1	"	"	7738	M	1	
M1	"	"	7737	M	1	Recapt. in L.Mfv. on St.M1, 28.10.83
M1	"	"	7735	M	1	Recapt. in L.Mfv. on St.M1, 27.10.83
M1	"	"	7734	M	1	Recapt. in L.Mfv. on St.M1, 28.10.83
M1	"	"	7733	M	1	
M1	"	"	7732	F	1	
M1	04.10.83	9 ³⁰	7729	M	2	
M1	"	17 ⁰⁰	1612	M	1	
M1	"	"	1613	M	1	Recapt. in L.Mfv. on St.M1, 10.10.83
M1	"	"	1614	M	1	Recapt. in R.Bugda on St.B1 10.10.83 and in L.Mfv. on St.M1 27.10.83
M1	"	"	1616	M	1	
M1	"	19 ⁰⁰	7713	M	1	Rec. in R.Bugda(Bugavad) 09.10.83
M1	"	"	7714	M	1	Rec. in L.Mfv. on st.M1 10.10.83 and in L.Mfv. (74cm,3.2kg), 07.09.84
M1	"	"	7715	F	1	
M1	"	"	7716	M	1	Recapt. in L.Mfv. on St.M1, 10.10.83
M1	"	"	7717	M	1	Recapt. in R.Bugda on St.B1 26.10.83

16.	Date	Time	Tag No.	Sex	Sea age	Recaptures
M1	04.10.83	19 ⁰⁰	7718	F	2	
M2	"	9 ³⁰	7731	F	1	
M2	"	"	7730	M	1	Recapt. in L.Mfv. on St.M1, 10.10.83
M2	"	"	7728	M	1	Recapt. in L.Mfv. on St.M1, 27.10.83
M3	"	16 ⁴⁰	7727	M	1	
B1	04.10.83	18 ⁰⁰	7726	M	1	Recapt. in R.Bugda(Fosshyl) 10.10.83
B1	"	"	7703	F	2	
B1	"	"	7705	F	1	
B1	"	"	7706	F	1	Recapt. in R.Bugda(Fosshyl) 10.10.83
B1	"	"	7707	M	1	
B1	"	"	7708	M	1	
B1	"	"	7709	F	1	
B1	"	"	7710	M	1	
B1	"	"	7711	M	1	
B1	"	"	7712	M	1	Recapt. in L.Mfv. on St.M1, 28.10.83

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