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COMPARATIVE GROWTH STUDIES, II.

By

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ABSTRACT

Atlantic salmon smolts of Norwegian and Swedish (Baltic) origin and rainbow trout fingerlings were stocked in floating pens at several farms along the Norwegian coast. The fish were counted, measured and weighed with approx. six months intervals, until slaughtered. Temperature, salinity, food rations and mortality were recorded at the farms.

Salmon and rainbow trout have the best growth rates at the farms in southern part of Norway. Comparison of salmon of Norwegian and Baltic origin favours the Norwegian. Reasons for the large diversities in growth of fish at the different farms are discussed.

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INTRODUCTION

In cooperation with some commercial fish farmers we wanted to study growth, mortality and "uncontrolled" loss of Atlantic salmon (Salmo salar L.) and rainbow (Salmo gairdneri) trout of the same origin but reared in different environments in order to find factors of economical interest for the commercial fish farming industry. Another aim of the study was to compare the farm localities in the southern and northern part of Norway. We were also interested in investigating whether salmon of Baltic origin could be acclimatized to the North Atlantic environment and whether they could compete with the Norwegian salmon as a farm fish.

The study was started in 1973 by a shipment of fish to 5 fish farmers and continued with a new shipment of fish in 1974. The results of the 1973 batch together with the results of the first half year for the 1974 batch are presented in a pervious report (Møller and Bjerk 1975). Thus only the results of the year class delivered to the farms in 1974 will be reported in this paper.

MATERIAL AND METHODS

In May 1974 3000 each of rainbow trout fingerlings and Atlantic salmon smolts of both Norwegian and Swedish (Baltic) origin were delivered to ten commercial fish farms along the coast (Fig. 1). The Norwegian smolts came from the Mowi farm at Sotra (A, Fig. 1), while the Baltic salmon came from Långhult, Sweden. Unfortunately, two farms (no 6 and 10, Fig. 1) gave up business in January 1975 and a third one (no 8) resigned at the end of 1975. Thus only seven fish farms were represented throughout the whole experimental period.

The fish were measured before transportation in May and then counted, measured (fork length) and weighed again every six months, in Oct./Nov. and in May/June until they were slaughtered after 1½ and 2 years (rainbow trout and salmon respectively). In 1975, the fish at five farms (no 1, 3, 5, 7 and 9) were measured in January, i.e. after 3/4 sea year. The final measurements were made in March 1976 at all except two farms where the fish were measured in mid. February and end of April (farms no 4 and 2 respectively). All results concerning the salmon are, however, transformed by extrapolation from the growth curve to expected growth at March 15.

The means are based on samples of 100 fish of each population. For calculation of total biomass and food conversion factor at the farms, the Swedish and Norwegian salmon populations were counted as one, otherwise they were treated separately.

The fish were given a profylactic terramycine treatment before transportation to the farms.

Sexual maturation was, when possible to detect by external inspection, recorded when measuring the fish in Oct/Nov 1975 (1½ sea year).

After 1 sea year the number of salmon at two farms (no 1 and 2) was reduced to ~ 1000 fish/pen in order to faciliate handling and after 1½ sea year farm no 5 reduced their salmon to ~1500 fish/pen.

A severe attack of disease reduced growth of the salmon at Hitra (no 3) between the 1½ and 2 years measurings. The results of the 2 years measurements were therefore not considered representative and were omitted. At farm no 9 the Swedish and Norwegian salmon were not separated at the two first measurements and later on only Norwegian salmon were found in the pen, thus the results are only presented as "mixed population".

The fish farmers were to send feed samples each fortnight to be analysed by the State Vitamin Laboratory. However, the samples were sent very irregularily and the results are therefore incomplete.

For further details cf. Møller and Bjerk (1975).

RESULTS.

Environment

The temperatures were, with a few exceptions highest at the southern farms (no 1 and 2) throughout the year (Table I). In 1975 the summer temperatures were remarkably high at all farms. The recorded temperatures at farms no 4 and 5 in Jan./Febr. 1976 are unusually low.
The salinity has been stable. The monthly averages have varied between 27 $^{o}/oo$ and 32$^{o}/oo$ for all farms.

Salmon

There was a wide variation in the growth rate of the salmon at the different farms (Table IIa, Fig. 2a). The two southern farms (no 1 and 2) had the best growth although the northmost farm (no 9) also had a fairly good growth. Table IIb and figures 2b and 3 show mean lengths and weights of the Swedish and the Norwegian populations; with one exception (farm no 4) the Norwegian salmon grows faster than the Swedish.

The condition factor K ($K = \frac{\text{weight (g)}}{\text{length}^3\text{ (cm)}} \times 100$) is based on mean length and weight of the populations (Table IV). The Swedish salmon have in general somewhat higher condition factor than the Norwegian.

Maturation was recorded when measuring the fish after 1½ sea years. Beneath (Table 1) is an account of the proportions of mature fish found at the different farms. The percentage of mature fish was higher in the Swedish population although the difference was not remarkably great. In the Norwegian population only mature males were found.

Table 1. Proportions of mature fish at the different farms.

Farm	Swedish salmon % ♂	% ♀	Norw. salmon % ♂	% ♀
Blomvåg	10	2	1,3	0
Sotra			6	0
Svanøy	5	2	4	0
Hitra	*	*	*	*
Rørvik	14	0	2	0
Halsa	10,3	0	0	0
Eidet	13,4	0	0	0
Lia	4,4	0	0	0
Kalfjord			0	0

The registered mortality was high during the first six months in the sea, but during ½ - 1½ sea year the reported mortality was only 100 - 140 fish.

Rainbow trout

The growth rates of the rainbow trout are also very diverse at the different farms (Table III, Fig. 4 and 5). Two of the farms in mid-Norway (no 4 and 5) had an excellent growth during the first half year after stocking. At slaughtering after 1½ sea year one of the southern farms (no 2) had a mean weight of 3570 g, which was almost 1400 grammes more than the farms which had the lowest mean weight.

The condition factors for the rainbow trout are calculated in the same way as for the salmon. The condition factors (Table IV) are mostly lower in the autumn than in the spring which is somewhat unusual.

At the last measurement (1½ sea years) it was not possible to detect any signs of maturation without opening the fish, and the figures are therefore lacking.

After the heavy losses the first half year, the mortality, except at one farm was less than 10 % during the last 12 months (cf. Table III). At the farm where the highest number of fish had "disappeared" (farm no 1) when counting the fish at 1½ sea year, 230 of the missing 285 fish were already reported dead, thus giving an unregistered loss of 55 fish. At farm no 3 most of the rainbow trout were stolen in summer 1975, which should explain the low number at the last counting.

Feed and conversion

Table V and Fig. 6 show a survey of the food conversion factors at the farms based on monthly reports on feed consumption sent by the cooperating fish farmers. Due to incomplete reports some results are lacking.

Only two farms (nos 3 and 4) sent in food samples for analysing of contest regularly for some time and these results are presented in Table VI. Because analyses of the samples sent in sporadically by the other farmers showed similar values the present values can be considered representative.

DISCUSSION

On an average the growth rates of the salmon are good. Earlier experiences of commercial fish farmers have proved the possibility of producing salmon which have a mean weight of 5 - 6 kg after 2 years. The results of some of the farms, e.g. no 1 and 2 (Fig. 2a, 2b) must therefore be characterized as very good.

Since the origin of the fish is the same for all the farms, the reason for the differences in growth rates must be in the environments as well as in the caretaking of the fish.
The environmental factors at the farms did not differ greatly although the lower sea temperatures towards the north certainly were causing slower growth at the northern farms. However, the reduction of the density in the salmon pens at two of the southern farms evidently has contributed to their good results, since growth is known to be correlated with stocking density (Braaten 1974).

Laboratory experiments have shown that also the light i.e. the length of daylight, is of importance to the growth of fish. (Gross et al. 1965, Saunders 1970, Knutsson and Grav 1976). These experiments were made with smolts and young fish, but one might presume that differences in photoperiod directly or indirectly influence also the adult fish.

Not only the environment but also the origin of the fish is decisive for the growth. Among others, Nævdal et al. (1975) found great variations in growth rate of Atlantic salmon originating from different rivers. The Swedish (Baltic) salmon might therefore have less ability for growth, but explanation for the slower growth of the Swedish salmon might also be that the fish from the Baltic are adapted to an environment with much less salinity than the North Atlantic water.

The somewhat higher proportion of mature individuals in the Swedish population used in this experiment is evidently due to their genetic constitution, but whether early maturation is common to all populations of Baltic salmon is difficult to tell from the present experiment.

After the first six months mortality and loss of the fish go down, which could be expected since the larger the fish are, the more seldom they are taken by predators such as birds and minks and the less susceptible they are to disease.

The growth of the rainbow trout has been satisfactory at most of the farms, especially considering the small size of the fish at start of experiment. The wide variation in growth rate of the rainbow trout at the different farms is, as for the salmon, correlated with environmental factors.

The sea temperatures apparently count for some of the difference in rainbow trout growth between the southern and the northern farms. The effect of temperature seems to be emphasized by the fact that the fish stocked in 1973 (cf Møller and Bjerk 1975) had somewhat better growth, presumably due to the fact that temperatures were higher during their sojourn in the sea than the temperatures were for the 1974 year class. However, it is difficult to compare different yearclasses.

Mortality and loss of the rainbow trout are evidently of the same reasons as for the salmon decreasing after the first months in the sea.

The great divergence of the feed conversion factors among the farms indicate that at some farms feed is wasted and that considerable savings might be made by a more controlled feeding.

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Table I. Fortnightly mean temperatures (^{o}C) at the cooperating fish farms.

	1	2	3	4	5	7	9
1974	BLOMVÅG	SVANØY	HITRA	RØRVIK	HALSA	EIDET	KALFJORDEN
May	9,6		7,7		5,5		4,5
"	11,5				9,0		5,6
June	12,5	12,0	10,8	12,0	10,9	8,9	8,4
"	12,5	15,4	12,2	12,2	14,5	11,4	11,4
July	12,7	14,5	13,0	12,2	13,9	11,6	9,1
"	12,7	13,6	12,6	12,8	14,4	13,3	11,0
Aug.	14,3	14,0	12,7	13,3	14,3	13,8	10,9
"	14,5	14,2	14,1	13,5	13,8	11,8	9,6
Sept.	14,9	14,0	14,1	13,3	13,2	11,3	8,2
"	13,7	12,2	13,6	11,9	11,8	10,7	7,5
Oct.	11,8	11,4	11,3	10,3	10,6	9,7	6,3
"	10,6	10,8	9,5	8,6	10,0	9,0	5,2
Nov.	9,3	9,4	8,2	7,5	8,2		5,1
"	8,4	8,3	7,9	6,8	7,7		4,2
Dec.	7,6	8,3	7,4	6,1	7,1		3,5
"	7,6	7,3	6,3	5,6	6,2		3,1
1975							
Jan.	6,5	6,6	5,9	4,7	4,5	4,7	3,3
"	6,2	6,4	5,2	3,6	4,5	4,0	2,7
Febr.	5,3	5,5	5,3	4,2	4,2	3,6	2,6
"	4,9	5,9	5,3	3,5	3,8	3,4	3,0
March	5,2	5,7	5,4	4,0	3,3	3,6	2,7
"	4,8	5,3	5,3	4,0	3,7	4,0	3,0
April	5,2	5,2	4,7	4,4	3,6	4,3	3,1
"	6,4	6,5	5,3	5,3	4,8	4,9	4,0
May	7,6	8,1	6,8	6,4	6,1	5,4	5,0
"	9,3	9,2	7,7	6,6	6,7	6,1	5,9
June	11,3	11,0	9,1	7,8	8,0	6,7	6,9
"	11,4	12,1	9,6	9,7	9,4		7,4
July	13,2	14,3	10,7	10,6	10,3		8,5
"	13,6	14,8	12,1	11,8	11,9		9,0
Aug.	17,3	16,7	11,2	12,5	12,9		10,6
"	16,8	15,8	12,0	12,3	12,1		9,5
Sept.	15,6	14,8	11,4	11,6	10,9		9,0
"	13,4	13,6	11,7	11,3	10,2		9,0
Oct.		11,7			9,6		8,1
"		9,9			7,9		6,8
Nov.		10,0		8,0	7,6		5,7
"		9,3		6,8	6,3		6,0
Dec.		8,3		6,5	5,9		
"		6,5		5,8	4,7		
1976							
Jan		5,2		3,5	2,7		
"		4,8		2,8	3,2		
Febr.		4,1		2,0	3,0		
"		4,3			3,7		
March		4,6			3,4		
"		4,8					
April		5,7					

Table IIa. Mean lengths and weights of salmon at ½ - 2 sea years at cooperating fish farms.

LOCALITY	MIXED SALMON STOCKED SPRING 1974.																	
	At start May 1974			After ½ year			After 3/4 year			After 1 year			After 1½ year			After 2 year		
	l,cm	w,g	No	l,cm	w,g	No	l,cm	w,g	No	l,cm	w,g	No	l,cm	w,g	No.	l,cm	w,g	No.
1 Blomvåg	Length approx. 16 cm	Weight approx. 30 g	3000	29,4	330	2750	36,3	628	2650	45,8	1110	1000 [1]	61,4	2670	910	74,0	5460 [x]	900
2 Svanøy			3000	31,4	339	1960	-	-	-	49,3	1520	1020 [1]	63,5	2810	1010	74,5	5120	1000
3 Hitra			3000	30,1	288	2640	37,2	520	1520	43,6	920	1200	54,1	1720	1000	-	-	-
4 Rørvik			3000	36,4	603	2900	-	-	-	46,8	1330	2850	61,0	2790	2830	68,8	3850 [x]	2780 ca
5 Halsa			3000	36,4	610	2970	43,9	1050	2960	50,4	1430	2900	56,8	2060	1520 [1]	65,3	3410	1500 ca
7 Eidet			3000	27,1	210	2400	30,5	325	2400	34,7	510	2370	43,8	1010	2350	51,5	1500	2300
8 Lia			3000	28,4	253	?	-	-	-	35,2	470	?	42,2	800	2000 ca	-	-	-
9 Kalfjord			750	35,1	536	540	42,5	950	450	[2] 46,5	1240	440	[2] 55,6	2040	420	[2] 61,2	3000	400

1) Number of fish were reduced to 1000.

2) Only Norwegian population was found.

x) weight of capped fish.

l = length
w = weight

Tabell II b. Lengdevekst for laks utsatt 1974, fordelt på populasjon.

SWEDISH AND NORWEGIAN SALMON STOCKED SPRING 1974												
			Length, cm:									
LOCALITY	POPULATION	At start	½ year		3/4 year		1 year		1½ year		2 year	
			Norw.	Swed.	Norw.	Swed.	Norw.	Swed.	Norw.	Swed.	Norw.	Swed.
SOTRA	No	Swedish smolt ab. 15,5 cm Norwegian smolt ab. 17,3 cm	30,3		-		48,8		65,5		-	
BLOMVÅG	Sw			27,8		34,8		43,4		59,2		71,9
	No		35,0		41,8		50,5		64,7		78,0	
SVANØY	Sw			28,3		47,8		47,8		61,7		73,2
	No		32,8		-		52,4		66,6		76,5	
RØRVIK	Sw			33,7		-		44,9		60,4		66,4
	No		38,7		-		50,5		62,1		73,5	
HALSA	Sw			36,5		43,3		50,1		56,8		64,4
	No		36,3		44,1		50,6		56,9		67,2	
EIDET	Sw			26,2		29,7		34,1		43,1		50,5
	No		28,6		32,3		37,2		45,9		53,5	
LIA	Sw			27,0		-		33,6		40,3		-
	No		30,1		-		39,5		45,3		-	
KALFJORD	No		35,1		42,5		46,5		55,6		61,2	

Tabell II c. Vektdata for laks utsatt 1974, fordelt på populasjon.

SWEDISH AND NORWEGIAN SALMON STOCKED SPRING 1974													
LOCALITY	POPULA-TION	w e i g h t, cm:											
		At start	½ year		3/4 year		1 year		1½ year		2 year		
			Norw.	Swed.	Norw.	Swed.	Norw.	Swed.	Norw.	Swed.	Norw.	Swed.	
SOTRA	No	Swedish smolt ca 30 g Norwegian smolt ca 50 g	341		-		1320		3310		-		
BLOMVÅG	Sw			278		543		950		2490		5080	
	No		537		849		1430		3060		6225		
SVANØY	Sw			254		-		1430		2620		4850	
	No		378		-		1710		3180		5420		
RØRVIK	Sw			501		-		1200		2700		3450	
	No		694		-		1610		2960		4660		
HALSA	Sw			634		1084		1460		2120		3350	
	No		551		963		1330		1950		3540		
EIDET	Sw			186		304		500		980		1460	
	No		237		366		580		1060		1660		
LIA	Sw			227		-		410		730		-	
	No		289		-		620		950		-		
KALFJORD	No		536		950		1240		2040		3000		

Table III. Mean lengths and weights of rainbow trout (stocked 1974) after ½-1½ sea year.

LOCALITY	At start (May 74)			After ½ year			After 3/4 year			After 1 year			After 1½ year		
	l,cm	w.g	No	l,cm	weigth g	No.	l,cm	Weigth g	No.	l,cm	Weigth g	No	l,cm	Weigth g	No.
1 Blomvåg	Length, 13,6 cm	Weight 33,0 g	3000	29,5	413	2435	35,9	845	2350	43,4	1385	2300	54,2	2470	2150
2 Svanøy			3000	31,7	498	2695	-	-		43,6	1671	2600	58,0	3570	2550
3 Hitra			3000	31,3	479	1840	34,5	665	1050	42,1	1482	?	53,6	2740	99
4 Rørvik			3000	36,0	845	1670	-	-		43,8	1617	1620	55,5	3420	1610
5 Halsa			3000	37,1	961	2140	41,4	1370	2100	46,6	1832	2050	54,2	2500	2010
7 Eidet			3000	31,4	430	1590	34,2	620	1550	36,4	879	1500	46,1	1770	1550
8 Lia			3000	31,6	486	950	-	-		36,9	784	900	43,3	1290	ca900
9 Kalfjorden			3000	32,2	554	—	39,2	1170	1500	40,8	1352	1450	47,0	1900	1400

Table IV. Condition factors (based on mean length and weight) of salmon and rainbow trout at cooperating farms.

FARMS	SALMON								RAINBOW TROUT		
	After ½ year		After 1 year		After 1½ year		After 2 year		After ½ year	After 1 year	After 1½ year
	S	N	S	N	S	N	S	N			
1 Blomvåg	1,29	1,25	1,10	1,11	1,19	1,13	1,35	1,31	1,61	1,69	1,56
2 Svanøy	1,12	1,07	1,31	1,19	1,12	1,08			1,56	2,00	1,83
3 Hitra	1,06		1,11		1,09		-	-	1,56	1,98	1,78
4 Rørvik	1,31	1,20	1,33	1,25	1,23	1,24	1,19	1,20	1,81	1,92	2,00
5 Halsa	1,30	1,15	1,16	1,03	1,16	1,06	1,25	1,17	1,79	1,81	1,59
7 Eidet	1,03	1,01	1,26	1,12	1,22	1,10	1,10	1,08	1,39	1,82	1,80
8 Lia	1,15	1,06	1,08	1,01	1,12	0,97	-	-	1,54	1,57	1,59
9 Kalfjorden	1,24		-	1,23	-	1,19	-	1,31	1,66	1,99	1,83

Table V. Food conversion factors at the cooperating farms.

FARMS	SALMON					RAINBOW TROUT			
	0-½year	½-3/4 yr	3/4-1 yr.	1-1½ yr.	1½-2 yr.	0-½ yr.	½-3/4 yr.	3/4-1 yr.	1-1½ yr.
1 Blomvåg	6,0	4,6	3,2	3,3	-	4,9	5,5	4,6	6,7
2 Svanøy	11,6	6,0	4,3	7,2	5,5	7,8	5,5	7,1	6,3
3 Hitra	10,0	24,2	20,7	13,0		8,6	27,9	13,2	-
4 Rørvik	4,6	8,0		6,9	13,6	7,2	14,0		8,3
5 Halsa	5 ± 0,5	5,6	7,2	15,6	5,6	5 ± 0,5	7,8	10,2	12,3
7 Eidet	14,3	16,0	6,9	-		12,6	12,8	9,2	-
9 Kaldfjord	7,9	8,9	-	-		5,9	5,8	13,9	17,4

Table VI. Food analyses from Hitra (no 3) and Rørvik (no 4).

Date of sampling	Protein (N x 6,25)	Fat (benzene-method) g/100g	Fatfree dry matter g/100 g	Ashes (550°C) g/loo g	Composition of food in %					
					capelin	saithe-offals	trash-fish	herring	shrimp-peels	fish-powder
Hitra:										
9. 7 74	15,5	4,5	20,1	3,5	15	60	0	15	5-10	1
16. 7.74	13,9	4,1	18,8	3,4	30	0	60	0	5-10	1
29.10.74	15,9	8,4	20,7	4 3	45	45	0	0	10	-
15.11.74	17,0	8,4	21,7	3 9	0	30	0	60	10	-
28.11.74	15,4	11,9	19,3	3,0	0	45	0	45	10	-
12 12.74	14,0	10,9	23,2	2,6	45	0	0	45	10	-
16. 1.74	13,9	8,3	17,8	2 9	45	45	0	0	10	1
30. 1.75	13,3	5,0	18,3	3,2	45	45	0	0	10	-
13. 2.75	12,5	6,1	13,5	2,3	20	0	70	0	10	-
27. 2.75	14,1	5,0	18,6	3,2	30	0	60	0	10	-
Rørvik:										
17. 6.74.	11,9	9,9	23,0	2,2	90	0	0	0	0	10
1. 7.74.	12,2	5,3	19,9	2,5	90	0	0	0	0	10
31. 7.74	13,4	5,	18,9	3,3	90	0	0	0	0	10
14. 8.74	15,1	6,2	24,5	4,8	85	0	0	0	10	5
16. 9.74	13,2	5,1	20,4	3,5	30	40	0	0	20	10
30. 9.74	1_,1	3,6	16,4	2,6	25	45	0	0	20	10
14.10.74	14,2	8,6	19,3	2,7	40	40	0	0	0	10 [1]
28.10.74	14,6	6,9	23,2	3,9	30	30	0	0	20	10 [1]
11.11.74	13,9	7,6	20,7	3,4	35	35	0	0	20	10

1) 10 % roe

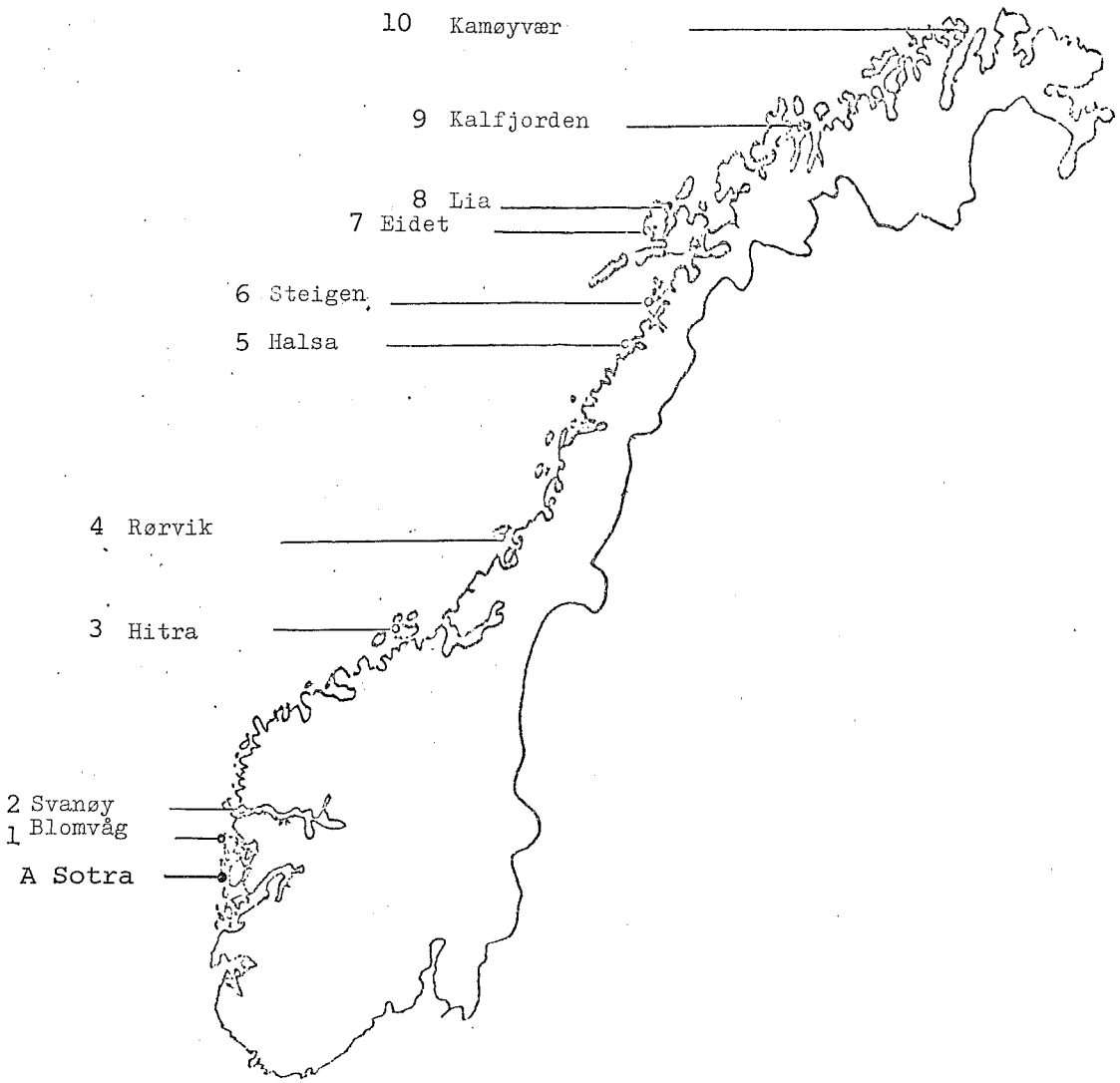

Figure 1. Locality of fish farms.

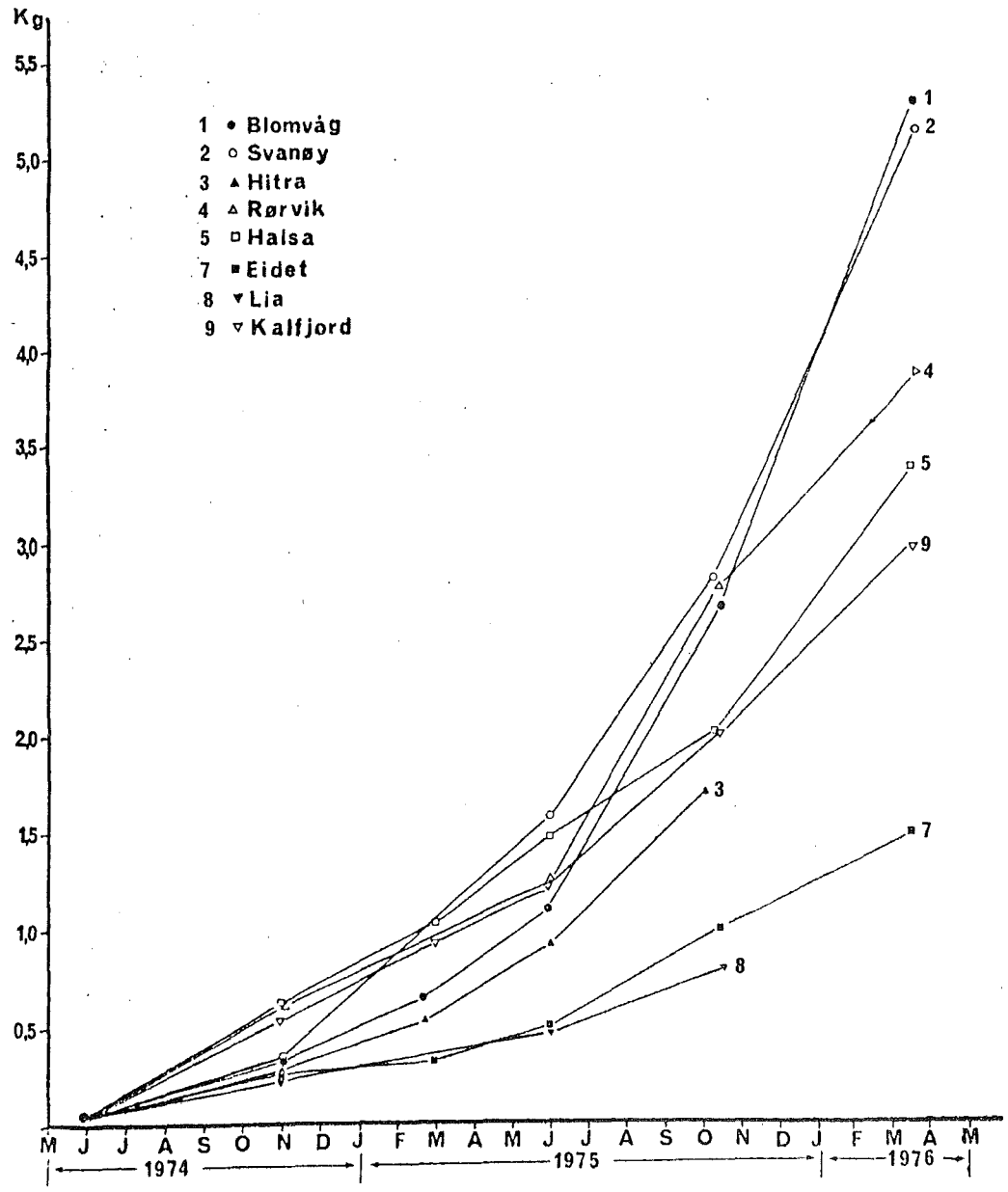

Fig. 2 a. Growth of salmon (stocked 1974) after ½, 3/4, 1, 1½ and 2 sea years. Swedish and Norwegian population calculated together.

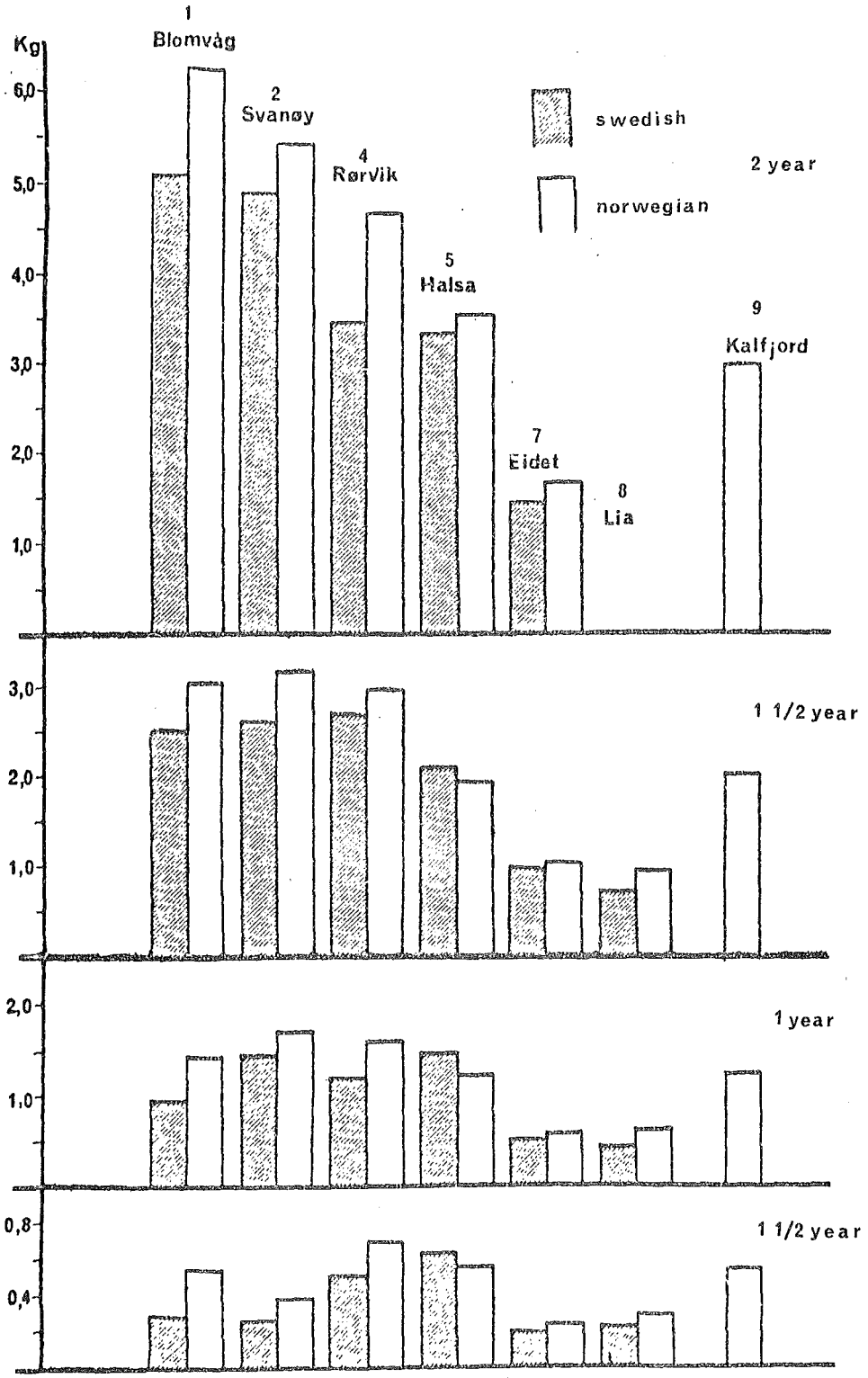

Fig. 2 b. Mean weights of Swedish and Norwegian salmon after ½, 1, 1½ and 2 sea years (stocked 1974).

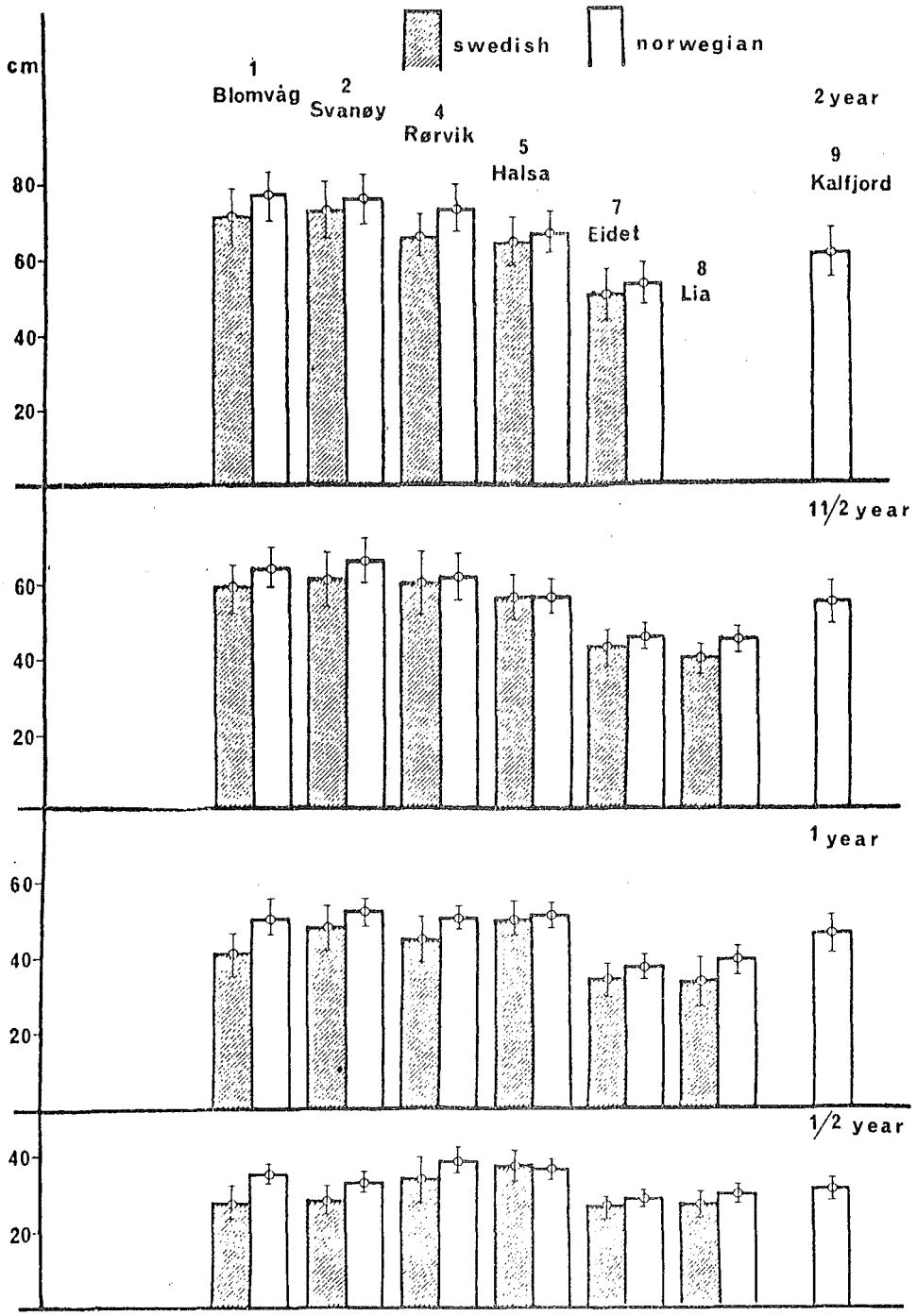

Fig. 3. Mean lengths of salmon at cooperating farms.
Horisontal lines represent standard deviation of mean.

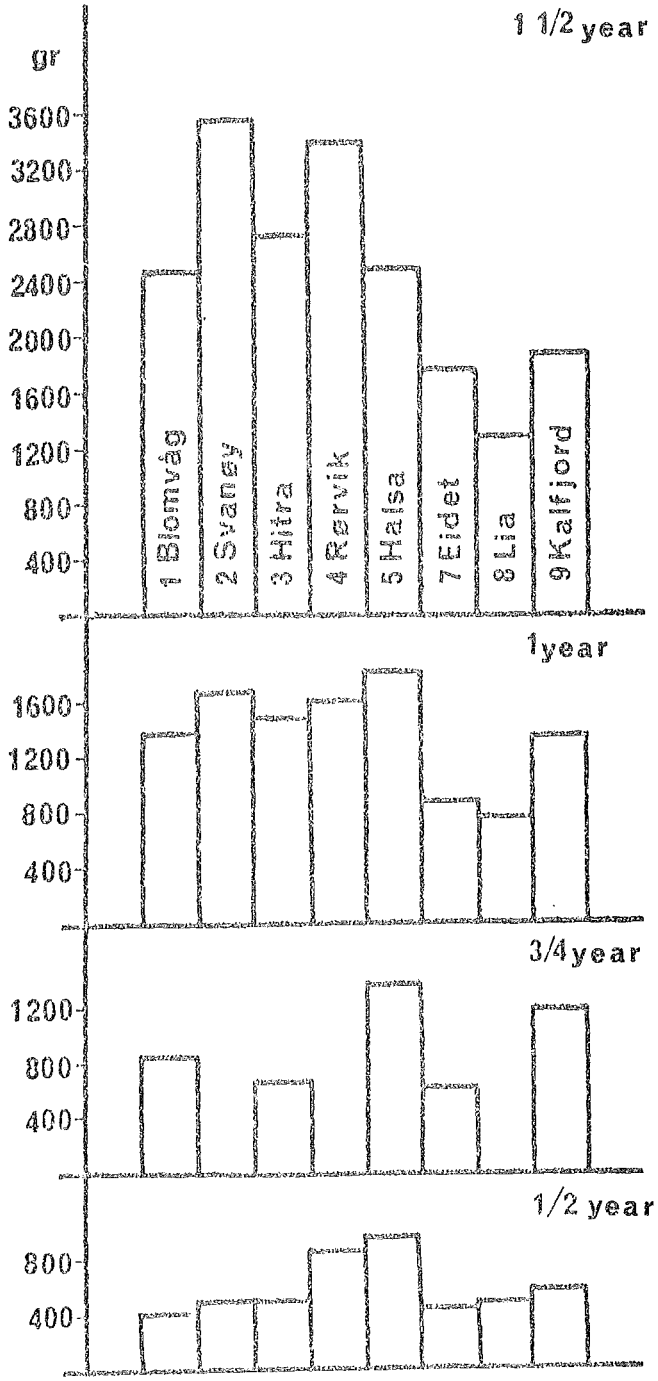

Fig. 4. Mean weights of rainbow trout (stocked 1974) after ½, 3/4, 1 and 1½ sea years at cooperating farms.

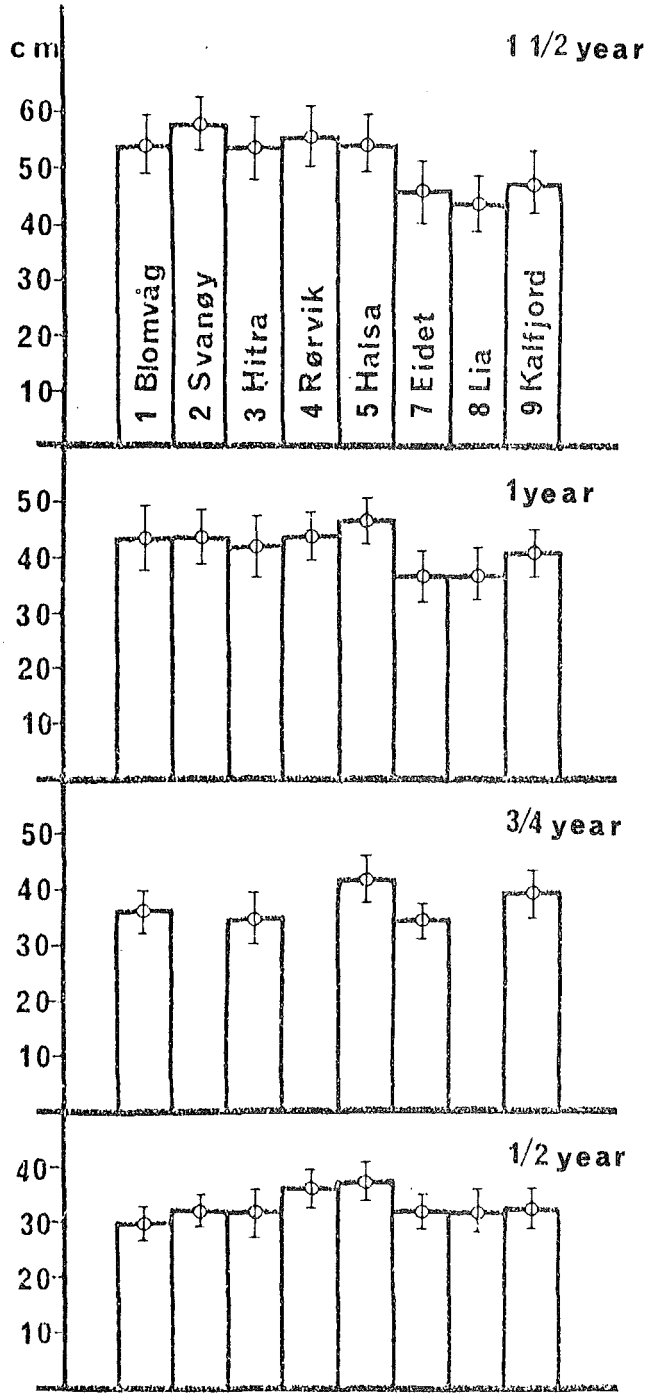

Fig. 5. Mean lengths of rainbow trout (stocked 1974) at cooperating farms after ½, 3/4, 1 and 1½ sea years. Horisontal lines represent standard deviation of mean.

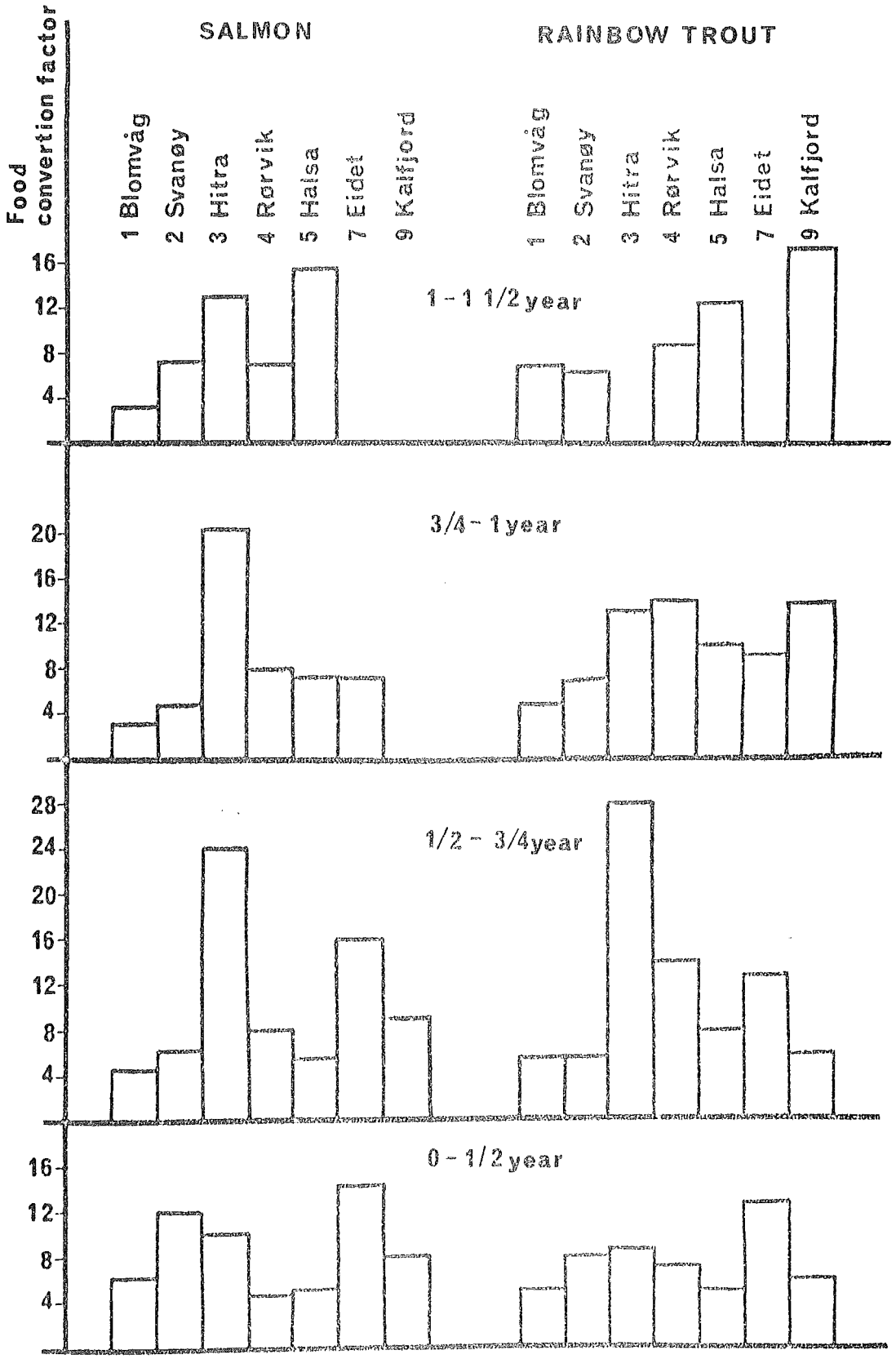

Fig. 6. Food conversion factors (=kg wet feed/kg weight increment) of salmon and rainbow trout at cooperationg farms.