ICES CM 1996
C.M.1996/M:8
ANACAT

Exploitation Ratio of Salmon in Relation to Salmon Run in Three Icelandic Rivers

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ABSTRACT

Since 1935 salmon ascending River Ellidaar SW-Iceland have been counted. The run in River Ellidaar consists almost entirely of grilse (one sea winter fish). In the glacier fed River Blanda, N-Iceland, salmon ascending the river have been counted since 1982. In another river in N-Iceland, River Nupsa, a tributary to River Midfjardara, down-migrating smolt have been tagged since 1987. Later tagged fish are recovered in the catch in the main river and the fish entering River Nupsa were inspected in a trap. Both grilse and salmon (two sea winter fish) are in these rivers in the North. The fishing effort in the rivers has been fairly constant where only limited numbers of rods are allowed and no or only small changes have occurred in the number of rods. Accurate catch statistic, (where each fish and its size is recorded) are available for all the rivers. Therefore it is possible to calculate the exploitation rate of both grilse and salmon in the rivers in relation to the total salmon run.

The average exploitation ratio during the study period in River Ellidaar was 0.36, in River Blanda it was 0.62 and 0.75 and in River Nupsa it was 0.70 and 0.85, for grilse and salmon, respectively. For hatchery smolt the exploitation ratio in River Nupsa was 0.66 and 0.77, for grilse and salmon respectively. The exploitation rate was generally higher in years with small salmon run than in years with large run.

Key words: Atlantic salmon, exploitation rate, stock size.

Introduction

Salmon fishery in Iceland only takes place in rivers, with minor exceptions. In most rivers rod and line is the only fishing method. Only limited number of rods are allowed in each river and, very little, or no changes have been in the number of rods used in the rivers. Therefore the fishing effort in the rivers is fairly constant over long period of time.

Catch statistics of salmon rivers in Iceland are very accurate where each salmon caught is recorded along with its size (Alexandersdottir *et al.* 1978, Gudbergsson 1996). The catch of salmon from year to year can vary and the variations are large, especially in North Iceland (Antonsson *et al.* 1996). For sound management of the salmon stocks it is important to know the exploitation rate in years with different size of salmon runs in order to see if the spawning stocks are large enough.

The purpose of this paper was to analyse the exploitation rate in context with the stock size of salmon in three rivers in Iceland, located both in south and north Iceland (Figure 1).

Material and methods

River Ellidaar, SW-Iceland is spring-fed river with 4-5 m^3/sec flow on average (Table 1). The flow is even all year around but can be lower in the summer during the fishing season. Hydro electrical power station has been at the river since 1920 and along with other alternations on the river bed and the river's surroundings have caused degradation on the natural condition for the salmon stock in the river system. The salmon stock in River Ellidaar consist almost entirely of grilse. A trap is located on the river about 500 m above its estuary (Figure 2). There the fish were counted manually since 1935 to 1960, when mechanical fish counter was installed. In the year 1970, 1972 and 1976 the counter was broken. Mundy *et al.* (1978) estimated the total run from catch statistics for these years. The number of salmon caught below the trap was added to the number counted and that gave the size of the salmon run. The number of salmon left in the river below the trap are few and their numbers have little effects.

River Blanda is in North Iceland and is direct runoff river. It is partly glacier fed (10%) that makes the river water turbid in the summer. The water flow in River Blanda was around 40 m^3/sec on average and higher in the summer (Table 1). In 1991 a hydro electrical power plant was

installed in the river. After that, the water is less turbid in the river and the flow is more even, and lower than before during the fishing season. The salmon stock in Blanda consist both of grilse and salmon. About 2 km above the estuary there are cascades, the Ennis cascades. Fish ladder was built around the cascades in the 40's and reconstructed in the 70's. A trap was put in the ladder in 1982 (Figure 2). Since then all salmon passing through the ladder have been counted and their sizes measured. All fish passing through the trap were also tagged using Floy tags. Part of the run each year ascended the cascades. The number of salmon ascending the river that way could be calculated using number of tagged/untagged fish in the catch above the cascades. The fishing takes place below the cascades and above the cascades both in River Blanda and its tributary, River Svarta. In 1991- 1992 an automatic fish counter that counts and measures the fish size was tested along with the trap and since 1993 it has been used entirely (Gudjonsson and Gudmundsson 1994). It is assumed that 20 % of the run passes the cascades but that number was experienced in 1991 and 1992, that are the years fish were tagged, after the power plant was installed (Gudjonsson and Jonsson 1996). To calculate the total run the number of salmon caught below the cascades was added to the number of salmon passing through the ladder and the number of salmon going up the cascades. Very poor or none spawning grounds exists below the cascades and no salmon are left there in the autumn.

River Midfjardara is a direct runoff river with water flow of 10 m^3/sec (Table 1). Its salmon stock consists both of grilse and salmon. In River Nupsa, one of its three main tributaries, natural smolts have been trapped and microtagged since 1987 (Figure 2). The adipose fin of all tagged smolts was removed for external recognition of microtagged fish. In 1987-1993 hatchery reared smolts were released after a period of adjustment in a pool situated near the smolt trap. At the same location as the smolt trap, a trap catching adults ascending River Nupsa has been operated during the study period throughout the angling season. Anglers' catches were monitored for tagged fish. Adults going through the trap were examined for adipose fin clip, measured, their sex determined and tagged with Floy tag. In the autumn after the angling season (mid September), the traps were removed and the distribution of remaining microtagged individuals was assessed by seining in Nupsa and other parts of the river system. The exploitation rate was calculated separately for returning adults according to origin, i.e. hatchery or wild as:

Exploitation ratio = (Total catch/ catch below trap + adults monitored in trap)/100

Results

Salmon catch was generally higher in years with large runs in all the rivers for both grilse and salmon and the relationship between size of the run and catch is statistically significant (Figures 3a, 4a, 5a, 6a, 7a, 8a).

Exploitation ratio was higher in years with low run in River Ellidaar and for grilse in River Nupsa (Figures 3b, 7b) but not for salmon in River Nupsa nor grilse or salmon in River Blanda (Figures 4b, 5b, 6b, 8b, Tables 2, 3, 4). The average exploitation ratio during the study period in River Ellidaar was 0.36, in River Blanda it was 0.62 and 0.75 and in River Nupsa it was 0.70 and 0.85, for grilse and salmon, respectively (Table 5). For hatchery smolt the exploitation ratio in River Nupsa was 0.66 and 0.77, for grilse and salmon respectively.

The average annual exploitation ratio (and range) in River Ellidaar was 0.39 (0.20-0.80), in River Blanda 0.66 (0.45-0.81) for grilse and 0.75 (0.64-0.90) for multi sea winter salmon, and in Nupsa 0.73 (0.47-0.86) for grilse and 0.84 (0.74-0.94) for multi sea winter salmon.

Exploitation ratio varied between years in all rivers but no major trend in the ratio could be seen, except for River Blanda where exploitation ratio for grilse seems to be lower after damming of the river in 1991 (Figures 3c, 4c, 5c, 6c 7c).

Discussion

The are some important factors that make it ideal to study exploitation rate in relation to variable runs of salmon in Icelandic rivers. There is ban on ocean fishery of salmon within Iceland's 200 economic zone. The fishing effort has been unchanged for long period of time and the catch statistics are very accurate. It has been shown earlier that the catch reflect the size of the run into Icelandic rivers (Gudjonsson et al. 1995). The result of this study manifest these findings.

Exploitation ratio is higher in years with low run in River Ellidaar where the data series is longest. This can also be seen for grilse in River Nupsa. Many environmental factors can affect the fishery each year and mask out the relationship especially if relatively few years are included as in the two northern rivers (Blanda and Nupsa) in present study.

The exploitation ratio is higher on multi sea winter salmon in the two northern rivers in all years. This can also be seen in other studies around the Atlantic ocean (Anon 1996). Multi sea winter salmon enters rivers early in the fishing season and it is therefore possible to catch them for long period of time compared to grilse that enter the rivers later in the summer. There are more females that return as multi sea winter fish and males are dominant in the grilse run in the northern rivers (Gudbergsson 1996). It is possible that if females are more aggressive in defending their sites in the rivers they are more likely to be caught. If so it could partly explain the higher exploitation rate of multi sea winter fish. In River Blanda water turbitity due to melting of glacier caused delay in the fish migration, sometimes for long period of time. The salmon stopped below the Ennis cascades and then the fishing there was good. The time of this delay each year was very variable causing very high exploitation ratio in some years (Antonsson 1984, 1985, Gudjonsson and Jonsson 1996). It can also explain why exploitation on multi sea winter salmon is higher since more glacier melting generally took place during the migration time of salmon, than during grilse migration time. It also can explain why relationship between the size of the run and the exploitation ratio can not be seen in River Blanda.

Possible sources of errors in the present study are considered to be small, but should be mentioned. If more or less than the assumed 20 % of the run passes up the cascades in River Blanda it can change the results. The fish go the cascades at certain water level. The water level has been stable and similar during the fishing season after damming of the river and therefore diminishing this possibility. Losses of external tags are possible source of error in both River Blanda and River Nupsa, but inspection of fish showed low percentage of fish that had lost their tag. In River Nupsa it is possible that very few tagged fish could slip by inspection of the catch unnoticed.

The exploitation rate is high in the two northern rivers. Part of the explanation in River Blanda is the delay in run that could occur below the Ennis cascades. After damming of the river, salmon can more easily migrate up the river as water flow is more even and the river is less turbid, because suspended solids in the glacier water settle in the reservoir. The exploitation of grilse is lower after the damming, but exploitation of multi sea winter salmon is still high. The exploitation ratio in the River Nupsa system is also high indicating that a rod and line can be very effective fishing tool. Returns of hatchery smolts into rivers are later than for wild fish and the hatchery smolts returns tend to be less distributed in the river catch than wild fish (Antonsson and

Gudjonsson 1996, Gudjonsson 1991). These could explain lower exploitation ratio of hatchery smolt returns than wild fish.

In River Ellidaar the exploitation ratio is much lower. The river is fed by a lake and many salmon migrate into the lake and are thereby not in the fishing. Annual surveys of juveniles takes place in all the rivers in the study and despite high exploitation ratio in the two northern rivers there are no serious signs of lack of spawning (Antonsson and Gudjonsson 1996, Jonsson and Gudjonsson 1995, Tomasson 1995). An earlier study (T. Gudjonsson 1986) showed that exploitation ratio was variable in different Icelandic rivers ranging from 0.36 to 0.85. The exploitation ratio in Icelandic rivers seems to depend on the type of the river system, that is the water discharge and if there are lakes in the system, etc. Studies in other countries have shown that exploitation ratio is as highly variable between rivers as the rivers are variable and the fishing methods (Hansen 1986, Marshall 1986, Shearer 1986, Whitaker 1986).

In Iceland rod and line is the only fishing method and no fishing at sea interferes the salmon migration as in other places. In spite of these facts it is seen in some rivers that the exploitation ratio can be very high especially in year with low run and the fishing effort should therefore be carefully considered.

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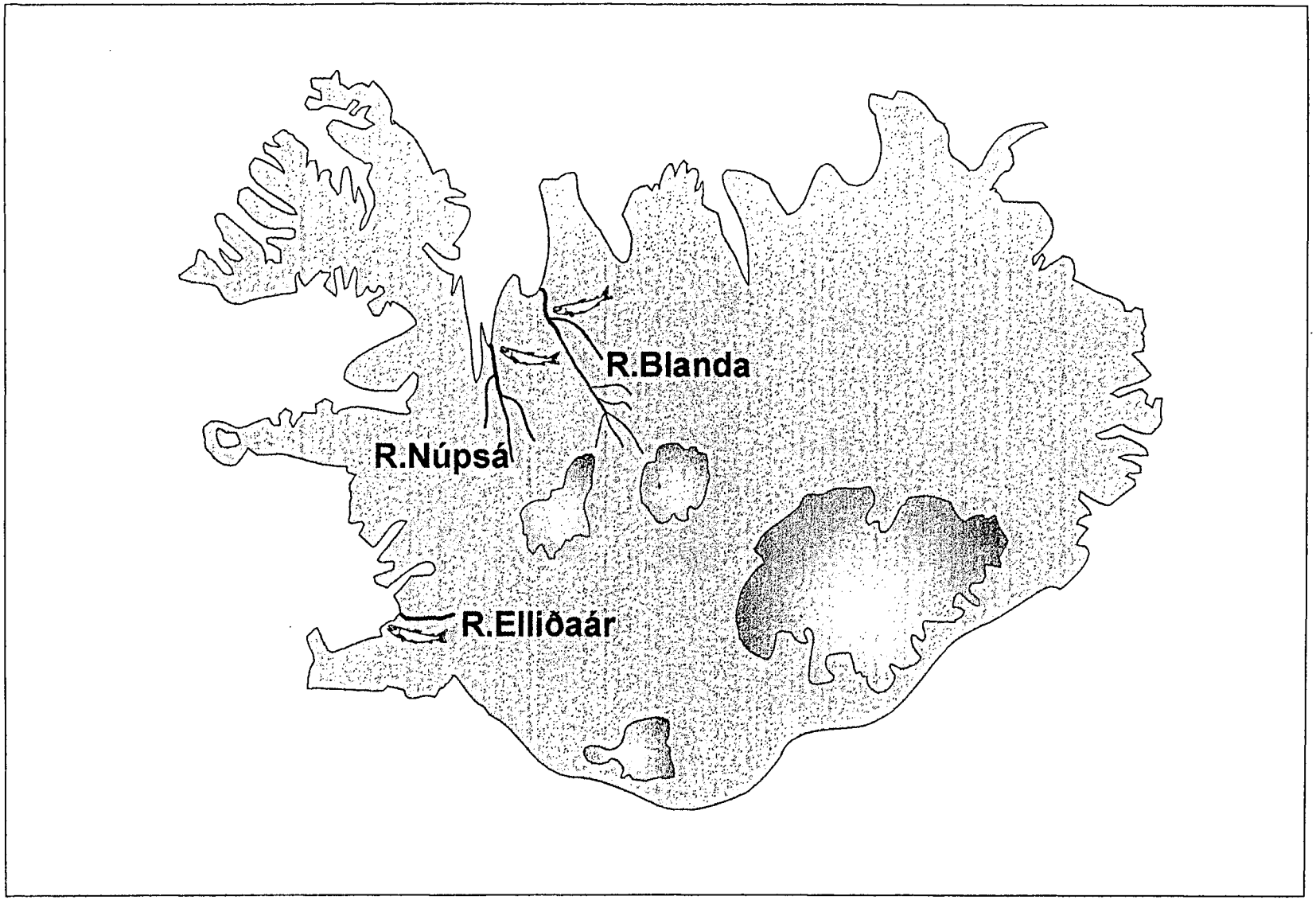

Figure 1. Location of the rivers in the study.

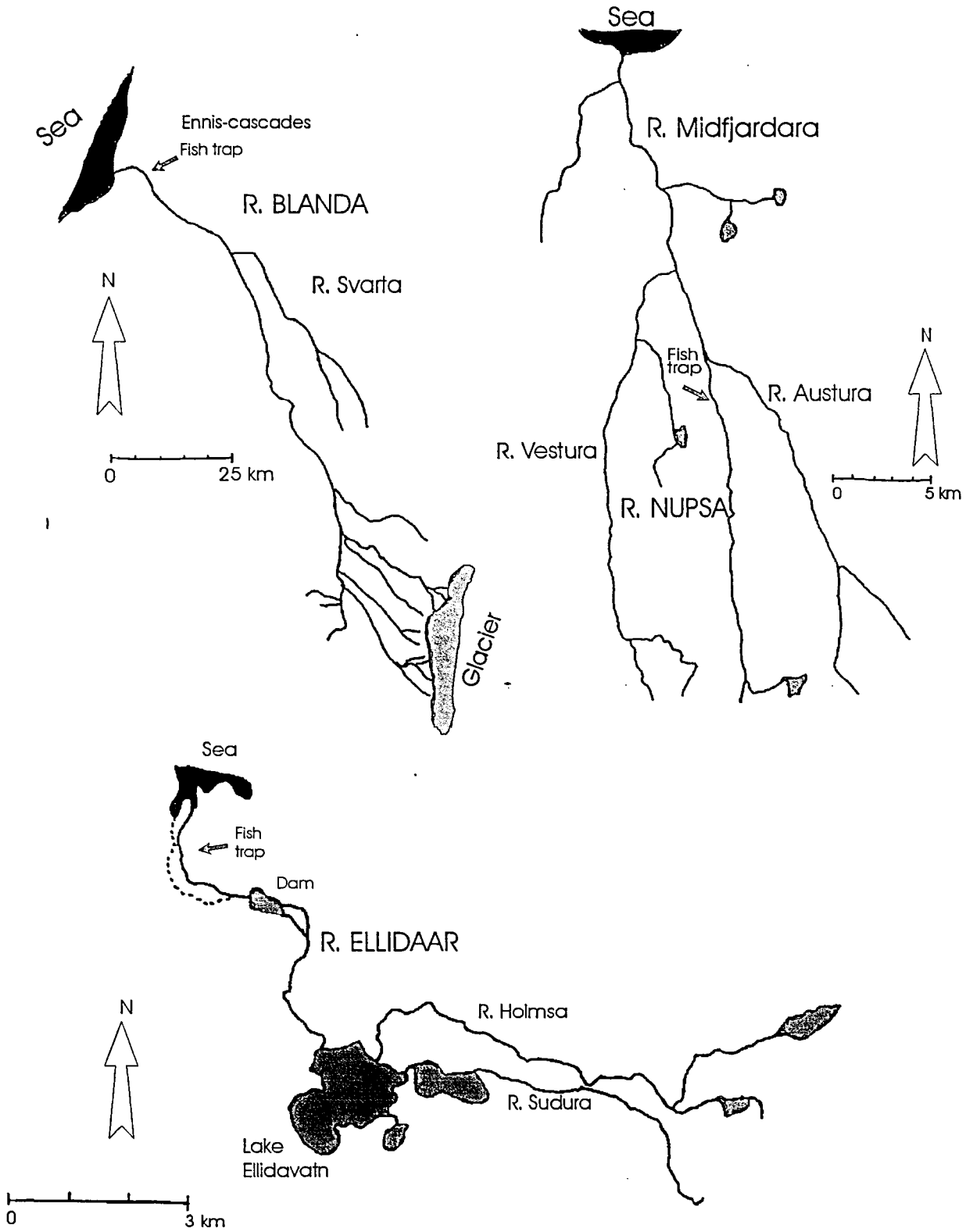

Figure 2. River Blanda, River Midfjardara (and its tributary River Nupsa) and River Ellidaar. Location of the fish traps are shown on the figure in each river. Notice the different scale (km) for each river.

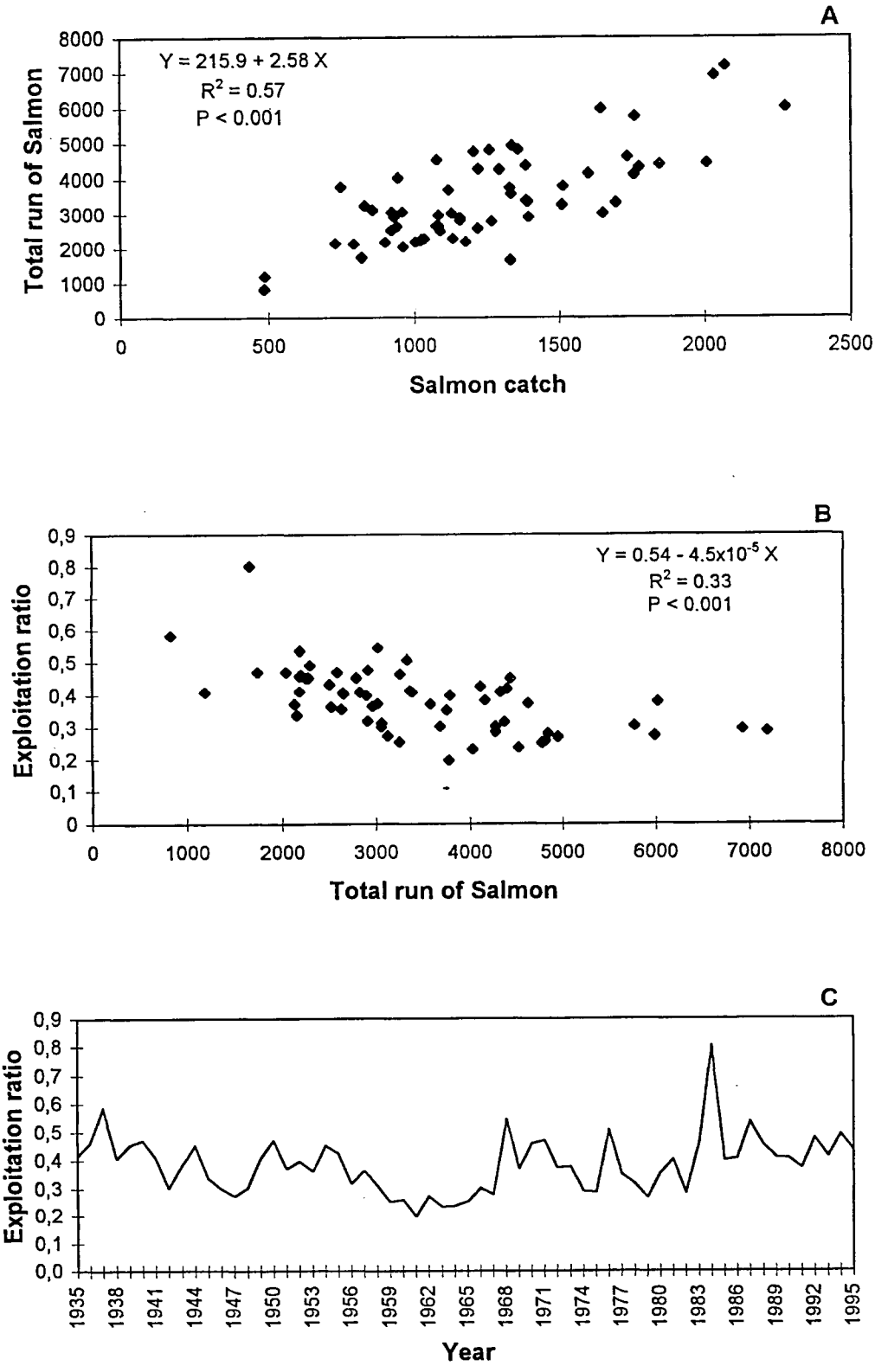

Figure 3. River Ellidaar, the period 1935-1995. A) the relationship between total run of salmon and salmon catch. B) the relationship between the total run of salmon and exploitation ratio of salmon. C) exploitation ratio from 1935 to 1995.

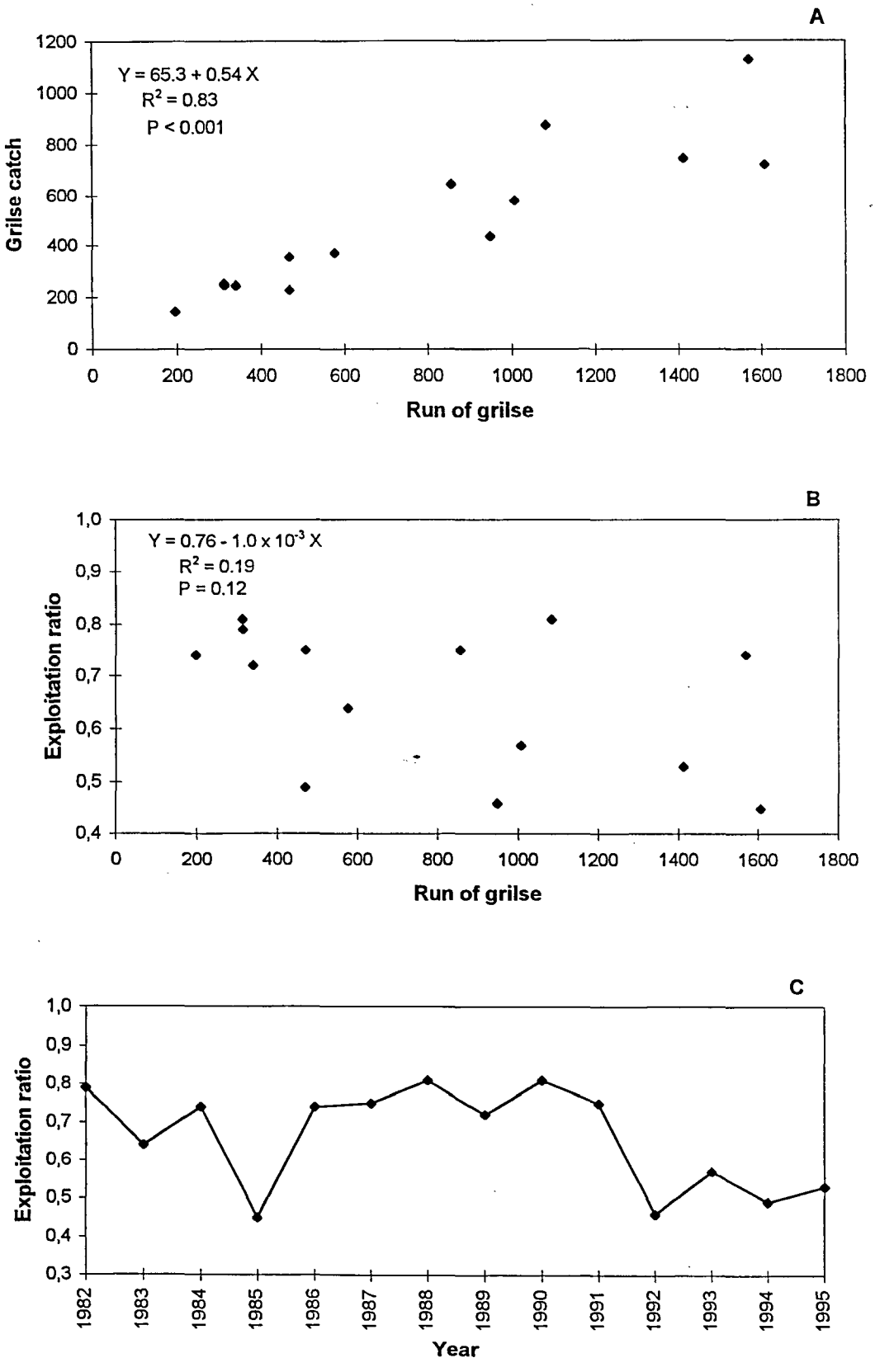

Figure 4. River Blanda - grilse, the period 1982-1995. A) the relationship between grilse catch and run of grilse. B) the relationship between run of grilse and exploitation ratio of grilse. C) exploitation ratio of grilse from 1982 to 1995.

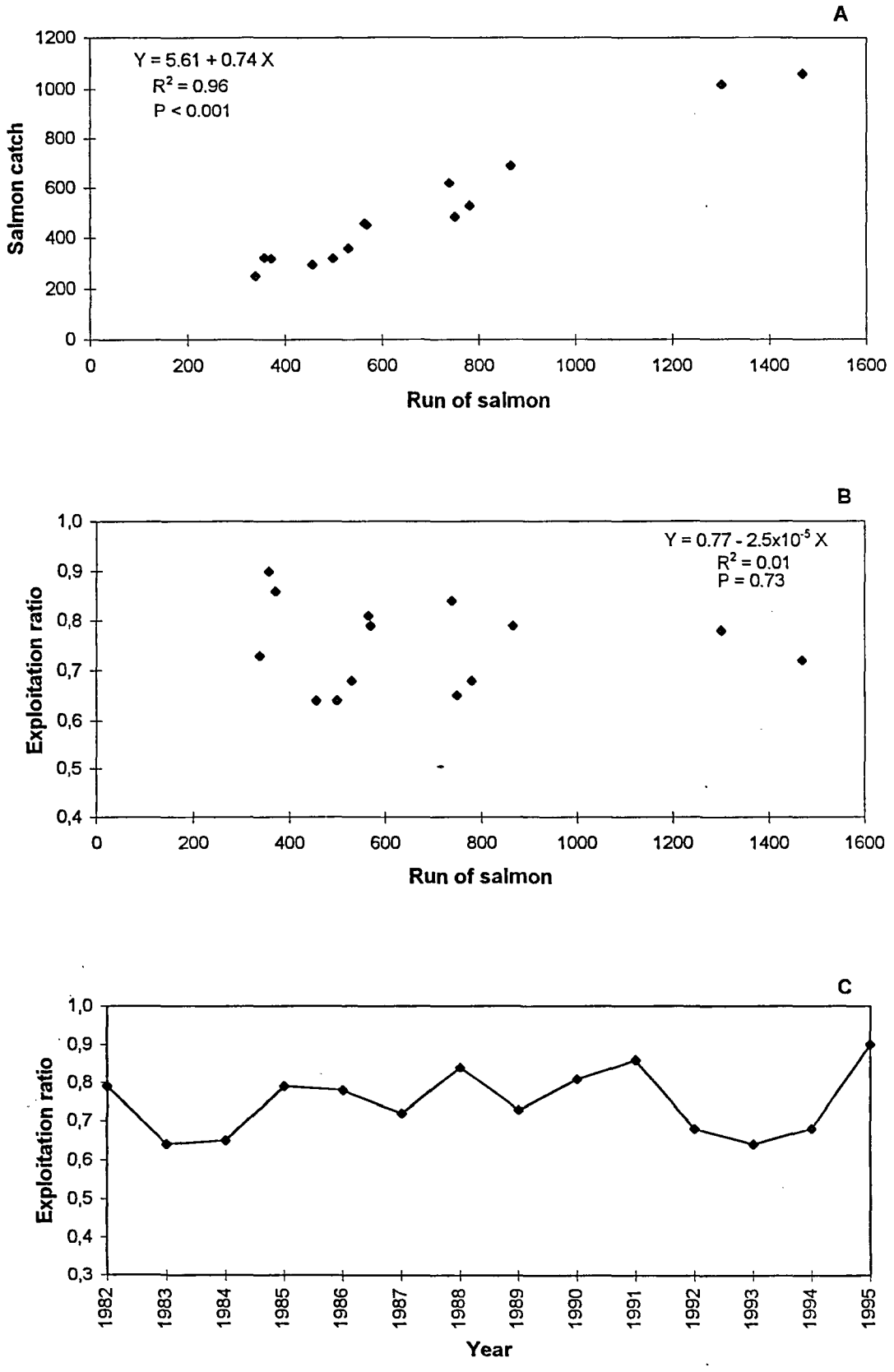

Figure 5. River Blanda - multi sea winter (MSW) salmon, the period 1982-1995. A) the relationship between MSW salmon catch and run of MSW salmon. B) the relationship between run of MSW salmon and exploitation ratio of MSW salmon. C) exploitation ratio of MSW salmon from 1982 to 1995.

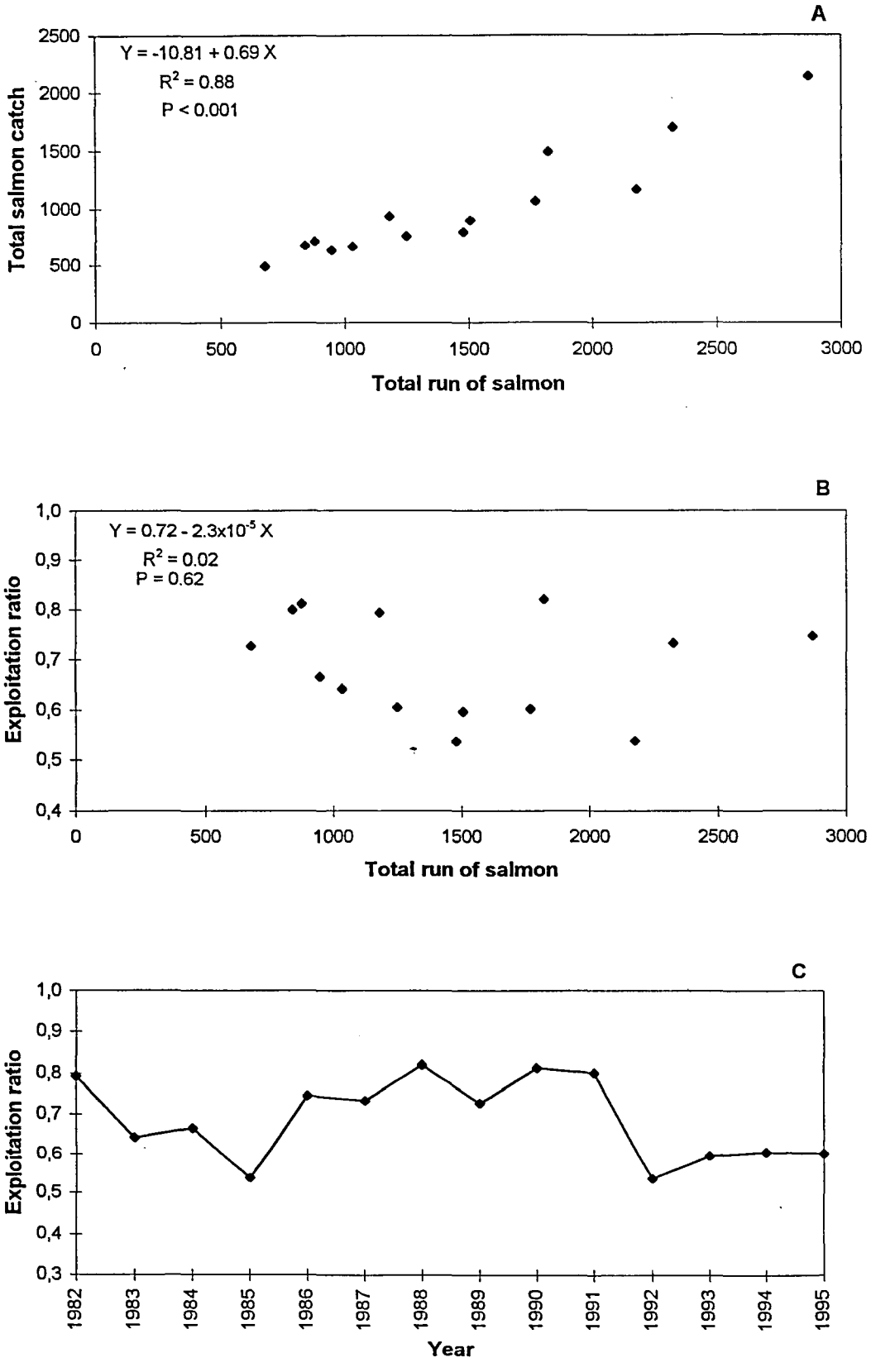

Figure 6. River Blanda - grilse and MSW salmon, the period 1982-1995. A) the relationship between total run of salmon and total salmon catch. B) the relationship between the total run of salmon and exploitation ratio of both grile and MSW salmon. C) exploitation ratio of both grilse and MSW salmon from 1982 to 1995.

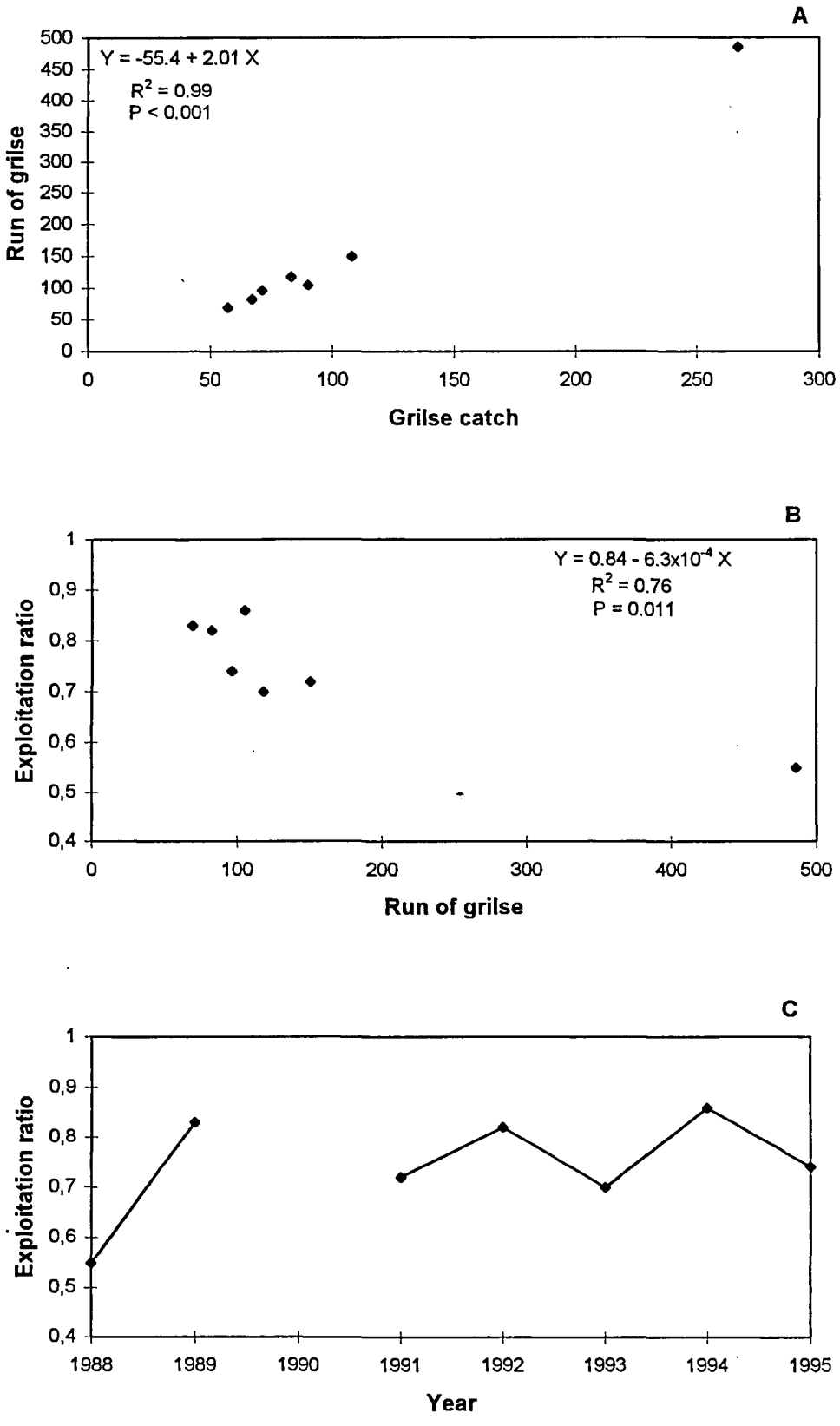

Figure 7. River Nupsa - grilse, the periods 1988-1989 and 1991-1995. A) the relationship between grilse catch and run of grilse. B) the relationship between run of grilse and exploitation ratio of grilse. C) exploitation ratio of grilse 1988-1989 and 1991-1995.

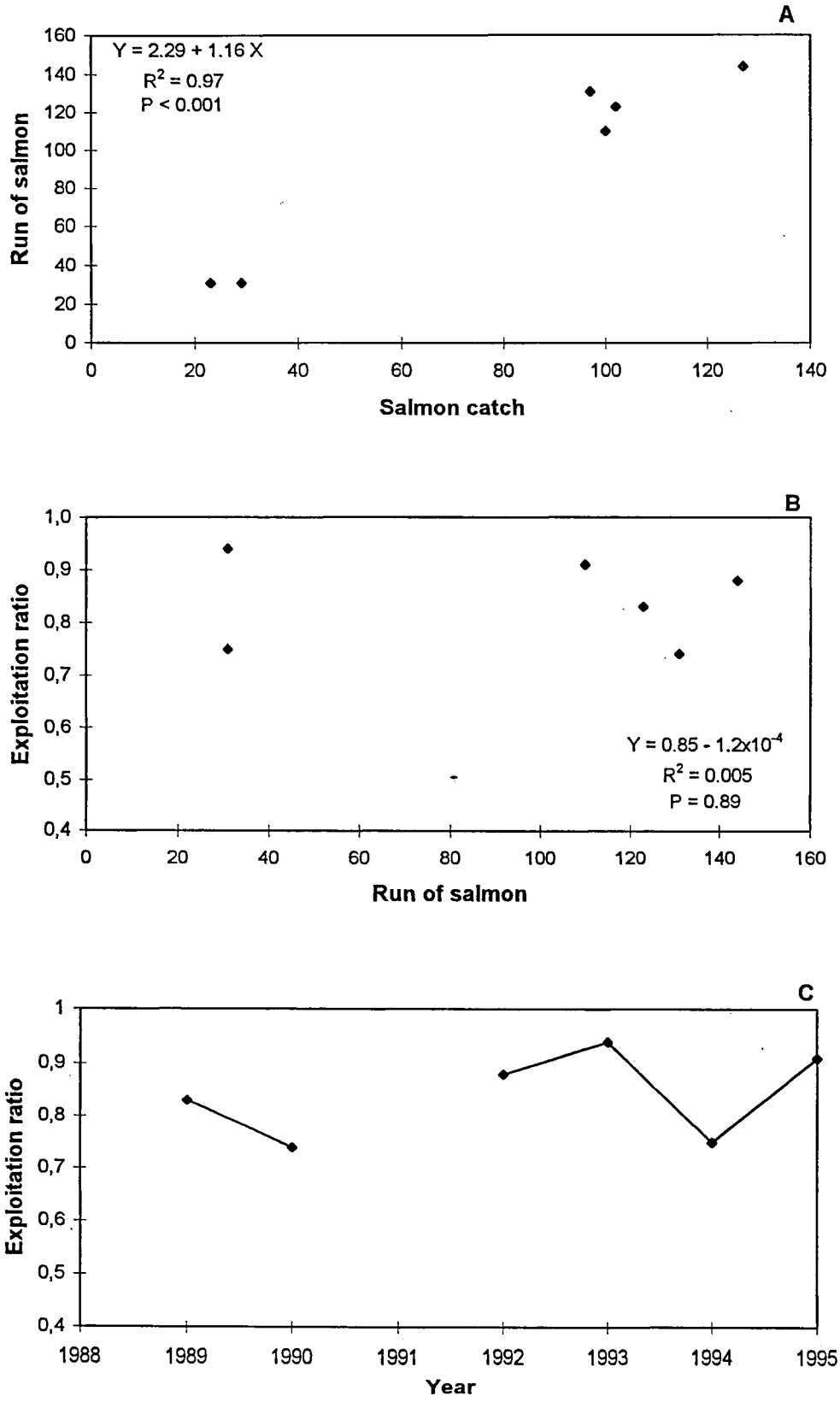

Figure 8. River Nupsa - salmon, the periods 1989-1990 and 1992-1995. A) the relationship between MSW salmon catch and run of MSW salmon. B) the relationship between run of MSW salmon and exploitation ratio of MSW salmon. C) exploitation ratio of MSW salmon 1989-1990 and 1992-1995.

Table 1. Statistics of physical parameters of the rivers in the study.

River name	Catchment area km^2	Discharge m^3/s	Length km	Mean salmon catch 1974-1995	Conductivity µS/cm
Ellidaar	286	5,0	29	1392	90
Nupsa	98	2,5	26	162	76
Blanda	2370	40,0	125	991	53

Table 2. Salmon catch, run and expoitation ratio in River Ellidaar 1935-1995.

Year	Salmon catch	Salmon run	Exploitation ratio
1935	1844	4403	0,42
1936	1020	2205	0,46
1937	485	830	0,58
1938	486	1189	0,41
1939	1033	2278	0,45
1940	818	1740	0,47
1941	898	2184	0,41
1942	1116	3682	0,30
1943	1599	4162	0,38
1944	1022	2259	0,45
1945	729	2155	0,34
1946	922	3059	0,30
1947	1643	5978	0,27
1948	1759	5764	0,31
1949	1157	2825	0,41
1950	960	2042	0,47
1951	792	2132	0,37
1952	1511	3792	0,40
1953	919	2526	0,36
1954	1265	2794	0,45
1955	1755	4118	0,43
1956	929	2911	0,32
1957	1083	2965	0,37
1958	958	3057	0,31
1959	1205	4773	0,25
1960	1258	4815	0,26
1961	748	3779	0,20
1962	856	3126	0,27
1963	943	4031	0,23
1934	1077	4526	0,24
1965	830	3249	0,26
1966	1292	4274	0,30
1967	1357	4839	0,28
1968	1648	3024	0,54
1969	1333	3580	0,37
1970	1002	2187	0,46
1971	1218	2590	0,47
1972	1733	4627	0,37
1973	2276	6014	0,38
1974	2033	6925	0,29
1975	2071	7184	0,29
1976	1692	3331	0,51
1977	1328	3756	0,35
1978	1383	4372	0,32
1979	1336	4948	0,27
1980	938	2632	0,36
1981	1074	2656	0,40
1982	1219	4275	0,29
1983	1508	3257	0,46
1984	1331	1659	0,80
1985	1157	2896	0,40
1986	1083	2651	0,41
1987	1175	2191	0,54
1988	2006	4435	0,45
1989	1773	4329	0,41
1990	1384	3383	0,41
1991	1127	3020	0,37
1992	1393	2917	0,48
1993	1390	3363	0,41
1994	1132	2298	0,49
1995	1088	2509	0,43

Table 3. Salmon run, catch and expoitation ratio in River Blanda 1982-1995.

Year	Run of grilse	Run of salmon	Expl. ratio grilse	Expl. ratio salmon	Grilse catch	Salmon catch	Total catch of salmon	Total run of salmon
1982	314	866	0,79	0,79	248	688	936	1180
1983	577	456	0,64	0,64	369	294	663	1033
1984	197	750	0,74	0,65	145	485	630	947
1985	1607	569	0,45	0,79	722	451	1173	2176
1986	1569	1301	0,74	0,78	1124	1017	2141	2870
1987	856	1469	0,75	0,72	645	1060	1705	2325
1988	1083	739	0,81	0,84	875	619	1494	1822
1989	340	338	0,72	0,73	245	248	493	678
1990	312	564	0,81	0,81	252	459	711	876
1991	469	371	0,75	0,86	353	319	672	840
1992	948	530	0,46	0,68	435	360	795	1478
1993	1006	499	0,57	0,64	579	320	899	1505
1994	468	781	0,49	0,68	229	528	757	1249
1995	1412	357	0,53	0,9	745	321	1066	1769

Table 4. Run, catch and exploitation ratio of wild salmon in River Nupsa 1988-1995.

	Grilse			Multi sea winter		
Year	Total run	catch	Expl. ratio	Total run	catch	Expl. ratio
1988	486	228	0,47			
1989	69	57	0,83	123	102	0,83
1990				131	97	0,74
1991	150	108	0,72			
1992	82	67	0,82	144	127	0,88
1993	118	83	0,70	31	29	0,94
1994	105	90	0,86	31	23	0,75
1995	96	71	0,74	110	100	0,91

Table 5. Total returns, catch and exploitation rate of microtagged fish in River Nupsa 1988-1995.

H = hatchery and W = wild.

		Capture				
	Total returning	Main stem	Nupsa below the trap	Nupsa above the trap	Total caught	Exploitation rate
Grilse - H	528	208	59	81	348	65,9
Grilse - W	255	84	31	64	179	70,2
MSW - H	125	69	15	12	96	76,8
MSW - W	144	77	24	22	123	85,4