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EVOLUTION OF CHARACTERISTICS OF ATLANTIC SALMON CATCH IN THE
ADOUR BASIN RELATED TO ENVIRONMENTAL VARIATIONS.

F.-X. CUENDE ET P. PROUZET
IFREMER/DRV/RH
STATION HYDROBIOLOGIE INRA
BP3 64310 St PEE/NIVELLE

ABSTRACT :

The characteristics of the Atlantic salmon (*Salmo salar* L.) caught by the commercial fisheries in the Adour-Gaves Basin at the ends of the 19th and 20th centuries were compared with regards to age structure and mean weight-at-age. A visual analysis of the monthly weight distributions determined an age structure for the 20th century data which was proved consistent with the one obtained by scale-reading. It was therefore used to study the 19th century weight frequency data. Age structure comparison showed a decrease of the mean sea-age between the two periods (most catches with one sea-winter for the 1985-1990 period, instead of two sea-winters for the 1873-1898 period), as well as a drastic decline of the three-sea-winter salmon stock and the almost total disappearance of the four-sea-winter fish. The mean weight of the one-sea-winter salmon seemed not to have changed while those of the multi-sea-winter fish showed a slight decrease between the two periods.

Keywords : Atlantic salmon, *Salmo salar*, stock, characteristics, age determination, professional fisheries, France, Adour Basin.

RESUME :

Les caractéristiques des saumons atlantiques (*Salmo salar* L.) capturés à la fin du 19ème et du 20ème siècle par les pêcheries professionnelles du Bassin Adour-Gaves ont été comparées en termes de structures d'âge et de poids moyen pour un âge donné. La structure d'âge des captures du 19ème siècle a été déterminée par une analyse visuelle des distributions mensuelles de poids, cette méthode ayant donné des résultats très proches de ceux de la scalimétrie pour les captures du 20ème siècle. La comparaison des structures d'âge a montré une baisse de la durée moyenne de vie en mer (un hiver de mer pour la plupart des captures de la période 1985-1990, contre deux hivers de mer pour la période

1873-1898), ainsi que le recul très important du stock de saumons de trois hivers de mer et la disparition quasi-totale des poissons de quatre hivers de mer. Le poids moyen des saumons d'un hiver de mer ne semble pas avoir changé, tandis qu'on observe une légère diminution des poids moyens respectifs des poissons de plus d'un hiver de mer entre les deux périodes.

1. INTRODUCTION

Several studies focused on the Atlantic salmon stocks of the Adour and Gaves rivers, since the 1950s. The first studies were by VIBERT (1950), on salmon caught during the 1942-1948 period and sampled mainly in the Basque country smoking plants. Observations have been conducted more recently by BOUSQUET and MARTY (1987), mostly from 1977 to 1981, on angling and gillnet catches, in the Gave d'Oloron and the Adour estuary. Lately, investigations have been carried out by PROUZET et al. (1990) as well as the Conseil Supérieur de la Pêche (Anon., 1990) on the commercial gillnet catches in the Adour river, and on the rod-and-line catches in the Nive and Gave d'Oloron rivers.

In addition, analysis of account books dating back to the 1880s, dealing with some commercial fisheries situated on the Gave de Pau and Gave d'Oloron rivers, enabled us to draw on much information on the characteristics and abundance of the catches at the end of the 19th century.

A comparison of the observations carried out on the different studied stocks, particularly those from the 19th century fisheries account books and those obtained by sampling commercial fisheries from 1985 to 1990 seemed important when considering that between these two periods several anthropic actions may have contributed to modify age structure and characteristics of the Atlantic salmon stocks of the Adour and Gaves rivers, and more especially :

- . building hydroelectric dams without efficient fish-pass, on the Gave de Pau and Gave d'Oloron rivers, during the first half of the 20th century, thus hindering salmon access to upstream spawning areas ;

- . salmon fishing in Greenland waters, beginning in the 1960s

- . using increasing numbers of juveniles from foreign sources for restocking since the 1980s.

2: GEOGRAPHICAL SITUATION OF THE SAMPLING POINTS

The 19th-century fisheries the account books of which have been analysed were situated on the lower parts of the Gave d'Oloron (Sordes fisheries) and the Gave de Pau (Lahontan, Cauneille and Puyoo fisheries), respectively about 45 km and 50 km away for the river mouth (fig. 1).

In the 20th century, the sampling area is situated downstream, between the mouth of the Adour estuary and the confluence of the Gaves Réunis and the Adour river. It consists of the 35-kilometre long sequence of the 6 major drift gillnet fishing areas.

Figure 1 - Situation map

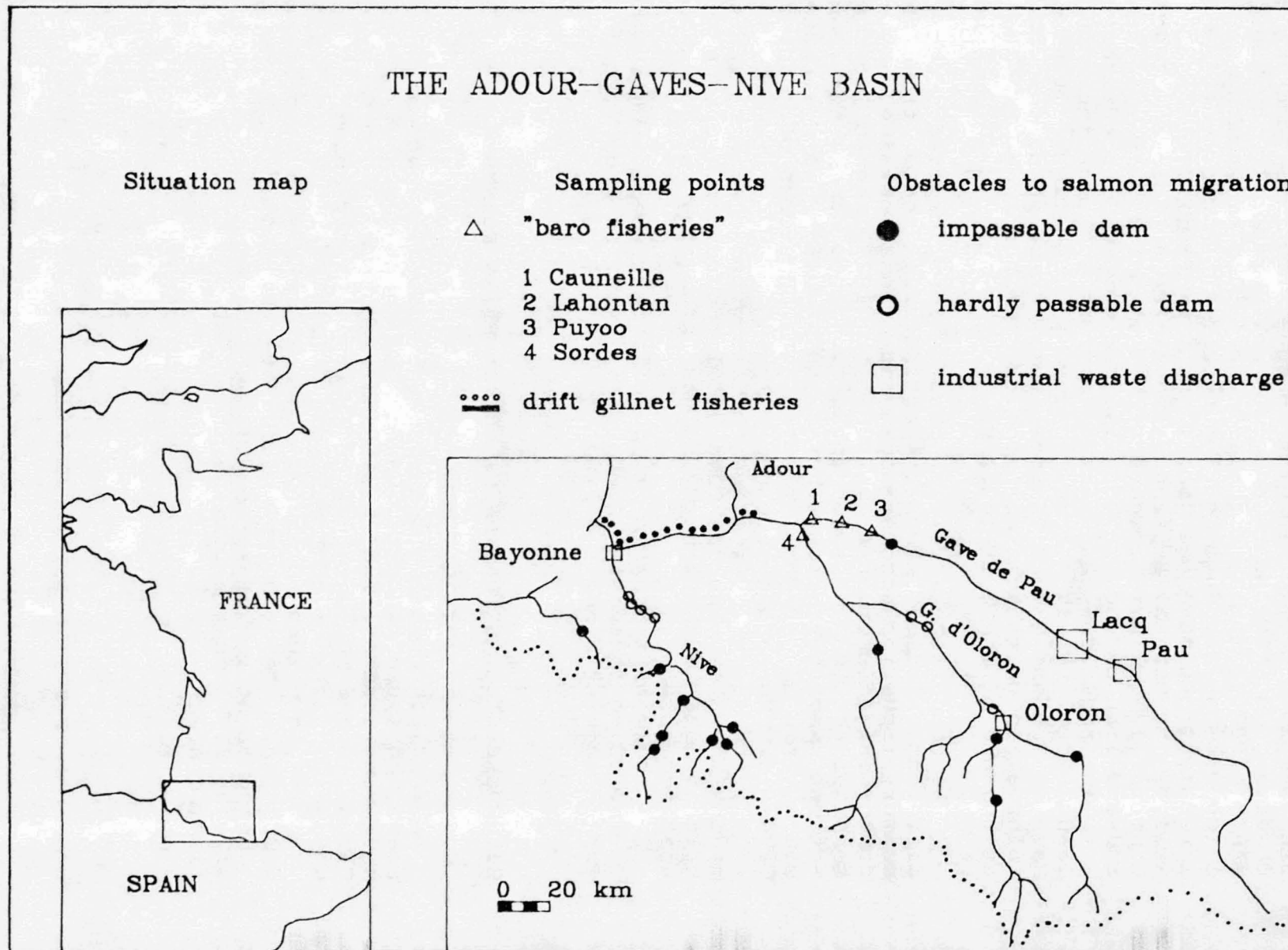


Table 1 - Number of salmon caught and weighed by the "BARO" fisheries at the end of the 19th century.

1873	1888	1889	1890	1891	1892	1893	1897	1898
1 376	1 409	970	830	1 051	921	497	619	552

Table 2 - Number of salmon sampled each year during the 1985 - 1990 period.

1985	1986	1987	1988	1989	1990
200	390	521	512	193	356

3. MATERIAL AND METHODS.

3.1. Characteristics of the fishing gear.

Two different types of fishing gear have been used during the two periods : the "baro", during the 19th century, and the drift gillnet at the end of the 20th century.

The "baro", as described by its contemporaries (de DROUIN de BOUVILLE, 1900), was a fixed installation, equipped with a kind of paddle wheel, with one blade out of two carrying an approximately 2-metre long, 1.5-metre wide and 3-to-4-metre deep net bag. The mesh size was 100 to 120 mm when stretched.

The drift gillnet is the only gear authorized nowadays for migratory salmonid fishing in the Adour and Gaves rivers. It is an upright trammelnet, comprising of three layers of net put side by side, the netting in the middle having a smaller mesh size (110 mm when stretched) than the other two.

3.2. The catch data.

Nineteenth century data were taken from daily log books giving weight (in 500-gram pounds) of each salmon caught by the "baros" throughout the fishing season, which lasted from the 1st of January to the end of September. Table 1 gives the numbers of salmon recorded for the years 1873 and 1888-1898.

Observations on the 20th century fisheries were obtained from a time- and space-stratified sampling. They deal with catches made by the maritime professional fishermen (around 95% of the total catch). Table 2 gives the numbers of salmon sampled each year during the 1985-1990 period in the Adour estuary.

3.3. Age determination methods for the salmon catches.

Scale-reading, for individual ageing of the fish sampled during the 1985-1990 fishing seasons was used as reference and these results were confronted with those obtained from the visual analysis of the monthly catch weight distributions.

3.4. Statistical treatments

3.4.1. Comparisons of weight frequency distributions.

Kolmogorov-Smirnov test (GOODMAN, 1954) has been used to compare weight frequency distributions obtained with the different ageing methods, scale-reading being used as the reference.

3.4.2. Comparisons of monthly catch age structures.

The cross-tabulated breakdowns of the catches by month and by age type which were worked out by the various ageing methods were compared with improved G^2 tests (LAWAL, 1984), on the one hand for the age structure of the catch for each month, and on the other hand for the distribution of each age group in the fishing season.

3.4.3. Analysis of weight characteristics.

Taking into consideration that we were using discrete data, the between-years comparison was carried out by comparing the average ranking of the weight for each year with a KRUSKAL-WALLIS test (KRUSKAL and WALLIS, 1952 ; TATE and CLELLAND, 1959).

For all statistics tests used, we chose a 5% significance level.

4. RESULTS.

4.1. Validation of the ageing method by visual analysis of weight distributions (1985-1990 period).

As far as visual analysis was concerned, its results were very close to those obtained from scale reading, for the apportioning of the catch between sea age types as well as for weight frequency distributions for each age group.

Considering this adequacy, visual analysis was used to study the catch weight distributions by sea-age group at the end of the 19th century.

4.2. Analysis of the age structures and weight characteristics of the end of the 19th century catches.

4.2.1. Catch distributions by sea-age groups.

The breakdown of the total landings into age groups (Table 3) noted that most of the catches had spent 2 winters at sea. More than one third of the catch consisted in 3 sea-winter salmon.

The 4SW salmon group being excluded, the annual proportions of the various types in the total catch could fluctuate much according to the years. They could indeed vary with a ratio of 3.8 for the grilse, 5.8 and 7.2 for 2SW and 3SW salmon respectively.

When the sharing cut had been based on the catches made during the only months corresponding to the current fishing season - i.e. March through August - (Table 4), changes appeared for the mean proportion of each type and more particularly a

Table 3 - Distribution (in %) of catches by sea-age group at the 19th century (January to August)

Age group	1873	1888	1889	1890	1891	1892	1893	1897	1898	1873-1898
1 SW	21.3	31.5	9.7	8.3	8.6	30.8	25.0	23.1	26.5	20.5
2 SW	69.5	24.9	58.7	47.8	68.5	11.9	62.4	23.6	48.9	46.3
3 SW	7.5	42.3	28.6	40.8	21.4	53.9	11.8	51.0	22.6	31.1
4 SW	1.7	1.3	3.0	3.1	1.5	3.4	0.8	2.3	2.0	2.1

S.W : Sea winter fish

Table 4 - Distribution (in %) of catches by sea-age group at the 19th century (March to august)

Age group	1873	1888	1889	1890	1891	1892	1893	1897	1898	1873-1898
1 SW	22.2	37.8	11.2	9.7	9.4	38.7	27.3	30.8	30.1	24.1
2 SW	71.6	29.8	67.7	55.8	75.2	14.9	66.3	31.5	55.2	52.0
3 SW	4.8	31.4	19.5	31.7	14.3	43.3	6.2	36.2	12.8	22.2
4 SW	1.5	1.0	1.6	2.8	1.1	3.1	0.2	1.5	1.9	1.7

S.W : Sea winter fish

Table 5 - Distribution (in %) of catches by sea-age group during the 1985-1990 period

Age group	1985	1986	1987	1988	1989	1990	1985-1990
1 SW	47.6	22.0	91.0	24.0	55.6	68.6	51.5
2 SW	44.2	74.7	8.3	74.2	41.2	31.0	45.6
3 SW	8.2	3.3	0.7	1.8	3.2	0.4	2.9

strong decrease (30%) of the mean relative abundance of the 3SW salmon. The between-year variation of proportion of each age group in the catches was still very high : 4.1 for grilse, 5.1 and 9.1 for 2SW and 3SW salmon respectively.

The analysis of correlations between abundances of the different sea-age groups supposedly belonging to the same cohort showed :

- . there was independence between the abundances of grilse on year (n) and 2SW salmon on year (n+1) ;
- . there was a positive correlation between the numbers of 2SW and 3SW salmon ($R=0.93$, $P=0.003$) ;
- . there was an inverse relation between abundances of 3SW and 4SW salmon ($R=-0.96$, $P=0.002$).

4.2.2. Weight characteristics by sea-age group (table 6).

On an average, the weight of the different sea-age types was 2.5, 5.8, 9.3 and 13.5 kilograms for 1SW, 2SW, 3SW and 4SW salmon respectively. A between-years comparison by age type indicated a significant variation of the caught salmon weight for the grilse and the 2SW fish (Table 7).

With regard to the evolution of the weight of the different salmon types descended from the same production year, no significant relation was noted between the grilse weight and the 2SW salmon weight, or between the 2SW and 3SW salmon weight.

4.3. Analysis of the age structures and weight characteristics of the 1985-1990 salmon catches.

4.3.1. Catch distributions by sea-age groups.

For this period, we could notice (Table 5) that, on an average, grilse made up the most plentiful salmon type in the catches, while 3SW salmon were almost absent from the catches (2.9% on an average) and 4SW salmon were exceedingly rare. Yet, the between-year variation ratio of the sea-age groups relative abundance is high : respectively 4.1, 9.0, 12.4 for 1SW, 2SW, and 3SW salmon.

Besides, no significant relation showed off between abundance of sea-age groups descended from the same production year.

4.3.2. Weight characteristics by sea-age group.

According to the years, a significant variation of the mean weights of 1SW and 2SW salmon could be observed (Table 7). For the investigated period, mean weights of the various salmon types were 2.6, 5.0, and 8.6 kilograms for 1SW, 2SW and 3SW fish respectively.

Figure 2 - Mean weights-at-age of salmon catches sampled during the different periods

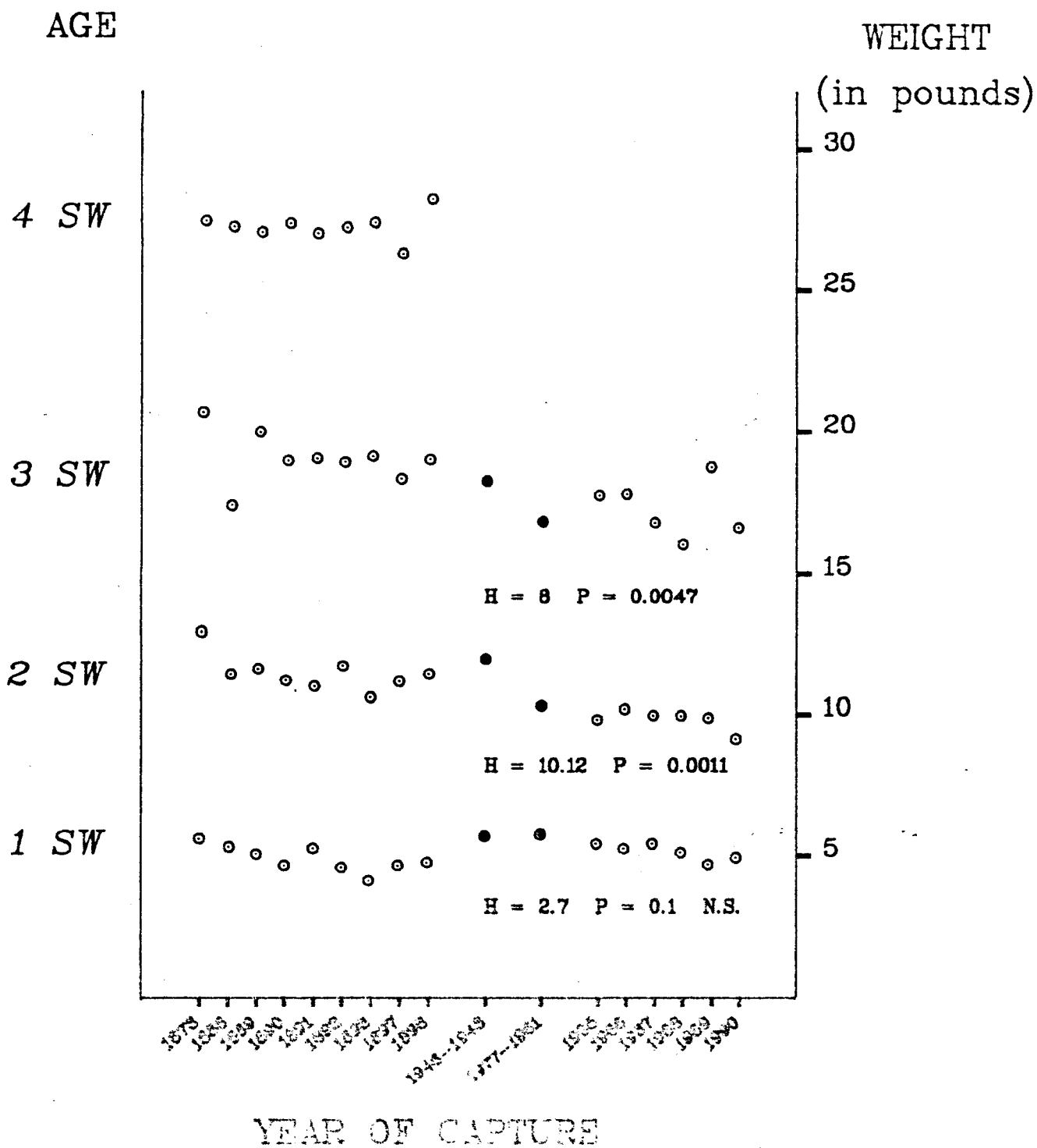


Table 6 - Mean weights (in 500 gr pounds) by sea-age group and by year of capture

	1 SW			2 SW			3 SW			4 SW		
	M	CV	N	M	CV	N	M	CV	N	M	CV	N
1873	5.63	17.1	293	12.89	15.4	956	20.59	9.6	103	27.25	8.6	24
1888	5.27	19.2	444	11.37	15.6	351	17.33	13.9	596	27.06	6.5	18
1889	5.06	18.5	94	11.52	15.2	570	19.90	11.6	277	26.93	7.6	29
1890	4.74	23.9	69	11.20	16.0	377	18.94	12.9	338	27.20	7.0	25
1891	5.25	26.5	88	11.02	15.0	720	19.05	12.0	225	26.90	4.9	16
1892	4.66	19.4	384	11.75	16.4	110	18.84	13.8	496	27.10	7.6	31
1893	4.18	27.1	124	10.51	19.1	392	19.12	12.0	59	27.25	8.1	4
1897	4.75	22.4	143	11.16	15.0	146	18.32	12.4	316	26.21	4.8	14
1898	4.79	18.0	146	11.45	17.3	270	19.05	14.0	125	28.10	12.2	11
1942 - 1948	5.79	n.a.	26	12.15	n.a.	158	18.22	n.a.	238	(1)		
1977 - 1981	5.80	n.a.	58	10.38	n.a.	758	18.40	n.a.	174	(2)		
1985	5.52	19.7	84	9.84	17.8	99	17.94	19.7	17			
1986	5.32	20.7	76	10.56	18.0	295	17.89	18.2	19			
1987	5.48	22.8	345	10.06	17.3	157	16.74	16.4	19			
1988	5.22	18.6	74	10.07	17.6	431	16.14	16.2	7			
1989	4.81	23.1	112	9.90	16.9	75	18.83	21.1	6			
1990	5.10	19.4	207	9.10	18.1	146	16.67	18.3	3			

M = mean fresh weight ; CV = coefficient of variation (%) ; N = number of fish
 SW = sea winters ; n.a. = non available

(1) after VIBERT (1950)

(2) after BOUSQUET et MARTY (1987)

Table 7 - H tests for comparison of mean weights

Series	1 SW	2 SW	3 SW	4 SW
1873 - 1898	H = 280 ; S	H = 551 ; S	H = 311 ; NS	H = 3.5 ; NS
1895 - 1990	H = 34.48 ; S	H = 60.14 ; S	H = 5.7 ; NS	
Both	H = 2.7 ; NS	H = 10.12 ; S	H = 8 ; S	

S = significant ; NS = not significant

For a given cohort, a strong positive correlation ($R=0.96$; $P=0.01$) was noted between the grilse weight one year and the weight of the 2SW salmon returning to their home river on the following year. No correlation showed off between the weights of 2SW and 3SW salmon born on the same year.

The comparison of weights-at-age for the 1873-1898 and 1985-1990 periods showed a significant difference between mean ranks of weights of multi-sea-winter salmon (Fig 2, Table 7) : 2SW and 3SW fish were averagely heavier at the end of the 19th century (Table 6). On the opposite, no significant difference was found for the grilse between the two periods.

4.4. Recruitment pattern of the different salmon types in the fisheries :

The recruitment of the different salmon types in the 19th century fisheries built up a well defined time sequence (fig. 3)

Taking the various sea-age groups' catch median as an index, the following sequence was generally observed :

- 3SW and 4SW salmon by mid-March ;
- 2SW salmon by the end of May ;
- 1SW salmon by mid-July.

However, a variability of the recruitment pattern of the different types was taken notice of, according to the years. As a matter of fact, the catches median was reached with an approximate shift of :

- one month for 4SW salmon (between the end of February and the end of March) ;
- two weeks for 3SW salmon (between the end of February and mid-March) ;
- one month for 2SW salmon (between mid-May and mid-June) ;
- two months for grilse (between the end of May and the end of July).

Similarly, in the 1985-1990 period, a delay was noted between early and late recruitments patterns for the various age groups (Fig. 3). The medians of the catches are reached around :

- mid-May for the 2SW salmon (between mid-May and mid-June according to the years) ;
- mid-June for grilse (between mid-June and mid-July).

5. DISCUSSION.

5.1. Limits of the investigation.

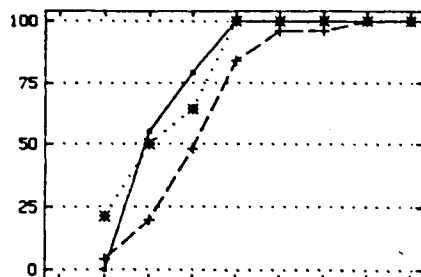
The comparisons between the characteristics of the salmon stocks caught during those two periods (1873 to 1898, and 1985 through 1990) could be tainted with several biases such as :

Figure 3 - Recruitment in the fisheries by sea age
 Earliest and latest patterns
 (in cumulative percentage of catch)

1873 - 1898

1985 - 1990

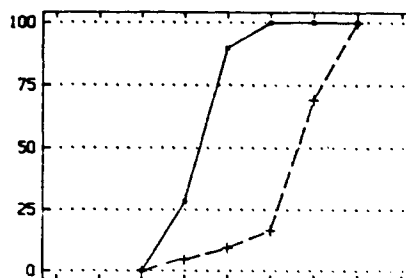
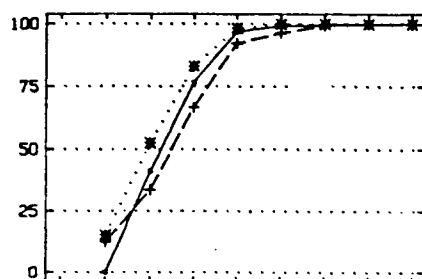
4 SW



not available

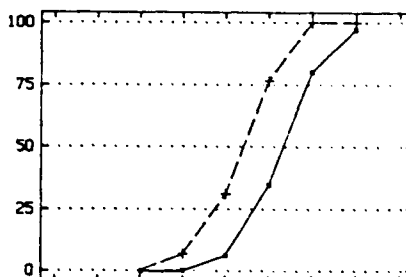
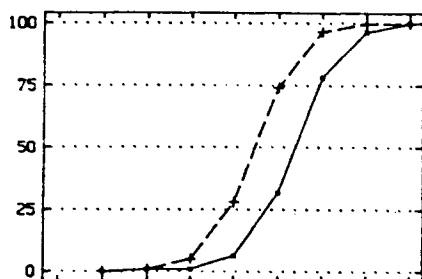
4 SW

3 SW



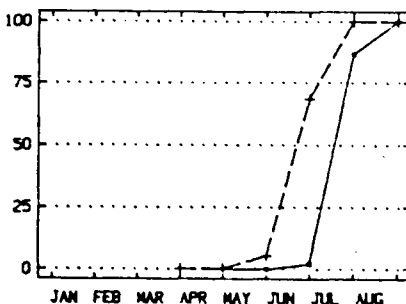
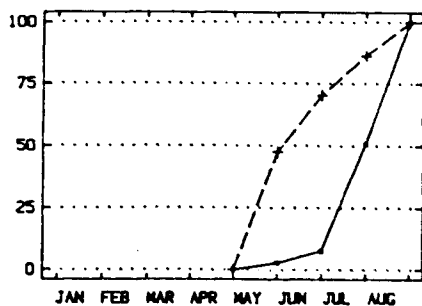
3 SW

2 SW



2 SW

1 SW



1 SW

. difference in the fishing seasons : at present, the fishing season (mid-February to the end of July) opens two months later and closes two months earlier than it did at the end of the 19th century. It has been appropriate to take this variation into account when comparing relative abundance of the various salmon types in the catches.

. difference in the geographical situation of the fishing areas : the upstream boundary of the current fishing area is a dozen kilometres downstream from the lower 19th century "baro" fisheries; this is three times as short as the river length exploited at the present time (35 km). Yet, the greatest part of nowadays' catches is done in the zone closest to the river mouth, thus increasing the distance between the two periods collecting points. Whence we took the time required to travel up this distance into an eventual account before comparing the recruitment pattern of the salmon types in the fisheries.

. difference in the selectivity of the fishing gears : the drift gillnet is also used with the same mesh size for others species, such as the shad (*Alosa alosa*, L.), the mean size of which is lower than that of the smallest 1SW salmon caught by the current commercial fishery (PROUZET et al, 1990). Therefore this gear seems to recruit the whole stock running up the river. As for the "baro", it was a trap that sampled stocks in a manner which could be considered as random in so far as the different salmon types would not have used different routes up the river.

. variability of freshwater life duration : a decrease of the mean freshwater-age of the Adour river salmon from the mid-20th century onwards has been ascertained (PROUZET, 1990). An important variability of the proportion ratio of 1-year smolts on 2-year smolts was noticed at that time (VIBERT, 1950). If that had been the case at the end of the 19th century, that variability could have an influence on the relations between the abundances of the various types of salmon, determined by their only sea-ages (PROUZET et JEZEQUEL, 1987).

5.2. Comparison of salmon stocks at the end of the 19th and 20th centuries.

The comparison of the weight characteristics as well as that of the age structures of the 19th and 20th century salmon catches brought out a certain number of constants.

We noted in particular that the grilse made up an important, though variable regarding the years, component of the salmon stocks running up the Adour and Gaves rivers, in the 19th and 20th centuries. The mean weights of this stock part did not differ from one period to the other.

No relation was displayed, for any of the two periods, between grilse abundance in year (n) and 2SW salmon abundance in year (n+1).

Lastly, whatever the sea-age type of salmon, the patterns of recruitment in the fisheries seemed to be unchanged from one period to the other. It was remarkable that fall runs were scarce at the end of the 19th century as well as at present (as shown by complementary observations carried out after the closure of the fishing season).

However, several differences were disclosed between the catches made during the two periods.

First of all, the investigations established a clear decrease of the mean sea-age of the salmon population. Grilises make up the greatest part of nowadays' catches. The 4SW salmon have almost disappeared, and the 3SW salmon are quite scarce, while they used to form an important part of the 19th century catches.

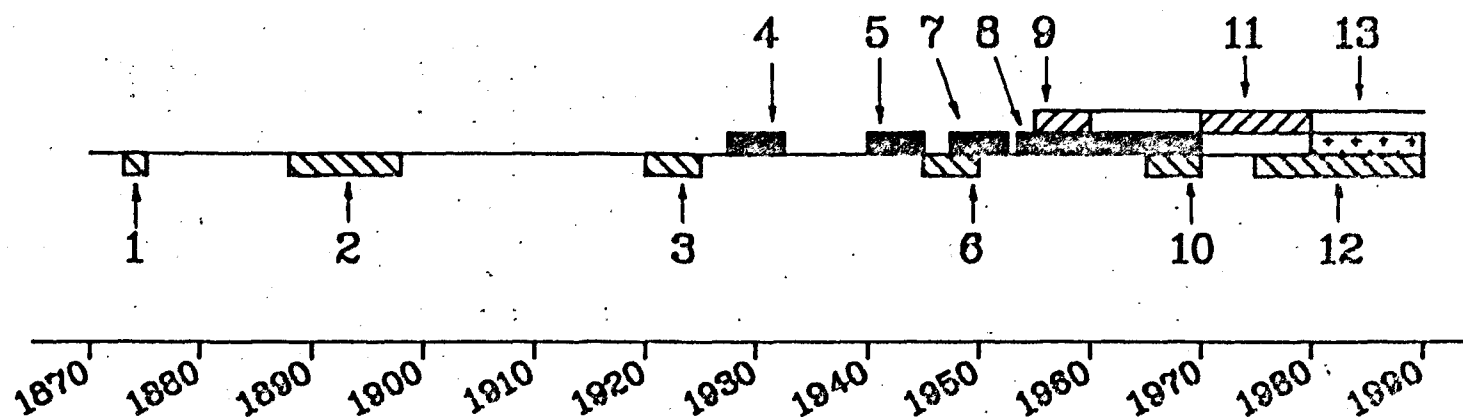
The shift of the fishing season opening (end of February now, instead of beginning of January at the end of the 19th century) was not sufficient in explaining it all. As a matter of fact, a larger 3SW salmon proportion was observed in the rod-and-line catches than in the driftnet catches (Anon., 1990), thus pointing out that most of the larger salmon would travel up the estuary before the driftnet fishing season had opened. But, the total amount of catch (line and driftnet) of large salmon has been low for years, and the salmon by-catches during the drift gillnet lamprey fishing season are very rare. The putting together of these two facts tends to establish that the stock of older salmon is quite small nowadays.

5.3. Main factors having affected the evolution of the stock characteristics.

Figure 4 shows off the most remarkable events having taken place between the two studied periods. After the gradual disappearance of the "baros" during the 1920s, the building of several dams, in Soeix and Saint-Cricq on the Gave d'Oloron around 1930 and above all in Baigts on the Gave de Pau in 1942, impeded salmon access to the upper water redds. This brought on an artificial shortening of the river length usable for spawning. These dams could have contributed to a decrease of both the mean reproduction age and the mean size of the fish: it has indeed been observed by SCHAFFER and ELSON (1975) in Canada, that the values of these two variables increase as the upstream migration becomes more and more difficult, for example when the redds are a long way from the river mouth. The significant drop of the Adour and Gaves 2SW and 3SW salmon mean weight seems to strengthen this analysis.

Vibert (1950)'s studies (1942-1948) should have brought some complementary informations. But the sampling, initiated in 1942, was carried out mainly in the Basque country smokehouses: it thus overestimated the proportion of 3SW salmon in the samples. Nevertheless, it can be noticed that the mean weight of the 2SW and 3SW salmon caught at the end of the 1940s belongs to the

Figure 4 - Account of remarkable events for the period under study



- 1 and 2 : account books of the "baro" fisheries
- 3 : progressive disappearance of the "baros"
- 4 : building of dams in Soeix and Saint-Cricq
- 5 : building of dam in Baigts
- 6 : studies by Vibert
- 7 : petroleum and gas deposits discovered in Lacq
- 8 : industrialization of the Pau area
- 9 : beginning of the fishing in Greenland waters
- 10 : end of seine fishing
- 11 : intensification of the fishing in Greenland waters
- 12 : restocking
- 13 : studies by the CSP and IFREMER

weight bracket of the 19th century fish of the same sea-age (fig 2) . This indicates probably that the alteration observed on the salmon stock have occurred after the 1950s.

From that date on, many other factors, along with that disturbance of the environment, led to the disappearance of the larger salmon :

- . the intensifying, from the 1970s onwards, of the fishing in Greenland waters, which exploits only the multi-sea-winter fish (MOLLER-JENSEN, 1988) ;

- . the worsening of the pollution in the upper and middle river waters, certainly with a heavier influence on the large salmon migrating early up these polluted waters than on the grilse running up later. .

As far as restocking is concerned, the intensifying of which dates back to the 1980s, the preferential use of grilse ova from foreign sources has probably further increased the grilse sub-group (DUMAS et CASAUBON, 1987). Yet, its impact has to be taken from a relative point of view . The investigations conducted by BOUSQUET and MARTY (1987) from 1977 to 1981, before the release of large numbers of alevins in the Adour-Gaves basin (1982), ascertained that the respective mean weight of the 1SW, 2SW, and 3SW salmon that they sampled belonged to the current catch weight bracket (Fig 2).

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