ICES C.M. 1995

C.M. 1995/M:28
ANACAT Fish Committee

WILD BALTIC SALMON STOCKS: FECUNDITY AND BIOLOGICAL REFERENCE POINTS CONCERNING THEIR STATUS

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ABSTRACT

The use of biological reference points in the assessment of the Baltic salmon was examined and evaluated. Increased knowledge of the productivity of Baltic rivers combined with data obtained from monitoring escapement and the resulting smolt production were found to be critical in improving the precision and applicability of the biological reference points. In initial trials aimed at calculating an egg deposition requirement for a potential production level in the Gulf of Bothnia rivers, a range of 70 - 700 eggs/100 m² of salmon nursery area was obtained. The egg deposition requirement for the Gulf of Bothnia stocks seems to be considerably lower than that for most North Atlantic salmon stocks. Studies on the productivity of the Baltic salmon rivers and specific stock-recruitment investigations are needed in order to establish more precise reference points and egg deposition targets in the Baltic region. However, studies from outside the Baltic area combined with Baltic studies on productivity levels in the salmon populations may be used to give ranges of suitable egg deposition levels and also provisional targets.

The reproductive potential of Baltic salmon was assessed by examining fecundity data from the wild salmon stocks in the Gulf of Bothnia. A fecundity of 1 200 - 1 500 eggs/kg of female salmon was found to prevail among the wild salmon stocks in the Gulf of Bothnia. Relative reproductive values for Baltic salmon of different ages were calculated based on the sex ratio and mean weight for each age-class. The relative reproductive value of salmon was found to rise steeply with sea age.

1. Introduction

The International Baltic Sea Fishery Comission has asked the ICES for scientific advice to help attain the management goal of "safeguarding of wild salmon stocks". What this objective means in terms of biological reference points is a question of debate. The status of Baltic salmon stocks has generally been poor for several decades, and there is lack of well documented examples of what a "good status of stocks" would mean in Baltic. Thus it is important to examine possible interpretations of management targets for Baltic salmon. Another good reason for such an evaluation is that the improved monitoring techniques recently developed might allow a new assessment system, based on well defined reference points, to be set up.

One recent emphasis in the management of North Atlantic salmon stocks has been to establish egg deposition and spawning stock targets, which are based on the studies of biological reference points in the stock-recruitment relationship. This management regime aims at conserving resources by maximising/optimising recruitment while minimizing the risk of stock collapse and loss of genetic diversity. The approach requires studies on the productivity of the river systems and the fecundity of salmon stocks and a means of monitoring the size of the spawning stock and the corresponding smolt output.

The following sections describe the recent status of Baltic salmon assessment work concerning biological reference points. Possibilities to develop assessment towards egg deposition/spawning stock targets were studied in some example rivers. Special emphasis has been placed on fecundity data because efforts thus far to examine the fecundity of Baltic salmon have been limited.

2. Current biological reference points in the Baltic

2.1 Reference points and their interpretation

Baltic reference points used thus far have included

- the potential smolt production in the rivers supporting wild stocks
- the potential density level of parr in the rivers
- river catch

Current values have been compared with corresponding potential or historical values without any analysis. Using river catch as an index of stock status is a preposterous approach, even though river catch and spawning stock size must be related to some extent. Usually these reference points have been used only as examples of what a good status of the wild stocks could mean. Less commonly, they have been considered as real target values.

There are two advantages of the above-mentioned approach:

- some relatively comparable historical data concerning the monitored variables are now available
- updating of the variables does not require too much work

The corresponding disadvantages are as follows:

- the approach does not take into account the dynamics of the stock-recruitment relationship or the variability in production capacity in nature
- it is difficult to convert the reference points to escapement values and to link them to real management proposals
- M74 has weakened the relationship between the parent stock and the production of parr and smolt; it is therefore difficult to evaluate management success in terms of escapement, which is a direct object of fisheries management

No long-term studies of the stock-recruitment relationship have been carried out in the Baltic region. As stated earlier, estimates of parr denstity levels and smolt output have been made, but little is known about the adult stock, not to mention the stock-recruitment relationship.

2.2 Estimation of the reference points

Values have often been established for the purpose of compensatory rearing or stock enhancement rearing. Potential smolt and parr production levels have been designated on the basis of data obtained using several approaches: analysis of historical records, habitat inventories, stocking experiments, etc. The data in question are far from precise, and some inconsistencies can be found between the values estimated in different ways.

Estimates from three rivers in the Gulf of Bothnia are given as examples in Table 1. The table also contains a little extra information about the rivers and their salmon stocks in order to provide a better description of the characteristics of the Baltic salmon and it's freshwater habitat.

The production capacity of salmon in Baltic rivers is, on average, lower than that of salmon in most other European and Canadian salmon rivers. For example, the potential smolt production in the rivers emptying into the Gulf of Bothnia is estimated to be 1-3.5 smolts/100 m² of nursery area (Karlström 1977, Jutila & Pruuki 1988, Kemppainen et al. 1995), which corresponds to approx. 0.3-1.5 smolts/100 m² of fluvial habitat accessible to salmon. By contrast, a smolt production potential of 3 smolts/100 m² of fluvial habitat is considered to be the average level in Atlantic Canadian rivers, and this level has been considered as too low for Atlantic European rivers (Anon. 1994). Productivity in the southern Baltic rivers is assumed to be closer to the level observed elsewhere in Europe (Karlström 1977).

3. The fecundity of Baltic salmon

3.1 Material and methods

Data on fecundity for a number of wild salmon stocks in the Gulf of Bothnia were obtained from the sources given in Table 2. The mean fecundity of a number of females was calculated using the equation

Mean fecundity= Sum of eggs/Sum of fish weights

Most of the salmon females were of wild origin. The data were collected when stripping salmon females in the autumn. The number of eggs per litre of roe was normally estimated using the so called Brofeld scale, which is based on the number of eggs needed to cover a length of 25 cm. Data collected in connection with stripping suggest that it was not always complete; thus fecundity was probably underestimated to some extent.

Data used for calculating sex ratios and mean weights for the different sexes and age classes were collected from the trap at Norrfors, in the River Ume, where fish ascending to the River Vindelälven are caught. Data based on reared salmon tagged in Sweden over the years 1966- 94 were also used for calculating sex ratios. Tagged salmon originated from the Rivers Lule, Ångermanälven and Indalsälven.

3.2 Fecundity and the relative reproductive values

Fecundity values from 1 050 to 1 500 eggs/kg of female have been reported for several Baltic salmon stocks (Carlin & Johansson 1971, Brännäs et al. 1985) and fecundity is often assumed to be in a range of 1 100 - 1 200 egg/kg (Christensen & Larsson 1979). Estimates based on the new data presented here, which are mainly for wild females, are slightly higher (1 200 - 1 500 eggs/ kg female), not considering the Rivers Lögde, Byske and Öre, where the stripping is thought to have been the least complete (Table 2). Tables 3 and 4 summarize the data collected on age and sex ratios, as well as mean weights at different ages, in the Gulf of Bothnia. At ages of 1SW, 2SW and 3SW, respectively, females constitute about 10 %, 45 % and 80 % of the individuals and weigh about 2.3 kg, 5.4 kg and 8.7 kg. The limited amount of data available on 4SW salmon suggest that the proportion of females is slightly higher than that of males.

Using values for age class specific mean weights obtained from the trap at Norrfors in 1994 combined with the average values of sex ratios mentioned above, we can calculate the relative importance of salmon of different ages in terms of spawner fecundity as follows:

	1SW	2SW	3SW
Relative value	1	10.5	29.8

The reproductive value of a three-year-old salmon would thus be almost 30 times that of a 1SW salmon and about 3 times that of a 2SW salmon. However, this method of calculation does not consider the genetic aspects of stock maintainance since the genetic variability in a given stock is partly determined by the actual number of spawners that it contains.

4. Conversion of the potential smolt production values to egg deposition values - examples from the Gulf of Bothnia

Setting up egg deposition targets and the corresponding spawning stock targets on the basis of stock-recruitment studies has been judged the most appropriate way to manage salmon stocks in the North Atlantic (Anon. 1994). A similar approach in the Baltic region would offer several advantages in terms of standardisation of the methodology, data transportability and comparison, establishment of stock-specific monitoring etc.

We have chosen a range of estimate values (up-and-down method), which we find as most likely when we examine the egg deposition values at a potential production level for the salmon stocks in the Gulf of Bothnia. These values give the broad margins for the most sensible egg deposition rates:

> Assuming that the potential smolt production level in the salmon nursery habitat varies between 1 and 3.5 smolts/100 m² in the Gulf of Bothnia rivers and assuming that the egg to smolt survival rate varies between 0.5 and 1.5 %, the egg deposition value would lie somewhere between 70 and 700 eggs/100 m² of salmon nursery habitat. Conversion of this range to kilos of spawning females and comparison to highest historical catch levels (Table 1) indicate that we are at a proper level in our estimates: the lowest and the highest egg deposition values correspond to a river-fishing exploitation rate of 0.7-0.9 and 0.2-0.4, respectively, in the Simojoki and Tornionjoki rivers.

In general, egg deposition targets established or suggested elsewhere for Atlantic salmon are higher than the Gulf of Bothnia estimate, ranging from approx. 100 eggs/100 m² of fluvial habitat up to 2 000 - 3 000 eggs/100 m² of nursery area (Anon. 1994). This is in accordance with the recorded difference in the potential smolt production estimates (see chapter 2.2).The low salmon production capacity in the Gulf of Bothnia rivers can be explained as follows:

> 1) these rivers are located at high latitudes, where productivity is generally lower than further south;
> 2) they have a relatively diverse fish species composition, suggesting that habitat availability is limited and that young salmon are subjected to strong competition for food and a high risk of predation;
> 3) winter conditions in the area are severe, with a thick ice cover and low discharge values that tend to reduce overall productivity.

Although stock-recruitment studies with Atlantic salmon indicate that several kinds of stock-recruit curves can exist, their shape usually resembles that of an asymptotic curve (Anon.1994). Consequently, if maximizing the potential production level were to be chosen as a management target, overestimating the egg deposition requirement would be less serious of an error than underestimating it.

Egg deposition values with the range of the most sensible values have been converted to total egg deposition values and numbers of spawning females for three rivers: the Simojoki, Tornionjoki and Vindelälven (Table 5). A Canadian egg deposition target have also been calculated for the total fluvial habitat accessible for salmon in order to display the meaning of habitat component in the calculations. The range of values is naturally very large, because of the wide range in the egg deposition values. The sex ratio in the river is largely determined by the sea fishery (fishing mortality is higher for females than for males) which is why egg deposition values have not been converted to total spawning stock sizes.

5. Egg deposition values and M74

A syndrome called M74 has recently increased mortality among salmon alevins in the Baltic (Karlsson and Karlström 1994). The incidence of M74, first detected in 1974, has varied from year to year, and for many years it did not give rise to any major problems. However, in 1992 the frequency of M74 increased dramatically, and for the period 1992-95 the total mortality caused by M74 in hatcheries has been in the range of 40-98% among alevins derived from sea-run females. On the basis of elecrofishing surveys and catch statistics the extra mortality caused by M74 in years 1992-94 was estimated at 75% in rivers having wild salmon stocks in the Gulf of Bothnia (Karlström1995). Because the outbreak of M74 was of an unprecendentedly large magnitude it will weaken the stock-recruit relationship. In theory egg deposition values can be adjusted using a factor calculated based on the M74 mortality. At present we are of the opinion that any egg deposition target should be able to the buffer extra mortality caused, for example, by a low to moderate incidence of M74. An additional mortality of about 75% over several years should, however, not be accounted for in a normal egg deposition target. This kind of mortality must, instead, be treated separately and dealt with using special management.

6. Concluding remarks and recommendations for the future activities

It was suggested that the operational interpretation of the definition of conservation of Atlantic salmon in Canada should be based on the potential productivity of rivers (CAFSAC 1991). This kind of interpretation supports the use of variables linked to the fresh water production (smolt production, parr densities, egg deposition, spawning stock). The reference points linked to escapement and egg deposition values seem especially usefull from the assessment point of view, and we highly recommend that additional research in this area be carried out in the Baltic. Research on egg deposition targets can be divided into two parts, one dealing with potential freswater productivity and the other with monitoring and developing stock-recruitment relationship. We recommend that the following steps be taken on the research front.

1) The potential production capacity as well as the factors affecting to the productivity should be studied further to provide more exact information about the productivity of the Baltic salmon rivers

2) Studies on actual spawning stock size and egg deposition rates and the resulting smolt production should be started. Such studies would further our understanding of the dynamics of stock-recruitment relationships. They would also help us to

distinguish the influence of M74 from other mortality factors. Furthermore, with the actual escapement values that would be obtained, population models covering the sea phase of the life cycle could be developed. There are two good reasons for starting this kind of study in one of the smaller rivers in the Gulf of Bothnia: This region of the Baltic has the largest potential smolt production, and salmon rivers in this area are among those most endangered in the Baltic region.

It will certainly take a long time (decades) before any real stock-recruitment relationship will be established in the Baltic. We recommend that in the meantime provisional escapement and egg deposition targets based on present knowledge be established and used as a basis for assessment and management. Such targets should gradually become more precise and accurate as results from the studies discussed above start to accumulate.

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Table 1. Information from three example rivers in the Gulf of Bothnia - cases of River Simojoki, Tornionjoki and Vindelälven (Toivonen 1962, Karlström 1977, Jutila 1987, Jutila 1992, Jutila & Pruuki 1988, Romakkaniemi 1988, FGFRI, unpublished). The values are only rough estimates based on several data sets, calculation procedures, stocking experiments etc.

	SIMOJOKI	TORNIONJOKI	VINDELÄLVEN
INFORMATION FROM RIVER SYSTEMS:			
River length, main stem, km	170	520	370
River, accessible for salmon, km	110	800 - 900	290
Mean discharge, m^3/s	38	380	180
River catchment area, km^2	3 130	40 010	11 910
Mean gradient, %	0.103	0.091	0.095
Total fluvial habitat accessible for salmon, ha	830	approx. 15 000 1)	5 700
Total estimated nursery area for salmon, ha	255	5 000	1 000
Estimation range of nursery area, main stem, ha	234-293	2 342 - 5 250	-
Grade A nursery area, ha	130-180 1)	3 112	730
REFERENCE POINTS:			
Potential smolt production, ind./year	**75 000**	**500 000**	**200 000**
Potential mean parr density, ind./100 m^2 nursery habitat	**15-20**	**5-15**	**10-15**
Highest recorded river catch level, tons/year	**5-10**	**300-400**	**40 2)**
INFORMATION FROM STOCK CHARACTERISTICS:			
Sex ratio, % females	-	29	39.8
Mean weight female/male, kg	-	5.4 / 2.3	5.2 / 2.4
Mean fecundity, eggs/kg	1 316	1 200 3)	1 477
Sea age composition female/male, % 1SW, % 2SW, % 3SW...	-	9, 45, 42, 4 / 72, 22, 5, 1	9, 50, 41 4) / 67, 25, 8 4)

1) Value not established
2) No catch statistics available from the era of "full production"
3) Some old data sets indicate a lower fecundity than shown in the Table 2.
4) 3SW and 4SW combined

Table 2. Mean weight, mean fecundity (total eggs) and relative fecundity (eggs/kg) of salmon females from different rivers in the Gulf of Bothnia. Most females were of wild origin.

River	Year	No of female	Mean weight, kg	Mean fecundity, No eggs	Relative fecundity, eggs/kg	Source
Simo	1986	20	6.3	7923	1254	1
Simo	1987	26	8.9	10374	1166	1
Simo	1988	14	7.0	9976	1426	1
Simo	1989	17	5.2	5995	1145	1
Simo	1990	59	8.4	11608	1389	1
Simo	1991	30	7.0	9294	1320	1
Simo	1992	23	7.3	11006	1511	1
Simo	**Mean**	**27**	**7.2**	**9454**	**1316**	
Torne	1992	121	7.0	9444	1350	1
Torne	1993	44	9.1	6419	704	1*
Torne	**Mean**	**121**	**7.0**	**9444**	**1350**	
Lögde	1991	6	7.3	8768	1201	2
Lögde	1993	8	5.7	6506	1141	2
Lögde	**Mean**	**7**	**6.5**	**7637**	**1171**	
Byske	1991	26	5.7	6654	1167	2
Byske	1992	16	5.6	4375	781	2*
Byske	**Mean**	**26**	**5.7**	**6654**	**1167**	
Ume	1977-81	302	5.5	8246	1525	3
Ume	1993	13	5.0	7170	1428	4
Ume	**Mean**	**158**	**5.3**	**7708**	**1477**	
Öre	1992	3	10.0	11565	1157	2
Öre	1993	11	5.9	6603	1119	2
Öre	**Mean**	**7**	**7.95**	**9084**	**1138**	

* Stripping obviously incomplete, values not used for averages

Sources:

1. Juhani Rytilahti, Finnish Game & Fisheries Res. Institute, Lautiosaari and Simojoki hatcheries.
2. Ulf Carlsson, Project Västerbottenslax, Länsstyrelsen i Västerbottens län, Sweden
3. Brännäs et al. 1985.
4. Harald Johansson, hathchery manager in Norrfors, Sweden.

Table 3. Mean weight and SD by sex and age of wild and reared salmon caught in the trap in Norrfors, River Ume, in 1994. The values are calculated from 737 salmon, of which 620 were of wild origin and 410 were females.

	1SW				2SW				3SW			
	Female		Male		Female		Male		Female		Male	
	Mean, kg	SD, kg	Mean, kg	SD, kg	Mean, kg	SD, kg	Mean, kg	SD, kg	Mean, kg	SD, kg	Mean, kg	SD, kg
Reared	2.47	0.50	1.84	0.50	5.57	1.43	5.20	1.87	7.69	1.52	7.33	0.66
Wild	2.33	0.14	1.62	0.59	5.44	1.43	4.21	1.49	8.69	2.06	8.51	1.18

Table 4. Summary of age and sex distribution in coastal and river fishery in the Gulf of Bothnia. The values of the coastal, river and broodstock fishery are based on Swedish tag recoveries from the years 1966-1994 originating from the salmon of the Rivers Lule, Ångermanälven and Indalsälven. The trap catch in Norrfors, River Ume, has been collected during the years 1985-1994. The mean number of samples/year has been 202 in the coastal fishery, 90 in the river fishery, 23 in the broodstock fishery and 1141 in the trap catch in Norrfors.

	1SW		2SW		3SW		4SW	
	% of all ages	% female	% of all ages	% female	% of all ages	% female	% of all ages	% female
Coastal	31	19.4	50.7	41.9	15.7	72.1	2.6	60.7
River	48.4	11.4	38.6	37.9	13	78.3		
Broodstock fishery	56.3	3.2	34.4	37.3	9.3	83.8		
Trap in Norrfors, R. Ume	43.8	10.2	35	55	21.2	78.9		

Table 5. Three example rivers with Baltic salmon: total egg deposition requirements and consequent spawning stocks in numbers of fish (females) calculated using the lowest and the highest values in the range (70-700 eggs/100 m²) calculated in chapter 4, the Canadian egg deposition target and salmon stock characteristics in the Table 1. The mean weight of female salmon in the River Simojoki is missing and the corresponding Tornionjoki value has been used for Simojoki calculations.

	Simojoki		**Tornionjoki**		**Vindelälven**	
	Eggs, million	No of females	Eggs, million	No of females	Eggs, million	No of females
EGG DEPOSITION VALUES:						
"Baltic estimate", for the total nursery area of salmon:						
Lowest value: 70 eggs/100 m²	1.8	250	35	5 400	7	910
Highest value: 700 eggs/100 m²	18	2 500	350	54 000	70	9 100
Canadian target, for the total fluvial habitat:						
240 eggs/100 m²	20	2 800	360	55 600	137	17 800