ICES C.M. 1995

CM 1995/M:13

-NOT TO BE CITED WITHOUT PRIOR REFERENCE TO THE AUTHOR-

Effects of pre-release acclimatization period on salmon return rates

by

Skilbrei, O. T.[1], Holm, M.[1] and Jakobsen, P.[2]

[1]Department of Aquaculture, Institute of Marine Research
POB 1870, N-5024 Bergen, Norway
[2]Institute of Zoology, Department og Animal Ecology, University of Bergen, Allegt. 41, N-5007 Bergen, Norway

ABSTRACT

42.000 1+smolts of Atlantic salmon were size graded into two size groups and released during three weeks in spring 1993; one group of small and one of large smolts on each of the four release days. Approximately 25% of the fish had been individually tagged using Carlin-tags. The fish were transferred to net pens in a small marine bay in which estuarine salinity gradients had been established by a tarpaulin barrier. The smolts were held in the net pens for three days prior to the first and third release day and seven days before the second and fourth release day. Total recoveries of Carlin-tagged grilse in 1994 showed higher return rates for smolts acclimatized for three days compared with seven days. The difference was small for large smolts, but significant for small smolts, as return rate for the three days acclimatization was twice that of seven days acclimatization. The return of precocious mature males, males that were mature prior to release, were clearly higher than that of other smolts. Possible causes for these differences are discussed.

INTRODUCTION

When smolts are released in a marine or estuarine environment, the transition from fresh- to seawater may become critical, and the release method raise several questions related to biological mechanisms, and have practical consequenses for stocking and sea ranching operations.

One biological problem is the possible stress during the transfer from fresh- to seawater. The physiological stress due to the increase in salinity may be severe. During the parr-smolt transformation the presence of predators is an additive stressfactor possibly reducing the performance and survival of the smolt in the wild (Järvi, 1990; Järvi and Uglem 1993). Further, the handling procedures and transport of the smolts probably increase stress levels during this critical phase of smolting and release.

One other problem relates to the imprinting. It is assumed that salmon rely on a number of cues when orienting homewards, and these are learned by sequentiell imprinting during outward smolt migration (Harden Jones 1968). The significance of estuarine stay is unclear. Tytler et al. (1978) and Moser et al. (1991) proposed that estuarine stay may play a role for imprinting. If so, both release environment and the release methods may influence imprinting. Release methods should also take into account that the prepardness to enter seawater must be expected to vary within a release group because individual differences in developmental rates and smolting. If the smolts are transferred to, and released in an estuarine environment, then the acclimatization period before release may be of importance for imprinting as well as stress and survival.

An attempt was made to reduce some of these problems in a sea-ranching research project on the extreme coast of western Norway. Smolts were released in a small bay into which a small creek drains. The creek is far to small to significantly effect salinity gradients in the bay, and a tarpaulin barrier was stretched across the bay in the upper water coloumn to accumulate freshwater to build up an artificial estuary. When this methos was applied in 1992, the released smolts seemed to behave according to their stage of parr-smolt transformation and the estuarine gradients (Skilbrei et al. 1994a). During the next releases, in 1993, it was a goal to to study the pre-release behaviour of the smolts that had been held for either 3 or 7 days in net pens prior to release (Skilbrei et al., 1994b). These studies demonstrated that migratory behaviour is a part of the complex smoltification process and that estuarine releases is handy when studying biological mechanisms related to the transition from fresh- to seawater.

The goal of the present paper was to compare the effects of acclimatization periods on recaptures of adult salmon and survival. The null hypothesis tested was that acclimatization period does not influence total recaptures or homing and staying.

MATERIALS AND METHODS

42.000 1+ offspring of wild parents from 3 river populations (the Dale, Vosso and Lone strains) were transferred to the Selstø Hatchery in March 1993. Approximately 25% of the fish had been tagged using Carlin-tags in October 1992. The fish were size-graded on March 23-April 1 into 2 size classes and distributed in 4 tanks of the small and 4 tanks of the large size category. Fish were classified as precocious mature males if they were ripe.

Prior to release, the fish were transferred to net pens in the Selstø Bay. The outflow of freshwater from the Selstø Hatchery is to small to create estuarine gradients in the marine Selstø Bay (Skilbrei et al. 1994a). To establish salinity gradients a 55 m long and 3 m deep tarpaulin was streched across the bay to accumulate the surface freshwater. This resulted in estuarine salinity and temperature gradients from surface down to full seawater at approximately 2 m depth (Skilbrei et al. 1994b).

The smolts were held for 3 or 7 days in nets pens in this artificial estuary before they were released from the net pens. An acclimatization period of 3 days were used before the first and the third release date and 7 days were applied before the second and the fourth release date. One group of small and one group of large smolts were held in separate net pens and released on each of the 4 release dates. Numbers of Carlin-tagged smolts, and also of previously mature males, were higher in the large size-groups (Table 1).

Table 1: Numbers of Carlin-tagged smolts in the 8 release groups, separated into small and large smolts. Previously mature males (PMM) from are shown separately.

	RELEASE DATE			
	13/5	19/5	26/5	3/6
Small	860	871	544	933
Small-PMM	72	93	75	72
Large	1478	1454	1755	1899
Large-PMM	114	120	168	170
SUM	2338	2325	2299	2832
SUM-PMM	186	213	243	242

Carlin tags were reported from anglers, fishermen and from a floating net fishery operated by he Institute of Marine Research in the Selstø Bay.

On May 26 and on June 3 20 smolts of the small smolts were killed and checked for infestation of salmon louse (*Lepeophteirus salmonis* Krøyer) by use of binocular.

RESULTS

Total recaptures of grilse were higher for smolts held for 3 days in the estuary prior to release compared with those held for 7 days. This relationship was clearest for the small smolts and the two release dates of 3 days acclimatization, and also the two of 7 days, gave similiar results (Figure 1). For small smolts and for the combined material of both large and small smolts (previously mature males not included) the total recaptures varied significantly between the four release days (2x4 g-tests, $P<0.05$). There were no significant difference between the two release dates of 3 days acclimatization period (2x2 g-tests, ns), or between the two dates of 7 days of acclimatization (2x2 g-tests, ns) for small smolts, for large smolts and also for the combined material.

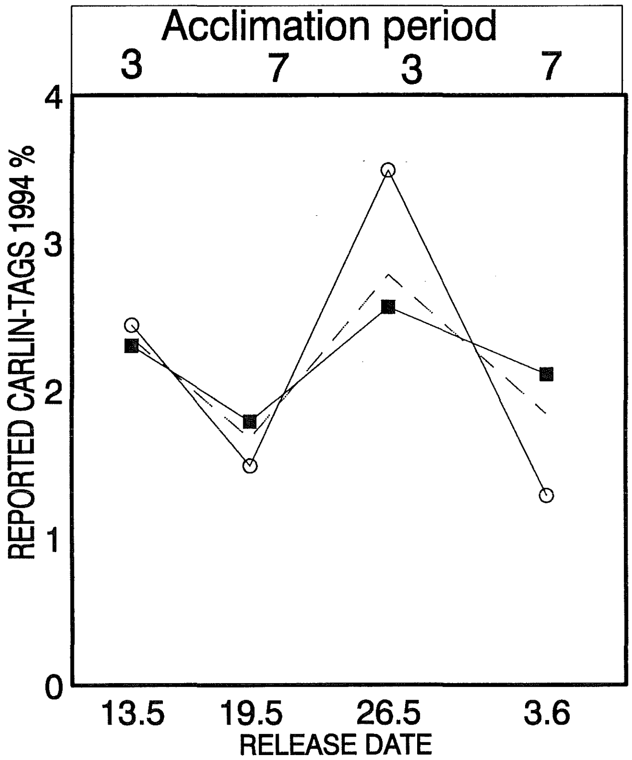

Figure 1: Recaptures of Carlin-tagged grilse shown separately for the groups released on each of the four release days shown for small (circles), large smolts (squares) and for sum of small and large smolts (single line). Previously mature males are excluded.

Previously mature males gave much higher recaptures as grilse after one year in the sea than immature siblings (Figure 1 and 2). The catch increased during the release period, and the acclimatization period did not seem to influence on the results. There were no significant difference between the two first releases, or between the two last (2 x 2 g-tests, ns). Most of the previously mature males originated from the Dale strain. Despite the low numbers in several families, comparisions between the previously mature males and immature siblings show that these males gave higher recapture rates regardless of family background.

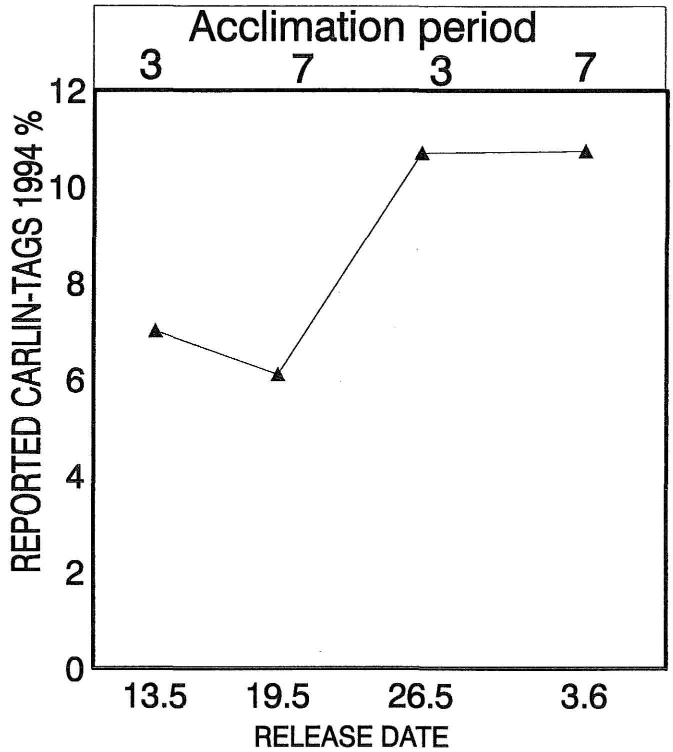

Figure 2: Grilse recaptures of Carlin-tagged previously mature males shown separately for the groups released on each of the four release days.

Table 2: Numbers of Carlin-tagged previously mature males (PMM) and immature smolts (I) in the different strains, numbers recaptured as grilse (C) and recapture %. For the Dale strain the 9 different families are shown.

STRAIN				DALE						LONE	VOSSO
FAM.	1	2	3	4	5	6	7	8	9		
PMM-n	19	34	7	129	10	401	37	51	17	130	63
PMM-C	5	6	1	15	1	36	3	2	0	7	0
PMM-%	26.3	17.6	14.3	13.2	10.0	9.0	8.1	3.9	0.0	5.4	0.0
I-n	170	1065	294	1800	400	800	762	1046	281	2370	1845
I-C	8	46	11	36	10	14	8	17	2	51	11
I-%	4.7	4.3	3.7	2.0	2.5	1.8	1.3	1.6	0.7	1.9	0.6

The recapture of 2-sea-winter salmon was much lower. Until early August 1995, after the termination of the commercial sea-fishery, 48 Carlin-tags had been reported. None of these were previously mature males. These data are not sufficient to treat the two size-classes separately. The combined material indicate a higher recapture of the 3 days acclimatization groups (Figure 2).

The two acclimatizzation periods did not influence the proportion of grilse caught in the sea-fishery, at the release site or angled in the rivers (Table 2, 3 x 2 g-test, ns).

The small smolts released on May 19 had a lower infestation rate of salmon lice than those released on June 3; 1.55 vs 9.15 louse in average. The prevalence was higher on June 3, 95 vs 65 %, and a larger fraction had developed from copopodites to chalamus larvaes (Figure 4 and 5).

Table 3: Numbers and proportions of Carlin-tagged grilse treated with 3 or 7 days of acclimatization prior to release that were reported from rivers, release site and sea-fishery.

	ACCLIMATIZATION PERIOD 3		7	
	n	%	n	%
Rivers	46	29	40	31
Release site	26	16	18	14
Sea-fishery	89	55	71	55

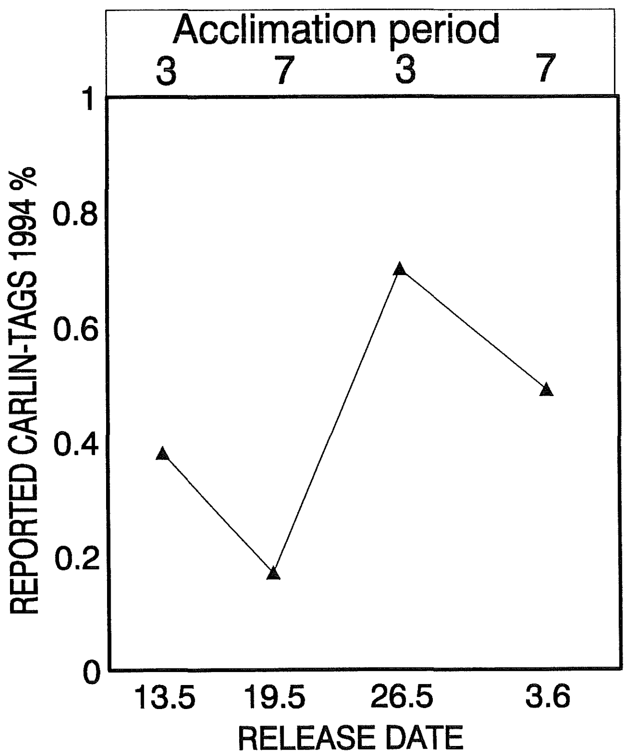

Figure 3: Recaptures of Carlin-tagged 2-sea-winter salmon shown separately for the groups released on each of the four release days.

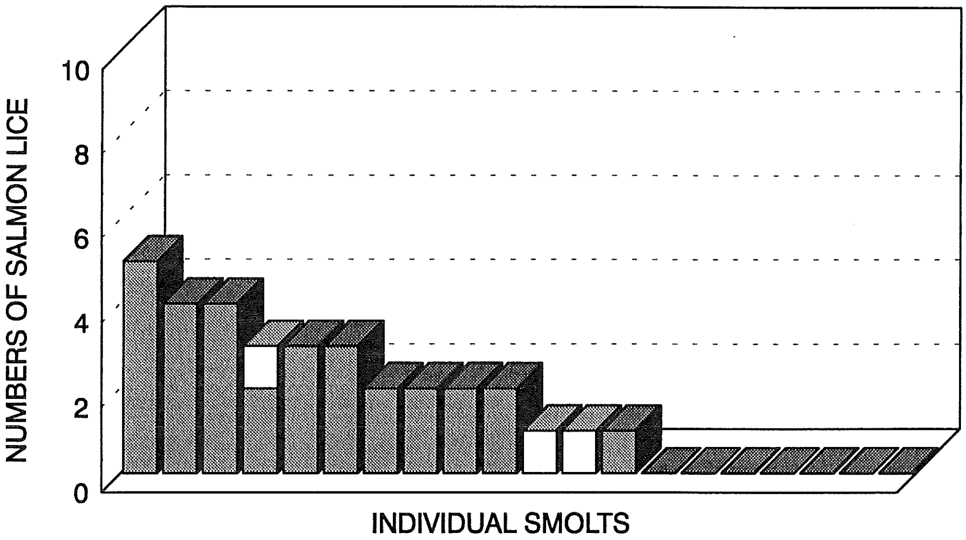

Figure 4: Numbers of salmon lice infested on sample of 20 individuals of small smolts on May 19. Copepodites (shaded bars) and chalimus larvaes (white bars) are shown separately .

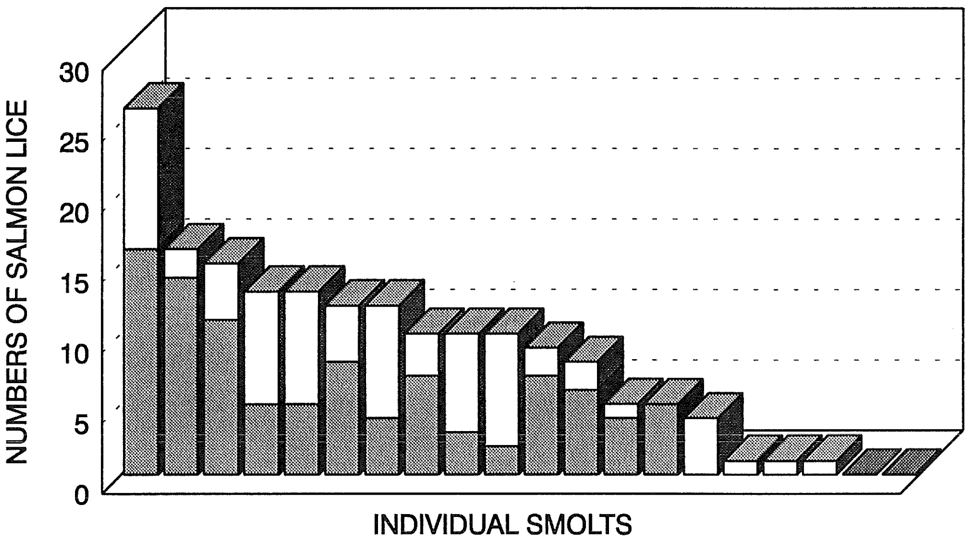

Figure 5. Numbers of salmon lice infested on sample of 20 individuals of small smolts on June 3. small smolts on May 19. Copepodites (shaded bars) and chalimus larvaes (white bars) are shown separately.

DISCUSSION

The smolts that were held in net pens in three days before release produced a larger number of adult survivors than those held for seven days. This relationship between acclimatization period in the seminatural estuary and survival in the sea was most evident for the small smolts. The release dates may have contributed to differences in survival, as predation and other factors influencing survival may have varied during the release period. The similiarity between the two pairs of release days of equal acclimatization periods, expecially for the small smolts, does indicate that acclimatization period was an important cause for the observed differences in recaptures. If this is assumed, the keeping of the smolts for 4 extra days must have introduced or strengthened some factor(s) limiting the chance of post-release-survival. There is no data on the pre-smolts outside the relese area and possible explanations must neccessarily be based upon speculations.

Video and divers observations during releases did not reveal any clear differences in migration behaviour when the smolts of the two acclimatizations periods left the bay. The migration motivation, measured as the proportion of the smolts leaving the bay within one hour, was clearly lowest early in the release period and inceased gradually with release date for both size groups. It was lower for the small smolts during the whole period. When comparing these data (see Skilbrei et al., 1994b) with the present recaptures, there is no similiarities in patterns that may point to a relationship between the behaviour of the smolts immedialtely after release and the recaptures of the groups. This may imply that, at this stage, the factor(s) that caused the sea mortality had not yet affected the smolts severely.

The salmon louse is the most obvious candidate that may, at least partly, explain the differences between the the two acclimatization periods. If the infestation rate is higher in the Selstø Bay than in the open ocean, then the higher infestation of the fish held for seven days in the bay may have increased the mortality of these fish during migration. Grimnes and Jakobsen (1995) report an experiment in which the smolts were infested with 30 chalimus larvaes or more. The louse had almost no effect during chalimus stages, but caused a sudden increase in fish mortality after more than 3 weeks when the lice reached preadult stages. Smolts suffered from osmoregulation failure and did not survive until adult lice stages. For released smolts, we must assume that predation is increased long before the osmoregulation breaks down. It is likely that salmon lice reduced the performance of the small smolts released on June 3. The presence of chalimus stages at this date show that fish were infested over a period, as copepodites use 3-4 days to reach chalimus stages (Johnson and Albright 1991). Both infestation of lice, and the reduction in recaptures compared with the previous 3 days acclimatization group, were lower for the 7 days group released on May 19. Salmon lice may have been a less severe problem for this group.

The precocious mature males that smolted the spring after maturation differed from the other smolts in several aspects. There were no evident differences between 3 and 7 days acclimatization period, and their total recaptures were superior that of their siblings. Their period of stay in sea before return also seems to be shorter, and this may partly explain their higher recapture rates. Mortality has been estimated to be quite high during the second year in open sea (Jonasson,), so fish returning after one-sea winter will have a higher chance of survival.

Precocious mature males have a developmental path different from immature smolts, and may also behave differently after being released. They grow slower during the winter of maturation and are smaller as smolts than their immature siblings (Skilbrei 1990). In an experiment on precocious mature siblings of the Lone strain, they were smaller than immature smolt in early May, but grew faster and consumed more food particles during for the next months (Heier et al., in press). Compensatory growth during the first summer in the sea has also been observed for previously mature 2+ smolts (Skilbrei, 1990). If the released males grew faster than the other smolts during the release period, the higher growth rate/consumption rate may have been advantageous when handling the physiological stress caused by the salmon lice. If the assumption that salmon lice increased mortality is correct, then the previously mature males must have some physiological advantage compared with their siblings.

Despite the high straying, acclimatization period did not influence the proportion homing to the release site, or the relative numbers caught in the sea-fishery or angled in rivers. According to the theory of sequentiell imprinting (Harden Jones 1968), imprinting is a gradual process during outward migration when the smolt learn to recognize different cues on its way. Due to the short distance from the release bay to open sea (1 km, map in Skilbrei et al., 1994a), the reason for the numerous strays may be too few local cues during the first part of migration. The freshwater discharge in the release bay may probably also influence homing success, but anyhow, the increase from 3 to 7 days did not influence homing rates and 3 days of keeping seem to be sufficient at this release site.

In conclusion, prolonged estuarine stay does not seem to increase homing and may be hazardious if parasites are present.

REFERENCES

Grimnes, A. and Jakobsen, P. 1995. Salmon lice (*Lepeophtheirus salmonis* Krøyer) infestation on Atlantic slamon (Salmo salar L.) post smolt: physiological consequences and host mortality. *J. Fish Biol.,* in press.

Harden Jones, F. R. 1968. Fish migration. Arnold, London. 325 p.

Heier, E., Jakobsen, P. and Skilbrei O. T. Growth pattern in previously mature parr (Salmo salar) prior to smoltification. *Can. J. Fish. Aquat. Sci.*, in press.

Johnson, S. C. and Albright, L. J. 1991. Development, growth and survival of *Lepeophtheirus salmonis* (Copopoda: Gaglidae) under laboratory conditions. *J. Mar. Biol. Ass. U.K.71*: 425- 436.

Jonasson, J. Johannsson, V. and Oskarsson, S. 1994. Ocean mortality of ranched Atlantic salmon during the second year in the sea. *Nordic. J. Freshw. Res. 69*: 79-83

Järvi, T. 1990. Cumulative acute physiological stress in Atlantic salmon smolts: the effect of osmotic imbalance and the presence of predators. *Aquaculture, 89:* 337-350.

Järvi, T. and Uglem, I. 1993. Predator training improves the anti-predator behaviour of hatchery-reared Atlantic salmon (*Salmo salar*) smolt. *Nordic J. Freshw. Res., 68*: 63-71.

Moser, M. L., Olson, A. F. and Quinn, T. P. 1991. Riverine and estuarine migratory behaviour of Coho salmon (*Oncorhynchus kisutch*) smolts. *Can. J. Fish. Aquat. Sci. 48:* 1670-1678.

Skilbrei, O. T. 1990. Compensatory sea growth of male Atlantic salmon, *Salmo salar* L., which previously mature as parr. *J. Fish Biol. 37:* 425-435

Skilbrei, O. T., Jørstad, K. E., Holm, M, Farestveit, E., Grimnes, G. and Aardal, L. 1994a. A new release system for coastal ranching of Atlantic salmon (*Salmo salar*) and behavioural patterns of released smolts. *Nord. J. Freshw. Res. 69*: 84-94

Skilbrei, O. T., Holm, M., Jørstad K. E. and Handeland, S. O. 1994b. Migration motivation of cultured Atlantic salmon, *Salmo salar* L., smolts in relation to size, time of release and acclimatization period. *Aquac. Fish. Manag. 25*: 65-77

Tytler, P., Thorpe, J. E. and Shearer, W. M. 1978. Ultrasonic tracking of the movements of Atlantic salmon (*Salmo salar* L.) in the estuaries of two Scottish rivers. *J. Fish Biol. 12*: 575-586.