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COASTAL RELEASES OF ATLANTIC SALMON, A NEW MODEL FOR SALMON RANCHING IN NORWAY.

by

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ABSTRACT

The present project is launched within the frame of a 7 year government funded programme to establish an additional livelihood for the coastal regions. The aim of the study is, through controlled experiments, to find ecologically and genetically sound release and recapture methods for salmon ranching. The coastal ranching model is based on releases from small coastal watercourses indepent large rivers with natural salmon stocks. The first releases were made in May- June 1991, when around 50 000 tagged smolts originating from three regional rivers were released in the Selstøvågen from the Selstø hatchery. The only fresh waters draining into the bay are the hatchery effluents amounting to about 2 m^3min^{-1}. Prior to release the fish were acclimatized to sea water in net pens. During release the fish were surveyed by divers with underwater- video, a SIMRAD EK 500 split-beam echo sounder and fisheries sonar. Hydrography and meteorology was monitored, test fishing for predators and smolts were undertaken.
The results indicate rapid westward migration of smolts and 0.1% loss of fish to predators, thus supporting the assumption that predation is a less important cause for postsmolt mortality in the marine environment.

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INTRODUCTION

Enhancement of Atlantic salmon (*Salmo salar L.*) through releases of newly hatched alevins in rivers was started in Norway in 1855. When the technique of artificial feeding was developed around the 1890s, releases of fry and smolts were also undertaken, but not until the 1950s were the first systematic releases of smolts made in Norway.

The main purpose of the traditional salmon enhancement work has been to strengthen the stocks of returning spawners, to augment river fisheries, or to repopulate rivers where the natural stocks for varying reasons have become extinct. During the last two decades, however, "sea ranching" has become a common definition for release work aiming to profit from the vast food resources in the ocean, not only to enhance the natural river stocks, but also to provide a basis for coastal and ocean fisheries.

Ranching of Pacific salmonids is performed on a large scale by Japanese, US, and Soviet Canada fisheries authorities, who are releasing millions of salmon fry and smolts in rivers and estuaries draining into the Pacific Ocean.Ranching of Atlantic salmon has been done in Sweden, The Soviet Union and Finland in the Baltic for some decades, while the countries around the North Atlantic, until recently, mostly have worked along the lines of traditional enhancement.

The first step forwards a Norwegian salmon ranching programme was set in 1986 when the Directorate of Nature Management set up a nationwide research programme on salmon ranching. The programme had its basis in large salmon producing rivers, restoration of acidified watercourses or riverstocks destroyed by *Gyrodactylus*.

However, since 1977, however,the Institute of Marine Research has been advocating large scale sea ranching as a means of broadening the economic outcome of the coastal regions (Møller og Nævdal 1977). Experiments with relation to coastal ranching of cod were started in 1983, and lobster ranching experiments were commenced in 1987). Based on Alaskan and Icelandic experiences, a model for ranching Atlantic salmon based on small coastal fresh watercourses, indepent of large salmon carrying rivers, was developed during 1986-1989 (Skaala et al. 1986, Jørstad et al. 1988, 1989).

The first release of smolts in concordance with the above model was made in May- June 1991 from Selstøvåg, a narrow bay draining into the vicinity of the Norwegian Coastal current (Fig.1.).

The present project is launched within the frame of a 7 year government funded programme to establish an additional livelihood for the coastal regions. The aim of the study is, through controlled experiments, to find ecologically and genetically sound release and recapture methods of ranched fish, that would augment the return rate of released Atlantic salmon smolts to a level where ranching could form an economically viable basis for regional developement in coastal Norway at the same time as interfering as little as possible with natural salmon stocks.

The working hypothesis of the project and preliminary results of the release experiments in 1991 will be presented below.

"COASTAL RELEASE MODEL"

The rationale behind the model can be summed up as follows:

> On the coast of Norway there are few large, but numerous small vatercourses. By developing salmon ranching adapted to such small coastal watercouses, the potential for a future salmon ranching programme can be substantially augmented.
>
> The coastal extremes are mostly dependent on sea based development activities. Fishing for returning ranched salmon in the immediate vicinity of the release area, may become a substitute for the closed driftnet fishery for salmon (closed in 1990).
>
> A similar model for ranching of Pacific salmon established in Alaska has been successful.

The ecological considerations behind the model is primarly, to keep the distance between the release sites and natural salmon rivers as great as possible in order to minimize risk of influence of ranched fish on wild populations. Secondly, the predation pressure on the outer coast (Gunnerød et al.1988) seems to be smaller than in the fjord area (Hvidsten and Møkkelgjerd 1987, Hvidsten and Lund 1988).

The scientific hypothesis on which the project is founded, is the ability of Atlantic and Pacific salmon to return to the site of release, rather than to river of origin when sexual maturation is approaching (Sutterlin et al. 1982, Dudiak and Hauser 1989, and Hansen et al. 1989 a). Harden Jones 1968, ascribes this ability to sequential imprinting of environmental cues during outward migration. Studies by Hansen et al 1987, 1989a and Jonsson et al. 1990 in the river Imsa seem to support the sequential learning theory. Holm et al. 1982 and 1986 and unpublished observed the migratory behaviour of wild and hatchery reared smolts by hydroacoustic tracking of tagged fish, and concluded that smolts seem to use the hydrographical conditions in the fjords as cues for migration. Thus we assumed that, provided smolts were released at normal migration time, after imprinting on the freshwater source and adaptation to sea water, the ability of sequential imprinting of migration routes apparent in estuarine and fjord environment, would also function in coastal releases.

DESCRIPTION OF SITE

The release-site, the Selstøvågen, is a narrow bay stretching East-West, only 500 m long and 50 - 90 m wide with steep rocks on both sides and sandy bottom. The lake Kvednavatn with its cathment area of 1.3 km 2 drains into the Selstøvågen via a small brook, but only when the hathery reservoir is filled up. Thus, during dry periods the only fresh water discharges into the bay are the effluents from the Selstø hatchery which amount to about 2 m^3 min^{-1}. The depth falls evenly from 4 m by the station to 14 m at the outlet. The Selstøvågen outlet opens into a fjord south of the inlet of the Tælavåg fjord. At a distance of approximately 1 km West of the Selstø inlet, there is a strand of small islands. The Norwegian Coastal Current fluctuates N - S along the western coastline of this archipelago Fig.1.

MATERIAL AND METHODS

The first fish released in the experiment were 1+ smolts (hatched in Jan. - Febr. 1990) descending from wild parents caught in the rivers Vosso, Dale and Lonevåg in the Osterfjord area, Fig.1. The groups were paternal halfsiblings, as one male was used to fertilize the eggs of two females. Scales and otholiths were sampled, and muscle, liver and eyefluid were taken for genetic analyses from every parent fish. All the fish were screened for diseases.

Yolk sac fry were transferred to Selstø hatchery in the immediate vicinity of the release area, Fig.1. The fish were raised according to standard fish farming practices. However, due to genetic considerations, the family groups were kept separated in 1x1x0.6 m tanks until the fish were large enough to be adipose finclipped. Then groups were united two by two and transferred to outdoor cylindrical tanks (Ø 6 m) in august 1990.

During autumn 1990 all groups were sampled for growth and checked for precociously maturing parr, which were removed to separate tanks.

25 000 fish were tagged in March- April 1991 by standard size individually coded Visible Implant Tags (Northwest Marine Technology, Washington, USA) placed behind the left eye. In addition groups were marked by freeze branding with liquid nitrogen. All fish had the adipose fin removed.

The release groups, six in all, were set up as identical as possible with regard to the number and origin of fish. Thus each release group consisted of approximately the same number of fish from individually tagged family groups, and three mixed groups, identifiable on river basis, marked with freeze brand symbols. The release groups consisted of 8- 10 000 fish.

Prior to release the fish were transferred to net pens in the Selstøvågen close to the hatchery. The salinity at 0.1 m detpth was around 32 ppm. Unfortunately the planned scheme for acclimatization of groups could not be followed, and the fish were staying in the pens from only 4 hours up to 22 days. The fish were released at high water or just before high water. Two daytime and four night- time releases were performed.

During some releases the fish were observed by divers with underwater video-equipment and by a boat equipped with a SIMRAD EK 500 splitbeam echo sounder. The swinger was mounted horizontally at the stern, and the boat was anchored perpendicularly to the fjord at a distance of 250 m from the point of release. The passage of all fish moving through the echo beam (opening angle 10°) could be observed. Before and after each release the Selstøvågen and the Tælavåg fjord was surveyed following a set of transects covering 1% of total area to observe possible contributions of smolts to the echo strength in the area. During one release a boat with a fisheries sonar was scanning the inlet of Selstø from a distance of 750 m from the release point. Fig. 2.

During the whole release period temperature, current and light conditions were logged with 20 minute intervals from a monitoring rig in the middle of the Selstøvågen. Currents were also monitored by drogues at 1 and 5m depth, and some plankton was sampled by plankton nets.

Fishing for smolts with fine meshed surface nets was made in connection with all releases. Predator fishing with several types of nets was made before, during and for two days posterior to a release.

Fish eating bird species were registered.

RESULTS

A very large data material was collected during the 1991 season, and remains to be treated in greater detail. Some data will be presented in separate ICES reports and some are in preparation for publication elsewhere. The results below will therefore represent a preliminary review of the data collected, and will be discussed with reference to the coastal release model.

Genetical characteristics and health status of parent fish

The results are reported by Skaala et al 1991 and Mortensen et al 1991 respectively, therefore in this context it is only worth mentioning that some rare genetic variants were found, and that the parent fish in 1989 were free of all diseases registered by veterinarian practices. The 1990 brood stock contained two cases of furunculosis and three cases of IPN, these egg batches were destroyed while still remaining in the quarantine hatchery.

Growth
There was a marked variation between families within rivers as well as between rivers both regarding growth and the occurrence of precocious males (Fig.3).

Hydrography and meteorology
The tidal forces in the area are relatively weak (difference approx. 90 cm). Thus the surface waters are stongly influenced by the wind forces and the direction of the coastal current. The Northernly coastal current presses the water inwards in the small fjords, a movement which is augmented when W and SW- vinds are prevailing. However, this movement is to some extent counteracted by falling tide and N to NE winds which drive the surface water out of the fjords. The predominant current pattern in the Selstø basin was an ingoing surface current on the south side and an outgoing surface current on the north side. At times of slack water and westernly winds, an outgoing current below the surface was created in the middle of the Selstøvågen. The sea temperature at 1m was 8.2°C during the first releases (24 - 28 May) and rose to 11°C during the last release (14 June). During the first releases there was only a 0.4°C difference between temperatures at 0 respectively 10 m depth, while the difference in salinity was 1.6 ppm.

Migratory behaviour
Divers observing the smolts reported that upon release the smolts left the net pen in large groups of thousands of fish. They moved fast in the midlle of the fjord at 2 -4 m depth in an outward (westernly) direction . Only a few fish were seen moving inwards. 2 to 6 hours after release there were only a few small groups (3 - 10 fish) remaining in the inner part of Selstøvågen. These fish were observed to have fin damages or otherwise showing abnormal swimming behaviour.

The first fish were crossing the beam of the echo sounder 3 - 10 min. after release,

corresponding to a speed of 8 - 3 body lengths sec.$^{-1}$. Thereafter smolts were passing in small and medium groups, or as single fish rather evenly during 4 - 6 hours, whereafter the echoes disappeared. There was an apparent tendency of the fish to be more dispersed during the dark hours than during light hours.

Every echo tracking cyclus was recorded on a PC connected to the EK 500 sounder. When worked up, these data will allow us to estimate the number and sizes of single fish as well as of schools , their speed, direction and tilt when passing through the echo beam.

After releases, surveys in the area west of the Selstø inlet and in the Tælavåg fjord revealed important contributions of echoes similar to smolt target strengths located at 6 - 15 m depth on certain ground areas. Probably due to incorrect fishing methods no catches whatsoever were obtained when setting nets on some of these grounds.

During a release at midnight, June 14th, a large concentrated school was observed on the sonar (Fig. 3), at 2 - 4 m, less than 10 min after release, at a distance of 500 m from point of release. Having left the Selstøvågen, at a distance of about 50 m from the boat, the fish lowered the speed, and the school started spreading out. While the boat pulled away the school dispersed more, rounded the southwestern point of the Selstø inlet, and became difficult to observe. 20 minutes after release a smaller school, moving SW was registered W of the inlet to the Grunnavågen. 11 smolts were later on registered at 2 - 4 m depth in setnets hauled 1.5 h. after release. (Fig.4, position IV). The sonar survey was interrupted shortly afterwards because of too much disturbance from bubbles mixed into the sea by rough wave action. The following day no conclusive registrations of smolt type signals were made in the area.

The data are not yet fully worked up, but are in preparation for publication elsewhere.

Predation and test fishing

The results of the fishing efforts are summarised in Table 1 below. A few predatory bird species were observed in the area. They occurred in small numbers, and no aggregation of birds during releases was observed, nor were any successful attacks on smolts observed.

Table 1. Species, number of predators caught, and prey registered in stomach content per day of fishing with 6 different types of set nets. Predator species indicated in parenthesis. * = day of smolt release

	SPECIES				
	COD G.MORHUA	POLLOCK P.POLLACHIUS	SAITHE P.VIRENS	OTHERS	SMOLTS
DATE	no	no	no	no	no
23.05	3	-	2	2	7 (in cod)
24.05*	8	6	21	2	-
25.05	8	5	26	-	2 (in pollock)
26.05	4	8	4	-	-
27.05*	2	13	2	2	-
29.05	4	4	1	3	-
03.06*		no recordings			
04.06	4	14	13	2	6 fresh; 12 digested (pollock)
05.06	6	13	-	-	7 digested
07.06	4	34	-	2	-
14.06*	6	25	-	-	-
TOTALS	49	122	69	13 = 253	35
$\bar{X}$ LENGTH CM	45	40	33	-	no records

The smolts were fished with fine meshed fresh water multifilament nets (8 mm, stretched halfmesh) mounted 2 and 3 together, either lengthwize or leadline to floatline. These nets were used as set nets or drift nets.

Table 2. Date of catch, number of smolts, position of smolts in the net, and location of net. Location refers to Fig. 4.

Date of catch/ time hau-led	Number of smolts	Catch depth m	Location of nets
03.06/	2	1 - 2	I
23.15 h	9	3 - 4	"
03.06/	21	0 - 1	II
23.25 h	11	1.1 - 2	"
-"-	9	3 - 4	"
03.06/			
23.35 h	5	3 - 4	III
14.06/			
01.40 h	11	3 - 4	IV
Total catch	68 smolts,	50% caught at 3- 4 m. depth	

DISCUSSION

The preliminary results of this years experiments indicate several interesting traits.

The migration was rapid and directed in comparison with observations made in estuaries and fjords with a pronounced brackish water layer (cf. Thorpe and Morgan 1978, Maclean et al. 1981, Holm et al 1982 and unpublished). Hydroacoustic tagging of migrating smolts has shown that they make frequent vertical and horizontal excursions when moving through areas with salinity or temperature gradients, or areas where the hydrographical conditions are turbulent. Holm et al.1986 have hypothesized that by diving through the gradients, the smolts in similar manner as the returning adult salmon do (Westerberg 1984) get cues for orientation and preferred environments. Migratory behaviour of Atlantic salmon smolts has been recorded in open sea only in a few cases which indicate a more directed behaviour and a preference for greater swimming depth in saline environments (Holm unpublished). The present study seems to support these observations. Thus, in accordance with the above hypothesis, once in an environment with stable and strong currents and uniform salinity indicating oceanic conditions, it would not seem meaningful for the smolts to waste too much energy on sensory excursions any more.

The pollocks made up almost 50% of the predator catches. Pollock is a dangerous potential predator on smolts as it combines the slow, non alarming approach behaviour

of a cod, with the mobility of a pelagic predator (Holm 1983). Local fishermen informed of regular migrations of large pollock by the end of June towards the coast of Sotra. However, predation was low, probably reflecting the non adaptation of the coastline predators to smolts. The 35 smolts registered in cods and pollocks represent a negligible loss (less than 0.1 %) in comparison with the 15 - 20% predation estimates by Hvidsten and Lund 1987 and Hvidsten and Møkkelgjerd 1988 in inner fjord regions.

Unless negatively correlated with e.g. return rate and precocious maturation, the variation in growth characteristics of groups will be a factor of vital economic interest that has to be followed up and taken into consideration in possible future breeding schemes for ranched salmon.

Smolts have long been considered difficult to survey by hydroacoustic methods, since the fish migrate relatively close to the surface and in disperced shoals. The large number of fish released, combined with the uniform hydrographical conditions and the advanced split beam technology allowed for observation of single fish as well as schools. Thus acoustics may become an important tool in resolving questions connected with postsmolt migration.
Releases in marine environments seem to augment straying (e.g. Gunnerød *et al.*1988). Most such releases, however, have been made either without prior adaptation to the site, or, without proper recapture efforts on the site. Provided the migration was not too rapid for the mechanisms behind the sequential imprinting of migration routes, there should be a fair chance for the fish to return to Selstø from 1992 onvards. In 1992 research and development of effective fishing gear for this particular site will have high priority.

CONCLUSIONS

The release from a coastal site worked as expected with regard to impact of predators and directionality of migration.

The setup with echosounder and sonar added useful information on smolt behaviour, and will be used with some modifications also in future studies of smolt releases.

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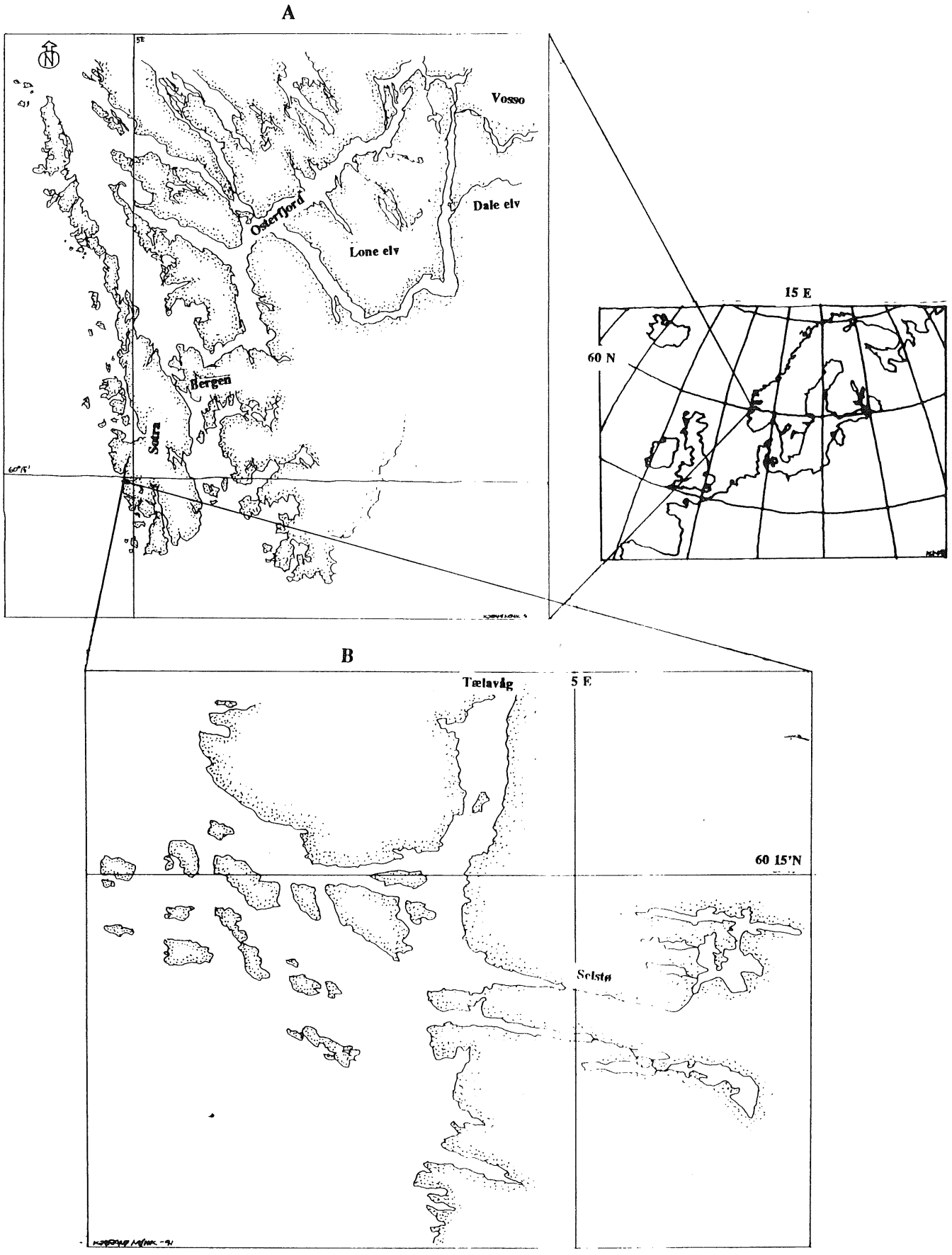

Fig.1. A. The rivers of origin of ranched fish.
B. The Selstø hatchery and the release site

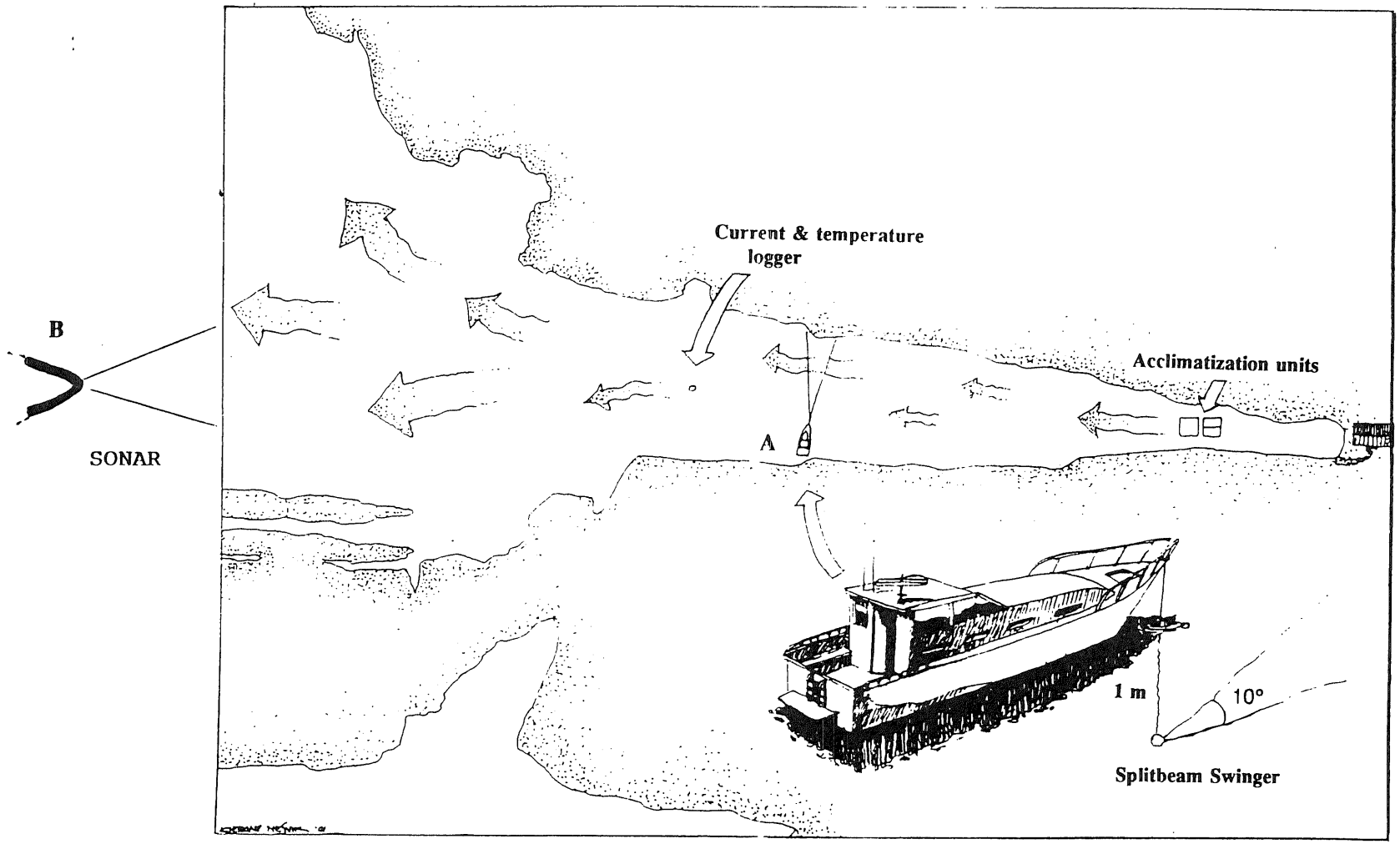

Fig.2. Setup of tracking in Selstøvågen.

A. SIMRAD EK 500 splitbeam echo sounder with horizontally mounted swinger.
Before and after releases the boat surveyed transects in the nearby fjords (vertically monted swinger).

B. Boat with fisheries sonar scanning the Selstø inlet.
Range approx. 700 m

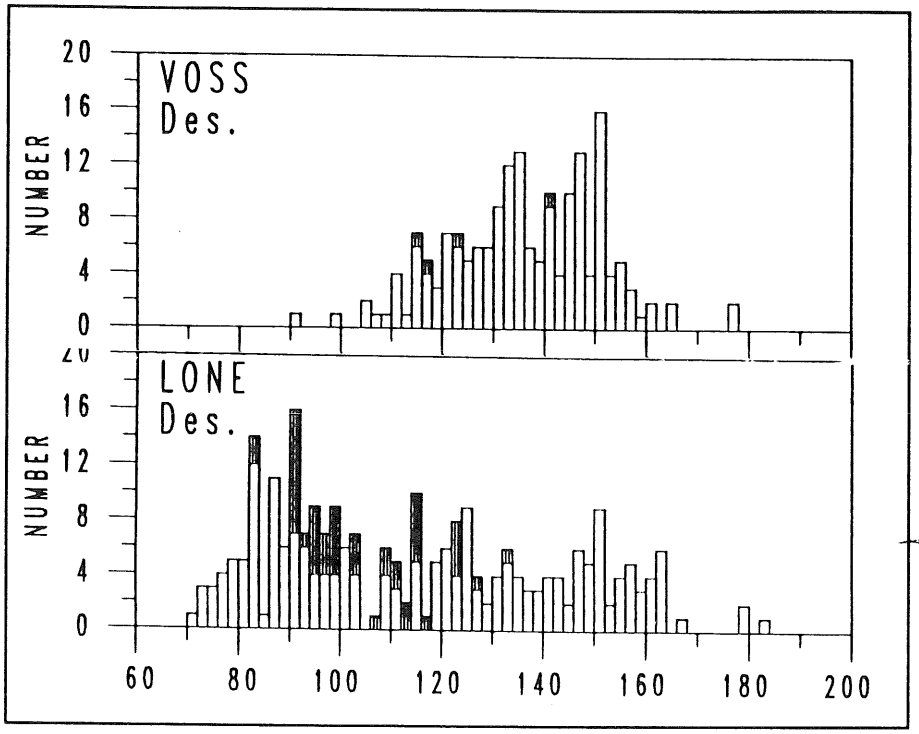

Fig.3. Growth comparison of Vosso and Lone- elv parr. Hatched bars indicate occurrence of precocious parr males.

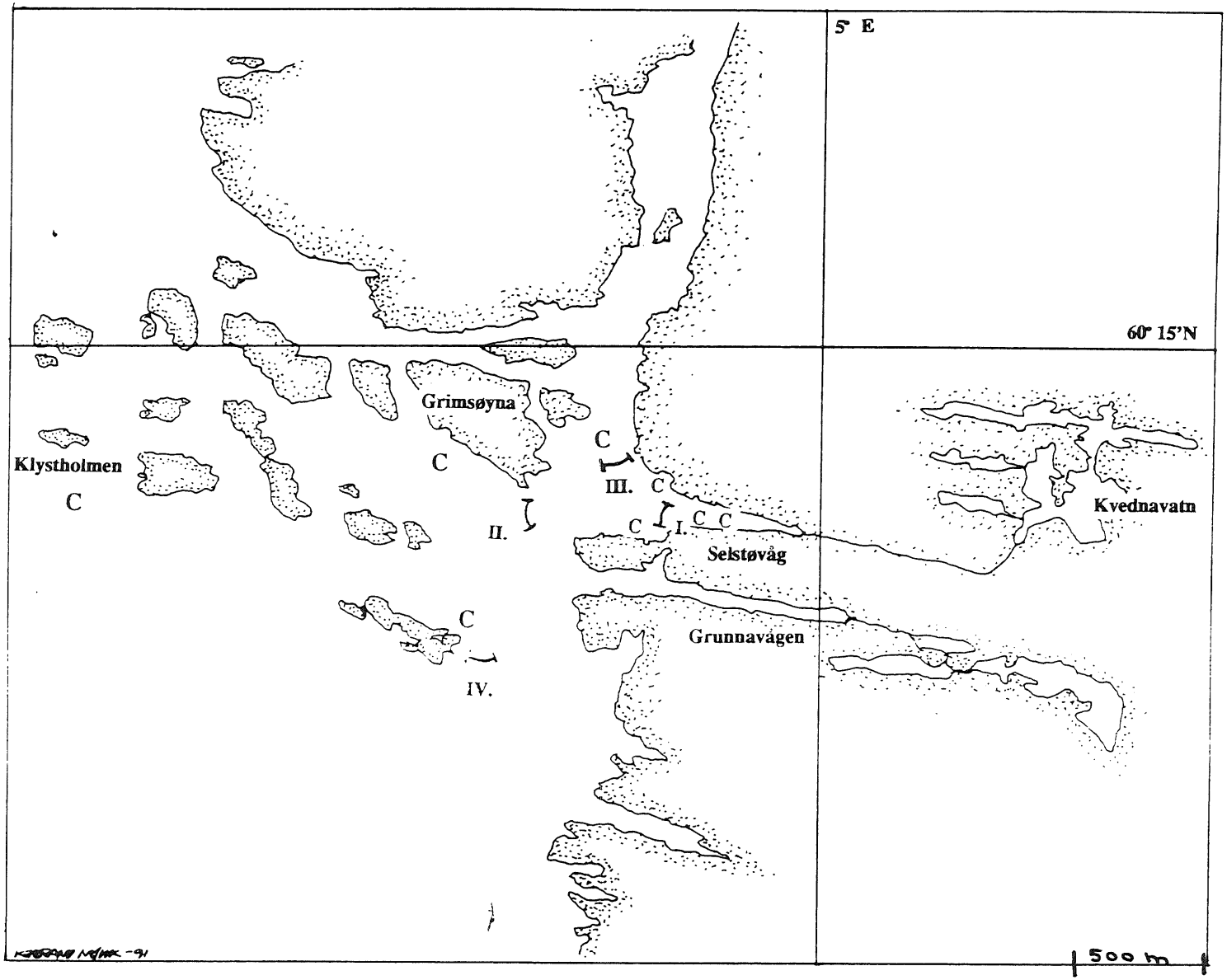

Fig.4. Smolt catches in finemeshed nets sites **I - IV**.
Predators containig smolts, catch sites **C**.