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J.E. Thorpe

Evaluation of Fish Cultivation Methods in the Northern Aquaculture Stations of the Finnish Game and Fisheries Research Institute

Helsinki 1999

RIISTAN- JA KALANTUTKIMUS

Riista- ja kalatalouden tutkimuslaitoksen pohjoiset kalanviljelylaitokset

Northern aquaculture stations of the Finnish Game and Fisheries Research Institute

Inarin kalantutkimus ja vesiviljely
Inari Fisheries Research and Aquaculture

Muonion kalanviljelylaitos
Muonio Fish Farm

Sarmijärven kalanviljelylaitos
Sarmijärvi Fish Farm

Taivalkosken riistan- ja kalantutkimus
Taivalkoski Game and Fisheries Research

Tornionjoen kalanviljelylaitos
Tornionjoki Fish Farm

Kainuun kalantutkimus ja vesiviljely
Kainuu Fisheries Research and Aquaculture

Kuvat: Risto Kannel, Anu Leppänen ja Suomen Ilmakuva Oy

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Riista- ja kalatalouden tutkimuslaitoksen vesiviljelyn tulosyksikkö pyysi keväällä 1998 Prof., Dr. J. E. Thorpen Glasgow:n yliopistosta Skotlannista arvioimaan Inarin, Sarmijärven, Tornionjoen, Muonion, Taivalkosken ja Kainuun kalanviljelylaitosten emokalan- ja poikasviljelyn toimintapoja, toiminnan tehokkuutta ja tekemään ehdotuksia toiminnan tehostamiseksi. Arviointi tehtiin 15.-26.4.1998. Prof. Thorpen laatimaa raporttia ja siinä annettuja suosituksia käsiteltiin 1.12.1998 Kemissä järjestetyssä tutkimuslaitoksen pohjoisten kalanviljelylaitosten seminaarissa. Tämä julkaisu sisältää arviointiraportin, arvioinnin taustana olleet kalanviljelylaitoskohtaiset viljelytekniset tiedot sekä raportin suosituksia käsitelleessä seminaarissa tehdyt toimenpide-esitykset viljelytoiminnan kehittämiseksi.

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Abstract

In spring 1998 the Aquaculture Unit of the Finnish Game and Fisheries Research Institute commissioned Prof., Dr. John E. Thorpe of the University of Glasgow to evaluate fish cultivation methods and practices at the Inari, Sarmijärvi, Tornionjoki, Muonio, Taivalkoski and Kainuu aquaculture stations. Dr. Thorpe evaluated the stations on April 15-26, 1998. The report prepared and recommendations given there in were subject to negotation in an internal seminar of the Aquaculture Unit on December 1, 1998 in Kemi. This report includes the evaluation report prepared, background information on the aquaculture stations and an action plan prepared in the seminar addressing the recommendations presented in the evaluation.

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Sisällys

ESIPUHE. Riista- ja kalatalouden tutkimuslaitoksen pohjoisten kalanviljelylaitosten viljelymenetelmien arviointi

Riista- ja kalatalouden tutkimuslaitoksen vesiviljelyn tulosyksikön keskeisiä tehtäviä ovat uhanalaisten, alkuperäisten kalakantojen ja niiden monimuotoisuuden ylläpitäminen viljelyn keinoin sekä laadukkaan, tautivapaan ja taustaltaan tunnetun mädin ja poikasten tuottaminen kalakantojen säilyttämistä, tutkimusta, valtion velvoitteita ja muita valtion sekä yksityisen kysynnän tarpeita varten. Tätä varten tutkimuslaitoksella on käytössään 12 kalanviljelylaitosta.

Viimeksi kuluneina vuosikymmeninä ovat viljelymenetelmät jatkuvasti tehostuneet ja teknistyneet. Yhä enenevissä määrin pyritään viljelyprosessia ohjaamaan ja säätelemään kullekin lajille ja tuotantotavalle mahdollisimman optimaaliseksi. Viljelylaitosten ympäristövaikutusten vähentämistarpeet ovat osaltaan voimakkaasti suuntaamassa kehitystä ympäristöystävällisempiin ratkaisuihin, jotka kuitenkin joissain tapauksissa ovat ristiriidassa kalojen viljelybiologian kanssa.

Tautitorjuntasyistä, viljelyn varmistamiseksi myös talviaikaan sekä toiminnan tehostamiseksi on laitosten allastiloja katettu viime vuosina. Uusien allasratkaisuiden, ruokinnan automatisoinnin ja katettujen tilojen myötä ovat muun muassa valaistuksen, ruokinnan, virtausolosuhteiden sekä viljelytiheyksien säätelymahdollisuudet olennaisesti tehostuneet. Samalla tiedon tarve ympäristöolosuhteiden vaikutuksesta kaloihin on lisääntynyt. Uusien olosuhteiden hallinnan parantamiseksi pyydettiin tunnustettua alan asiantuntijaa, skotlantilaista prof. J.E. Thorpea arvioimaan Inarin, Sarmijärven, Tornionjoen, Muonion, Taivalkosken ja Kainuun laitosten emokalan- ja poikasviljelyn toimintatapoja, toiminnan tehokkuutta ja esittämään toimenpide-ehdotuksia erityisesti viljelyolosuhteiden säätelyn vaikutuksista emokalojen lisääntymiskiertoon. Arviointi tehtiin keväällä 1998.

Prof. Thorpen laatimaa raporttia ja siinä annettuja suosituksia käsiteltiin 1.12.1998 Kemissä järjestetyssä seminaarissa, johon osallistuivat mm. laitosten johtajat ja tuotantopäälliköt sekä eräitä RKTL:n tutkijoita. Seminaarissa sovittiin toimenpiteistä arviointiraportin suositusten toteuttamiseksi. Emokalan- ja poikasten viljelyn ongelmia ja viljelyn kehittämistä on aikaisemmin käsitelty myös mm. lukuisilla vesiviljelypäivillä (viitteet Riista- ja kalatalouden tutkimuslaitos. Kalatutkimuksia-Fiskundersökningar 110,1996).

Riista- ja kalatalouden tutkimuslaitoksen puolesta esitän prof. J.E. Thorpelle parhaat kiitokset ansiokkaasta ja monipuolisesta viljelyn kehittämisraportista. Kiitokset kuuluvat myös arvioinnin suunnittelussa ja toteutuksessa mukana olleille tutkimusprofessori Antti Soiviolle, laitosjohtaja Petri Heinimaalle ja tutkija Sirkka Heinimaalle sekä arvioinnin kohteina olevien laitosten henkilökunnalle.

Kai Westman
Vesiviljelyjohtaja

FOREWORD. Evaluation of fish cultivation methods in the northern aquaculture stations of the Finnish Game and Fisheries Research Institute

The central tasks of the Aquaculture Unit of the Finnish Game and Fisheries Research Institute are to preserve endangered and indigenous fish stocks and their biodiversity by means of aquaculture, and to produce high-quality, disease-free eggs and juveniles of fish of known background to meet the requirements of conservation, research, State stocking obligations, and other governmental and private needs. To meet these demands, the Institute has twelve aquaculture stations at its disposal.

The last few decades have witnessed continual technological progress and improved effectiveness in aquaculture methods. Efforts are being made, to an ever-increasing degree, to control, regulate and thereby optimise rearing processes for each fish species and production approach. The need to reduce the environmental impact of fish farms has provided strong impetus to develop more environmentally friendly rearing methods, which may nevertheless conflict in some cases with aquaculture biology.

To prevent diseases, to ensure that aquaculture can continue all year round and to improve the overall efficiency of operations, rearing facilities have been roofed in recent years. New rearing basin technology, roofing and automated feeding have made it possible to improve regulation of lighting, feeding and flow conditions fundamentally. At the same time, there is an ever more urgent need for knowledge about the effects of environmental conditions on fish. To improve management under these new circumstances, we invited a recognised specialist in the field, Professor, Dr. J. E. Thorpe from the University of Glasgow in Scotland, to evaluate the operational approach and effectiveness of brood fish and juvenile culture at the Inari, Sarmijärvi, Tornionjoki, Muonio, Taivalkoski and Kainuu aquaculture stations. Dr. Thorpe was asked to present procedural recommendations, particularly with respect to the impact of regulating aquaculture on the reproductive cycle of brood fish. The evaluation was conducted in spring 1998.

The report prepared and the recommendations contained therein were discussed at a seminar organised on December 1, 1998 in Kemi. The participants in the seminar included the section directors and production managers of the aquaculture stations as well as a number of Institute's researchers. At the seminar, measures were agreed upon for carrying out Dr. Thorpe's recommendations. The problems of brood fish and juvenile rearing and the development of aquaculture have been treated earlier at numerous symposium on State aquaculture (for citations, see Riista- ja kalatalouden tutkimuslaitos. Kalatutkimuksia-Fiskundersökningar 110, 1996).

On behalf of the Finnish Game and Fisheries Research Institute I would like to extend my warmest thanks to Professor, Dr. J.E. Thorpe for his valuable and comprehensive report on the development of aquaculture in northern Finland. Thanks are also due to Research Professor Antti Soivio, Section Director Petri Heinimaa and Researcher Sirkka Heinimaa who assisted in organising and realising the evaluation, and to all staff members of the stations that were evaluated.

Kai Westman
Director of Aquaculture

1. TIMING OF VISIT

During the period 15-26 April 1998, together with Professor Antti Soivio I visited the rearing units of the Finnish Game & Fisheries Research Institute (FGFRI) at Tornionjoki, Muonio, Inari, Sarmijärvi, Taivalkoski and Kainuu, and the private farms belonging to Voimalohi Oy at Ossauskoski and Raasakka. The present report gives my impressions of the efficiency of the production of the FGFRI farms: my comments on the Voimalohi farms form a separate report provided for the managing director of that company.

2. GENERAL INTRODUCTION

The objectives of the individual farms differ slightly, but the overall purpose is to support the natural production of freshwater fishes (chiefly salmonids) in waters where that production has been compromised by overfishing, by pollution (as in the case of Baltic salmon, where the M74 problem reduces embryo survival severely) or by modification of the physical habitat for other human uses such as power production or timber flotation. Eggs, fingerlings, larger juveniles and smolts are produced for release into the wild, according to a programme of numerical target quantities determined centrally within the Ministry of Agriculture in Helsinki. In some cases these targets have been set by the Water Courts, and are legal requirements which must be met if the other uses of the water bodies are to be permitted (e.g. level regulation when water is being used for power generation). Details of these targets are passed to the farm managers through a chain of command from the headquarters office of FGFRI in Helsinki, and the management of the production and its release is the responsibility of regional and individual station managers. Broodstocks for this production are held on the farms, and often duplicated in different farms as an insurance against disasters. Some stocks exist solely as brood collections in the farms, as their original populations are destroyed now or are no longer self-sustaining in the wild. Thus the farms play a genetic conservation role as well as a fishery management one.

As the products of the farms are to be released into the wild, their ultimate success will depend on their ability to survive there, to compete successfully with other native species, to avoid natural predators, and to grow to an exploitable size. In the case of species being produced to supplement naturally reproducing stocks, the released fish must be able also to mature and reproduce successfully in the wild. So it is necessary that the material should be genetically similar to the original or existing local stock, and that rearing techniques produce individual animals which are as close as possible in their behavioural and physiological characteristics to those developing in the wild. This implies that the rearing methods should foster the retention of the animals' full repertoire of feeding and predator avoidance responses, and all techniques should consider the real biological needs of the fish before those of the convenience of the producer. This approach distinguishes rearing units such as these present farms from those aquaculture farms where the objective is to produce fish for food. In the latter the producers are using the animals as physiological machines, and looking for the most convenient and economically efficient methods to achieve this end in environments where food is not a limiting resource, and where predator avoidance does not need to be considered. With such goals, the producer aims to find ways of manipualting his animals to his own convenience. This approach has dominated modern aquaculture, but is inappropriate to culture programmes whose goal is supplementation of wild stocks. In view of this, it has been my primary approach during these visits to consider how appropriate are the rearing techniques in the FGFRI and Voimalohi farms for fishes for release.

At this point it is appropriate to comment on the technique of light manipulation which is practised in one form or another in each of the farms I visited.

Natural selection has equipped salmonid fishes to make good use of the energy resources available to them in their particular habitats, and these resources fluctuate seasonally in response to seasonal physical cycles, most particularly of light, but also of temperature. Consequently, the physiology of the fishes varies seasonally also, in response to this variation in resource availability. The timing of their physiological and behavioural rhythms is synchronised by changes in photoperiod. (Light cycles are highly predictable, and therefore are dependable predictors of seasonal change. Temperature cycles are much less predictable, and temperature variation modifies the rates of developmental processes rather than their timing). Because the timing of changes in physical conditions (for example, hydrological patterns) differs in different river systems, the temporal patterns of resource availability differ in those systems. The physiological state of the fishes is matched to resource availability, and so development patterns differ between different stocks of a species, and in some cases between geographically separate components within those stocks. As these development patterns are coordinated by photoperiod change, the particular phases of diel and annual photoperiod cycles which serve as signals for developmental change differ between separate stocks and stock components. In the absence of detailed knowledge of which particular phases of the photoperiod cycles are used by individual stocks as signals to synchronise their development, the safest way to ensure the appropriate timing of development in stocks held in hatcheries is to expose those fishes to natural light intensity fluctuations to provide them with a reliable source of information on time.

There is a problem here. No data exist on the actual pattern of light intensity fluctuations within the natural habitat of the fishes in northern Finland, nor within the rearing tanks at the level of the fish. Therefore it is not known how closely any of the present light regimes used in the hatcheries - with or without exposure to natural daylength in air - correspond to the normal experience of light rhythms by fish in the wild. It would be extremely valuable to obtain such physical data from a range of natural habitats throughout the year, and routinely from within rearing tanks. It is highly likely that these two data sets will differ, especially during the winter when intensities and the duration of the photophase under thick ice-cover in the wild will contrast sharply with the patterns in the tanks. When the discrepancies between these two data sets have been established, then there will be a sound basis on which to carry out comparisons of the effectiveness of particular light regimes for use in the production units.

The genetic conservation element of the programme is evidence of the recognition of the importance of stock structure among these species, and of the need to maintain genetic diversity within and between these stocks. It is therefore of paramount importance that the release programmes are carried out in such a way that the products of the hatcheries enhance rather than interfere with this diversity, so that release sites and times need to be chosen carefully with this in mind.

If a system is running well and achieving its targets, there is no virtue in changing it for the sake of change. By and large, the Lappland hatcheries are achieving their objectives well. So in the following report, where I have made suggestions for changes, they have been relatively minor and designed to make good performance even better. I emphasise that these are suggestions only: to ensure that they would make a positive contribution to efficiency they would need to be evaluated against present methods, in small scale production trials.

3. THE HATCHERIES

Introduction

For each rearing station I include a statement of its objectives and current activities, and some specific comments on rearing and release practices. Specific suggestions made in these notes are summarised in a subsequent section entitled *Summary of Recommendations*.

Tornionjoki

The primary purpose of the Tornionjoki unit is as a conservation hatchery for the maintenance of the Tornionjoki Baltic salmon stock, which is severely threatened due to M74, such that c.90% of embryos derived from spawnings of wild fish die. Consequently, broodfish from this stock are maintained here, with a second and larger component at Taivalkoski some 400km to the south east. Genetic management of these populations is by random pairings with no conscious selection (see comments on Taivalkoski below). Eggs derived from random pairings of these fish are reared at Tornionjoki. To achieve this, 1.8 million eyed eggs have been incubated: these are the progeny of c.240 females. After the UV-sterilation unit in the hatchery has been taken in use the yearly need for eyed eggs will be 1.2 - 1.4 millions. Half of the eggs are Tornionjoki production and half from Taivalkoski.

Eggs and alevins are incubated in EWOS troughs, eggs in a single layer in baskets, and then alevins free in whole trough. This is a good system, and the solid covers over troughs should reduce distrubance to the alevins and allow an efficient conversion of yolk into body tissue. First feeding of the fry is in 2m tanks. It is carried out by hand until the manager is satisfied that all the fish are feeding, and then feeding is entirely automatic. Rearing for the first year is indoors, in a large hall with windows allowing low level daylight, and thus exposure of the fish to seasonal signals. Light intensity is slightly augmented during working hours (0700-1600). The faster growing fish are transferred at their second spring to a second rearing hall to rear on to smolting in larger ponds, under a similar exposure to natural light, but without supplementary artificial light. This selection of the faster growing element implies a genetic selection for rapid development in the long term. It would be prudent to give as much emphasis in the rearing programme to all growth rate groups, to ensure that the entire spectrum of genetic diversity is retained within the stock. Parr are released in spring, after the ice has gone, mostly by hand-net from a large inflatable, at a rate of 10/100m^2 throughout a 3-400 km stretch of river (but avoiding regions where good natural reproduction is still occurring), and in the tributaries. Monitoring of these stocked fish is carried out by a separate unit of the FGFRI. Parr are fin-clipped to identify hatchery releases. Surplus parr are released into the Pyhäjoki, a salmon-less river discharging directly into the Bay of Bothnia about 200km south of the mouth of Tornionjoki.

1000 Carlin-tagged smolts are released directly to the river through a pipe from a road tanker after the ice has cleared in June, at each of 4 sites about 80km apart, the highest at a point about 400km upriver from the mouth. There is no knowledge of how rapidly migration occurs, but it is assumed to be immediate and that the smolts leave the river in only a few days.

Broodfish are reared on from hatchery production in deep tanks in a second hall, and kept for two years until June under a Baltic Sea light regime (equivalent to 58°N, the latitude of Gotland where it is supposed that they would have been feeding and undergoing the early stages of maturation if they had been free to migrate), and then are switched back to natural Tornionjoki lighting for completion of maturation. All stock ripen within 2 weeks, and all stripping is completed in two egg-takes.

Comments and suggestions: From the appearance of the hatchery and of the fish, I would have expected that these targets could be reached with fewer eggs - probably 1 million from Taivalkoski should be sufficient to augment the 200,000 fertilised on site at Tornionjoki to produce a total of 600,000 fish for release. This would permit the reduction of holding densities in the rearing tanks, an increase in survival rate and the production of an even better end product for release.

I applaud the care taken to watch that the fish are transferring safely from yolk-dependence to external feeding. It should be possible to make this transfer without loss in a hatchery, and I suspect that mortality at this time in Tornionjoki is very slight. In the fry rearing tanks I suggest that simple underwater covers could be provided under which fish can hide, to foster sheltering responses and retain predator avoidance behaviour. It would be necessary to test the efficacy of such covers, by marking differentially the products released from tanks with and without cover, and comparing the return rates from captures in the fishery and from the river.

The fish are not monitored regularly, and so it is difficult to gauge how they are performing. The manager had no knowledge of the ultimate success of his fish after release, and was not aware if any analysis had been made of the returns of marked fish. So there was no information on the relative success of stocking of parr and smolts, or of returns of parr and smolts released from separate locations, and no evidence that the assumption that all the fish would be able to reach the sea in the year of release. I understand that such analytical work is not the responsibility of the hatchery staff, but in view of the discussion of the importance of release place and timing given in the General Introduction, I assume that all this expensive rearing and release programme is being monitored and analysed appropriately. If it is not, then this should be done as a matter or urgency. Also, it seems important for the morale of the hatchery workers that they should be kept informed of the fate of the fishes that they release.

Muonio

The purpose of the Muonio hatchery is to replace the loss of natural production of brown trout and Arctic charr which has resulted from overfishing in the Muonio river drainage, which feeds into the Tornionjoki.

Production targets for trout are set at: 300,000 1+ (7-8cm) and 10,000 2 (14-18 cm), plus 80,000 1st summer fish produced in heated water for Pyhäjoki. In addition there will be 272,000 0+ Tornionjoki sea trout releases into 13 streams: 4,000 1+ into Pakajoki; and 700,000 unfed fry releases from Taivalkoski into 5 upstream tributaries. The production is limited because of restrictions on the amount of phosphorus that may be discharged from the station.

To produce these fishes, two broodstocks are held at Muonio: one from near the mouth of Tornionjoki; 1 from local streams; and 1 from small streams to the north (headwaters). There is also some headwater brood material kept at the Taivalkoski hatchery, from which 300,000 eggs are sent up for rearing at Muonio. There is a proposal to set up further brood lines at Muonio based on this material.

Genetic management is by pairing 1 female x 3 males (although the sex ratio was 1:1, so it was not clear why the pairing was not also 1:1), with no conscious selection.

Eggs (7000.l^{-1}) from Muonio broodfish (0.8 - 1.3. millions at the eyed stage: 1.3 millions in 1998) are incubated in EWOS style incubation trays, which have given problems with their elongated meshes, as hatching alevins may become trapped. This should be solved by going over to using smaller circular mesh in the trays, as practised elswhere. About 200,000 eggs are reared on heated water (May-June), for release as 0+ in summer. Survival to hatching was 70% (slatted trough problems); the manager was happy with the system but tconcerned about water supply restrictions. Additional trout are released either as eggs or as unfed fry into the tributaries.

In the production hall the fry and parr are reared in a range of round and square tanks, but the manager prefers the round ones as they are easier to clean. There is no natural daylight in this hall, and the artificial light regime in winter (1 October – 15 May) is 0700-1600. Automatic feeders operate from 0730-1530 from Monday-Friday. In summertime (16 May – 30 September) the lights are on from 0500 - 2200 and the automatic feeders from 0530 – 2130 daily. 60% of the daily food ration is given in the morning: 20% at about noon; and 20% in the afternoon. This regime is used to make it easier to clean the tanks in the afternoon. In the winter there is some food restriction (but the precise schedule and rationale were not very clear) which leads to cannibalism: evidently these fish are having a bad time. The stocking density is set at 1200.m^{-2}. The fish are monitored twice per year, in September, and in May just before release. This production regime seems to me a clear example of a technique designed for the convenience of the human operator rather than to meet the biological needs of the fish.

In the building which is used for the maintenance of the supplementary lines of brood fishes, large circular tanks have two inflows, one with a vertical sparge arrangement which should allow the maintenance of a moderate flow around the tank by jetting water through the sparge outlets, and the other directed across the floor towards the central drain to clear debris and faeces. For these tanks there is no natural daylight in winter, and there is a low intensity of artificial light during the working day .

Released fish are finclipped, which distinguishes them from wild fish, but does not distinguish the stocks, or ages at release: so recaptures cannot be allocated to rearing regimes or stocks. 2+ fish are released at 2,000-5,000 per site; 0+ and parr are released at 10/100m^{-2}. There is some planting of eyed eggs.

The manager claimed that there was no effect on the developmental timing of the broodfish under this light regime, and there was no need to induce ovulation. Few females failed to spawn, spawning was completed in two weeks, and fertilisation rates were high.

Comments and suggestions: Of the 1.3 million eggs more than 50% are surplus to rearing needs and are released as unfed fry in the 3 respective stock regions with no further monitoring. With no monitoring, there is no measure of the value or otherwise of this practice, so why hold the eggs in the first place? As at Tornionjoki, efficiency could be improved by holding less material, especially as parallel genetic material is kept at Taivalkoski.

The use of fixed artificial light schedules, no light at weekends, and no exposure to artificial light makes the holding regime at this station of very questionable value. The buildings need windows at the very least, and thought should be given to the feeding schedules, especially in the winter, when the existence of cannibalism should be ringing alarm bells for the managers. I suggest that success would be greater if there was a general change of approach to rearing here, consciously putting the needs of the fishes before those of the producers.

Some 4+ fishes of the headwaters stock are sold to private groups for stocking, but there is no control over where these fishes go. This practice runs counter to the declared objectives of careful genetic stock management. Some of these sales are to groups in Sweden, a practice which contributies to potential genetic pollution.

If there are really no assessments of the success of the stockings from this hatchery, they should be instituted as part of the programme as soon as possible. If monitoring of the Muonio stockings does exist, then the data should be analysed as a matter of urgency to establish the efficacy or otherwise of the rearing and release methods here.

There were also some salmon parr and broodfish here from the Tornionjoki hatchery - why?

Four lake stocks of Arctic charr were brought in from the wild in 1992, and have been held here ever since as a broodfish group for production of fry for supplementation and for sale for stocking. So far they have failed to spawn although a few have matured (1 litre of eggs was reared to free swimming fry in 1997, but no buyer was found), and so have not been used for anything. None have grown. As these charr are taking up space and using precious water, and not being used, they ought to be harvested.

Inari

The Inari station is a very impressive place, with some fine new rearing facilities. Its objectives are to produce fishes for local stock maintenance, principally in the large oligotrophic and regulated Inarijärvi (1,100 km^2) which is used as a storage reservoir for several power stations downstream in Russia and Norway.

All broodstock here originate locally, except for the landlocked Saimaa salmon (a Baltic *Salmo salar* derivative), and lake charr *Salvelinus namaycush.*

In the large new rearing hall there is some external light, so that the fish should get seasonal signals. Some windows are closed off, to prevent external street lights from influencing light schedules: are these street lights really necessary? Putting the fishes needs before those of the producers, would it not be better to give the fish more exposure to natural light rhythms over a greater intensity range, and forego the questionable need for street lighting? If such natural light is still insufficient for the fish to see to feed efficiently in the tanks, supplementary artificial light could be provided during the natural photophase.

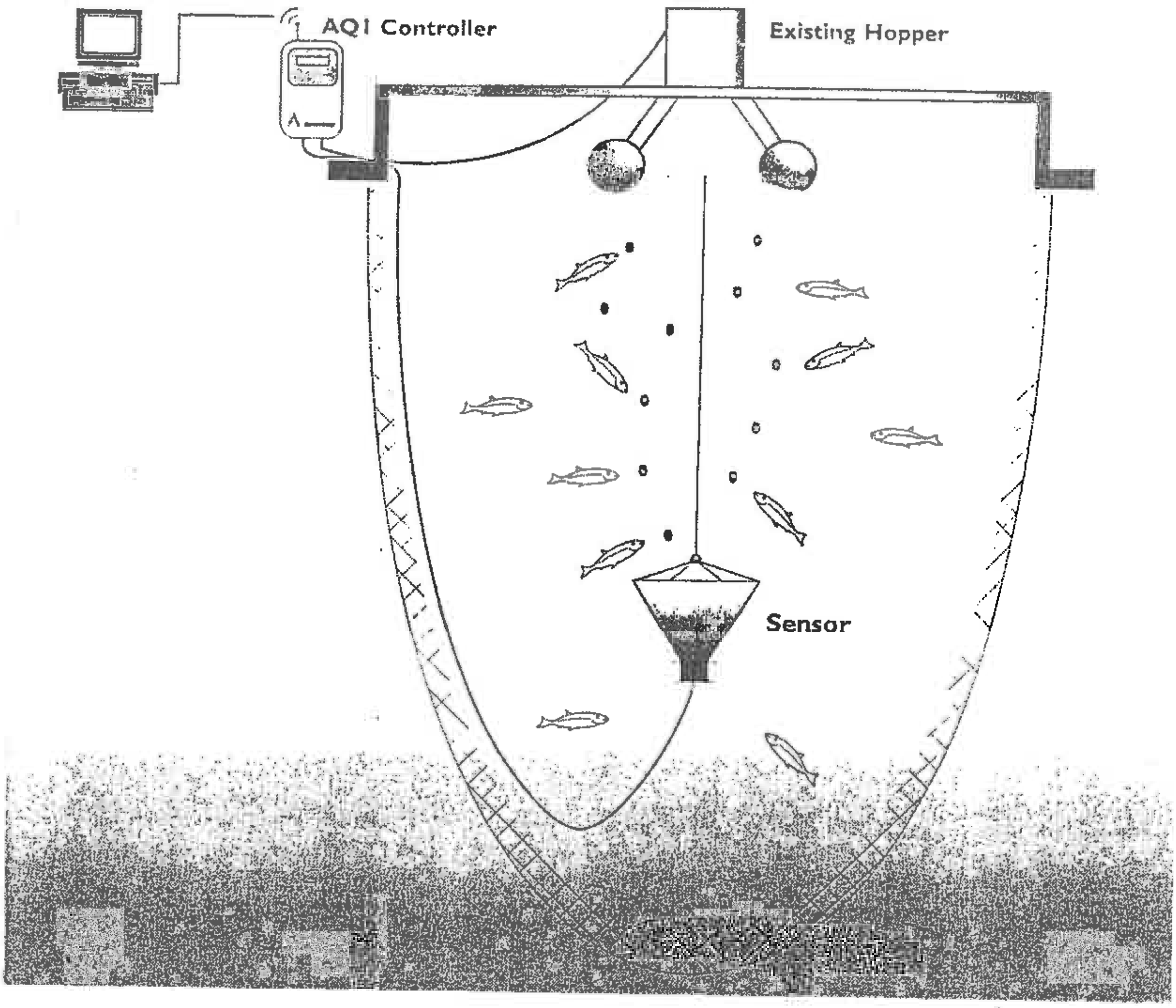
All production is stocked into the lake, except for some trout into their rivers of stock origin. In the lake the stockings are spread out to ensure fish will be available for fishing over wide areas. This includes trout which are derived from the different tributary river stocks. There seems to be an anomaly here: the stocks are managed carefully to conserve the genetic distinctions between the separate river components, but then releasing hatchery-reared material directly into the lake away from the appropriate rivers runs the risk of obscuring these genetic distinctions, since these fishes will not have appropriate homing behaviour when they mature. It is not known to what extent these maturing fish move to spawn in the wrong rivers, but the opportunity must be there. River releases are made from mid-April to May, with fry in the upper parts, parr in the middle and "smolts" (by definition fish >14cm in length) in the lower regions. Stocking into the lake occurs in mid-May to June.

During a short seminar at Inari there was discussion of feeding schedules for the fish during rearing in the station. Most manufacturers of fish foods provide a recommended feeding schedule which is based primarily on two variables - size of fish, and temperature. However, the fish feed to meet their energy needs, and so feed when they are hungry. Hunger is controlled hormonally by an endogenous appetite rhythm, and this does not correspond precisely with the characteristics of fish size and water temperature. So, ideally, feed schedules should operate so that the fish are fed only when they want to feed. For this, knowledge of the fishes innate feeding rhythms are needed. A few years ago a group in the Atlantic salmon farming industry in Tasmania established a detailed record of such feeding rhythms for their fish over a complete annual cycle. This was done by measuring the voluntary food intake of salmon in a sea cage throughout 24-hour periods, and the data are presented here summarised as percentage of the daily ration eaten in each 15-minute interval of the day, over 10-day periods, throughout a year (Figure 1). These data show that feeding was concentrated into the daytime; that it was not uniform throughout that lighted period; and that there tended to be relatively heavy spells of feeding in the morning and evening. Such a complex pattern is difficult to imitate with present feeder control systems. However, the Australians have devised a very simple and very effective feeder, the so-called Aquasmart system, which works as follows. A schedule approximating the fishes probable needs is set up, and when a feeder switches on, food scattered on the surface of the cage attracts the fish upwards to feed (Figure 2). While the fish are hungry all the particles are eaten, and little or nothing falls through the mass of fish to go to waste. As soon as the fish begin to be satisfied, then particles begin to fall below the mass of fish. By fitting a sensor ring in the bottom of a cone-shaped sampler suspended in the cage below the fish, the arrival of food pellets is recorded, and the feeder can be switched off automatically. The operation of the feeder is monitored by radio to a control base, and these data allow the feed schedule to be adjusted iteratively according to the information that the fish are providing all the time about their feeding needs. Such systems are now in commercial production, and have improved the efficiency of salmon culture so much that production has risen by about 10% compared to more conventional systems, and environmental contamination by waste food has been reduced substantially. This system has been used now for several other kinds of fishes reared in cages, with very different types of feeding behaviour, such as yellow tail in Japan, and sea bass in the Mediterranean. Modifications for use in tanks are being explored at present, including sensors set horizontally in tanks with high water circulation, and in the drain outlet of others. The seminar group discussed these ideas at length, and I suggested that serious consideration should be given to applying this simple principle to the feeding of the various species being reared here. Besides providing valuable background information on the appetite patterns of these fish, and ensuring that they get the appropriate amount of food at the right time, the method also has the potential of acting as an early warning system of change among the fish in the population. Loss of appetite may indicate sickness or physiological change, as both smolting and sexual maturation involve periods of anorexia. So differences from expectation in the pattern of feeding are signals to the manager to look carefully at what is happening to his fish. Such a system is not a substitute for the careful watchfulness of the manager, but it can be a sensitive aid to his good practice. There is an additional bonus: a feeder which switches off when the fish are not feeding is one which minimises the amount of waste food in the effluent from the tank, and so reduces the environmental impact of the farm.

The production programme and plantings from Inari are carried out in a joint programme with a second rearing unit at Sarmijärvi. It is therefore convenient to consider these two farms together.

Figure 1

Schematic Diagram of Aquasmart Adaptive Fish Feeding System



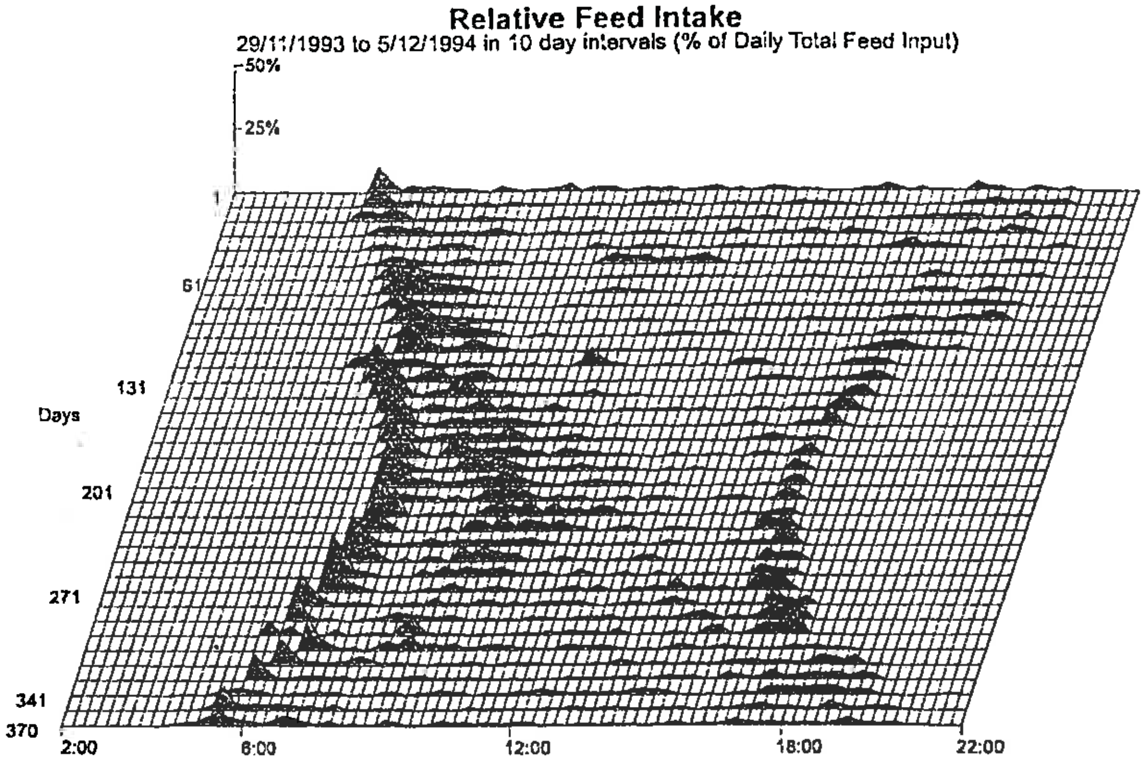


Figure 2. The relative feed intake of Atlantic salmon (500-6400gms) in Tasmania, Australia, expressed as a percentage of total grouped (10 day intervals) daily intake. Note: uncorrected for daylight saving.

Sarmijärvi

The objectives of this station are the same as those of Inari. The broodstock here are kept in large earth ponds, protected from bird predation by extensive netting. Some of the broodfish are very old, reaching 21 years among the lake charr ***Salvelinus namaycush***, which have been used for up to 15 successive spawnings. The eggs from these fish tend to become larger with the age of the female. The other species are not so old, and the broodlines have been renewed every so often from local material. Among the brown trout broodfish male mortality is much higher than female, so that sex ratios become biassed towards females with age: could this problem be alleviated by using frozen sperm for trout? Differential mortality is not a problem in the other species here. There have been attempts to use all recognisable local stocks.

The water supply for the hatchery is drawn from Sarmijärvi, which is slightly warmer than other local supplies, remaining just above 1°C during the 6 winter months. This has both advantages and disadvantages. It permits earlier hatching, but it also means that the fry are ready to feed before the temperature in the wild has reached 1°C.

The eggs are incubated in deep containers, with the water upwelling through the egg mass. Survival of eggs to hatching is 80-90%. Although there were EWOS type incubators there, they were not in use. It seems that practices here have not changed for many years, but as they have been successful, they have been maintained. However, success, as everywhere else that I have seen, is measured in terms of meeting hatchery production goals, and perhaps these goals could be met even more efficiently if alternative methods were compared in tests within the hatchery. For example, salmonid eggs incubate in the wild in undisturbed conditions in the dark. Such conditions are imitated better in a covered EWOS tray than within a continuously moving mass of eggs in a deep incubator. Maybe the differences in survival under the two systems would be small, but this ought to be evaluated.

Survival to first feeding at present is variable, and occasionally very low, for no clear reason. The alevins are hatched from trays floated in c.3x3m parr tanks, and allowed to develop lying free (no support substrate) and uncovered under generally low level artificial light from 0500-2300 in addition to low external natural light in the tanks where they will rear to the parr stage. This light regime is more appropriate to parr rearing than to alevins, which naturally would be in darkness before emerging to feed. Feed is offerred to these alevins well before their yolk-sac is absorbed: the first particles to be fed are very fine, but much of this food was lying on tank floor. Feeding is by automatic feeder, and the feed schedules are supplemented by hand feeding on subjective visual assessment. The water flows are low, giving rather poor circulation. There are no covers over or in the tanks. Stocking densities are adjusted subjectively. Fry and parr are reared in these tanks until 1+, receiving seasonal light signals, and are transferred to outside earth ponds or released (***S.namaycush*** grow faster, and are transferred out as 0+ in late summer).

I suggest that if the EWOS incubators were used, alevin rearing could continue in these incubators under covers until first feeding, and that losses would be reduced accordingly. Then at transfer to the rearing tanks underwater covers would provide shelter for the fry, from which they would move to intercept food particles travelling on the current. To improve the current flow in these tanks I suggest using a vertical sparge inflow pipe, like those at Muonio, to allow the water to be jetted into the tank at several levels, and so maintain a greater circulating momentum in the water mass without needing a greater volume inflow. It might also be useful to test feeders which scatter food widely across the water surface, in comparison with the present system where the feed drops in at one point below the feeder.

At the end of the growing season, 120 individuals are measured and weighed. From time to time 120 are monitored to check that they are receiving the correct food particle sizes. The reason for using 120 as a sample size is traditional rather than statistically determined. It is notoriously difficult to sample randomly from a fish tank, so if comparative tests of rearing methods are made, then statistical advice should be sought as to how best to sample these populations representatively. In particular it is necessary to test whether the weights and lengths are normally distributed, before optimal sample sizes can be determined.

In the large outside ponds feeding is entirely by hand. These ponds are all covered with bird nets, as there is some trouble from gulls and goosanders.

Production is too high for present needs, and there is no demand for fish for sale. It does not seem necessary to produce this excess at Sarmijärvi as an insurance for the Inari hatchery at present, and the manager would prefer to hold less material, as there is insufficient water when the temperatures are high in summer. The station is permitted to take 500l.s^{-1}, but there are only 400l.s^{-1} available at maximum.

Unmarked fish are released in spring into the lake as well as into the tributaries, so, as at Inari, there is no guarantee of the ultimate maintenance of genetic discreteness of stocks. Those released into the lake reach it directly from a boat, after road transport to a suitable point. There is no information on the impact of the planting programme, or on whether stocking goals are being met. If there is an evaluation programme, knowledge of its results is not reaching the hatcheries. Marking of fish is essential, if the impacts of the programmes are to be understood properly. Maybe this has been done in a general way in the past, but each new change in hatchery practice needs to be tested through a marking programme on the releases ensuing from it. The district manager is aware of this, but is also aware of the cost implications, and of the public relations and information collection problems. Nevertheless, there is a large investment here, and I think the issue should be debated.

A nice station: enthusiastic people: but needs some careful small scale experiments to test the real efficacy of the traditional techniques being used.

Taivalkoski

Taivalkoski is a very large station incorporating the major broodstock holding facility for Finland (carrying 30 strains of 13 species, including salmon, trout, whitefish spp., grayling, charr, lake charr and brook charr), and a small unit of the large mammalian predator group from the Game Division.

The station has its own dam on a local stream, from which two intakes deliver about 600l.s^{-1} of slightly peaty water to three large rearing halls and hatchery buildings, and a quarantine unit through which any material enters the station from outside, and all whitefish roe and fry for sale are routed. There is a 60l.s^{-1} additional supply of ground water, running at a constant 3°C in winter, and slightly cooler than the main supply in summer.

The broodfish halls contain a set of very nice, easily managed, 8m diameter steel tanks, 1.5m deep, with two water inlets (as at Muonio), one with a vertical sparge and the other with a single horizontal outlet. The lighting is natural, through large clear-pannelled doors at each end and low windows along the sides, bright, but supplemented with some artifical light which may help with feeding, which is supplied from an overhead robot feeder, which the manager does not like. This robot feeds the fish in each tank twice daily in winter and up to 5 times daily in summer. Robot feeding implies that only one tank in the line can be fed at any one moment, and so the timing of daily feeding schedules must differ between tanks. Also the robot feeder drops its food at one point, and does not scatter it over the water surface. There are also 8 9m-diameter Swedish style concrete outdoor ponds.

The active and responsive salmon broodfish (Tornionjoki, Iijoki, and Simokoki) are all kept together in one building, with spawning carried out in successive years on fish from 5-10 years old. Mortality of males is high, and few survive beyond age 7. While the sex ratio starts at 1:1, it is about 3:5 when using older females. In the conservation programme, pairings are made as 1M:1F, and progeny numbers are reduced to a standard 40 individuals at the eyed egg stage. The surplus egg take is sold to a power company for compensation stocking. 2000 broodfish are held for the Tornionjoki hatchery, and eggs are supplied there each year (see comments above on Tornionjoki). A new genetically based broodfish programme includes the PIT-tagging of individuals at age 1. The broodstocks are renewed continuously from feral broodfish caught in the rivermouths of the Simo and Tornio, the only so called natural Baltic stocks in Finland. The renewal is made according to the method described in the paper by Piironen, Eskelinen & Soivio, attached as an appendix to this report.

A salmon stock is held for the Iijoki also: 2000 individuals which are the 4th generation from a founding population of 500 from near the river mouth in the 1970s. However, the pairings from this founding population were not made by modern genetic standards, so the real effective population size consisted of probably many fewer than 500. Present genetic diversity (judged by average heterozygosity) is better than that of many Swedish maintained populations, but is not as high as that of the partially natural Tornionjoki stock. It is intended to make routine genetic sampling of this and other conservation stocks, but this is not in train yet. This Iijoki stock is being used also to rehabilitate the Kiimingijoki population, lost some time ago. This is being done successfully by releasing smolts, and encouraging the return of these fish to the 'new' river. Similarly, the Tornionjoki stock is being used to rehabilitate the Pyhäjoki, south of Oulu. In 1997, more than 100,000 smolts and parr were released there, as part of the Salmon Action Plan for the Baltic Region.

Eyed egg and fry planting is not very effective (tested on a local river). 1-summer-old and 1-yr-old releases gave better results: 5 1-yr old parr produced 1 smolt on the Kiiminkijoki; 10 1-yr-old parr gave 1 smolt on the Tornionjoki. These results were achieved by fin-clipping and electrofishing or trapping on these rivers. What was the adult return rate of these smolts, compared with that of hatchery-reared fish released as smolts? If this has not been estimated, it should be, in order to assess the relative efficiency of these rearing and release practices.

In the second hall, Taivalkoski carries several major stocks of brown trout, including the Iijoki stock, founded in the early 1970s from about 350 individuals, but as with the salmon, the N_e was probably <<350.

In the third hall were the *Salvelinus* and *Coregonus* spp. Brook charr have been difficult to synchronise at spawning, and have produced poor eggs. In discussion with the manager it was concluded that poor reproduction was probably because the fish were not getting enough to eat in the summer months when they would be laying down energy stores prior to ripening. I suggested that some supplementary hand feeding be tried there this summer. In the earlier days hand fed brook charr in outdoor ponds had reproduced successfully. Also in this hall were the disinfection unit, where egg material is dosed with iodine before package for transport out of the site: and the hatchery and fry/parr rearing tanks. Eggs are incubated in covered EWOS trays, where the alevins incubate after hatching. First feeders are transferred to small tanks with individual feeders, but the fish look as if the feed schedule may have been rather inadequate during the first summer. 2+ fish looked better, and one tank of sea trout were showing a beautiful tail-first downstream wheeling motion in their tank.

All these conservation stocks are sampled for quality control (genetic status, health, smolt status, etc).

As at Inari and Sarmijärvi, we had a long discussion about the need to allow the fish to determine when and how much they should be fed, and talked over the Tasmanian salmon data and the Aquasmart feeding system. We considered this in the context of all the fish species and age groups, and there seemed to be real interest in following up on the idea.

We also discussed the fertilisation failures (not just the brook charr, but also a major 50% failure among salmon last year). We recommended that they take things more slowly, and fertilise each batch of eggs with milt stripped directly from one male, even if this takes much longer.

The overall manager of this station has responsibility also for other stations in his region. At Kuusamo, there is a smaller unit whose job is to look after 4 trout stocks from this area. 3 of these spawn within Finland but migrate to grow in large lakes in Russia, where exploitation is light at present, but where there is a risk of heavy exploitation in future. The 4th stock is interesting in that it spawns downstream of a Finnish lake, where it rears. This stock is held in Taivalkoski also. Cooperation with the Russians at the same latitudes has shown that the fish stocks on the Russian side are still in good shape.

At Lautiosaari, on the coast near the head of the Bay of Bothnia, material collected from the wild is quarantined before eyed eggs are transferred to Taivalkoski. Here they are kept in the quarantine unit until they are 1 yr old, and then transferred to the normal rearing halls. Smolts are trapped at Lautiosaari also, and held until maturity, to provide more eggs for the Tornionjoki stock.

At Simo (coastal) 20,000 salmon smolts and 100,000 parr are produced annually, and smolts from Kainuu are released there also. The number of parr reared is determined as a compromise between the available rearing habitat and the available production facilities. Smolt numbers are also a compromise between numbers needed and production facilities available. M74 is still as bad as ever, but the open Baltic fishery has been restricted lately, allowing a larger number of adults to return to the rivers. These restrictions do not help trout, which remain coastal, and which are taken as by-catch in the whitefish fisheries (as in many lakes). This looks like a major limitation on the efficacy of these stocking programmes, since there seem to be difficulties in regulating the mesh sizes of nets to ensure management practices which reduce the exploitation of under-sized trout and of salmon smolts.

While genetic management is a major activity of the Taivalkoski station, sperm banks are not held here, but are maintained elsewhere in FGFRI.

Kainuu

In conjunction with Taivalkoski, the Kainuu station is involved with the release of Iijoki stock salmon smolts into the Kiimingijoki for the rehabilitation of that stock. This is a relatively new programme with the recovery of the first tagged fished at the river mouth in 1997. The return rates are similar to those at the Simojoki (a mixture of hatchery and wild stock), but really the comparison ought to be with Iijoki fish returning to the Iijoki estuary, if there is to be any meaningful comparative assessment of the efficacy of the programme.

The station is concerned also with the maintenance of fish stocks in the Oulujoki drainage. As noted at Taivalkoski, everyone seems to want to use small mesh nets in all the waters of Finland, with the consequence that stocked fish of all kinds get fished out very rapidly after planting. Brown trout are affected badly by this in the Oulujoki drainage. There is a need to change the fishing regulations to larger mesh sizes if there is to be any long term improvement in the fish stocks.

The rearing pratice for trout is as follows: 1-5 females are stripped into a basin, and then these eggs are fertilised by stripping 1-3 males directly into that basin (not into a tube for use of sperm later, as at Taivalkoski). It is the station manager's intention to move toward single individual parent pairings (1:1 sex ratio) in future. Some of the eggs are accelerated on warmed water at 5-6°C to eye in February, and then the temperature is raised gradually to 10°C during later incubation so that the fry feed first in mid-April and can be transferred on to unheated water when the natural water temperature reaches this level. (The incubation water can be heated to 12°C).

In the rearing hall there was no opportunity for external light signals to reach the fish. There was a need to open the blinds on the doors. As at Sarmijärvi, the circulation in the tanks could be improved by using sparge pipes on the inflows. There is evidence of stress when fish are transferred from the rearing halls to the outdoor ponds (at 15°C). This will probably be lessened after the blinds are opened on the doors of the rearing halls, so that the fish rear in light at a slightly higher intensity, as well as gaining appropriate seasonal light signals. I suggested that underwater covers might be introduced into the outdoor ponds to allow fish to hide - giving 2 advantages: reduced light intensity, and encouragement of predator avoidance behaviour, desirable for when they are released.

There were several factors here which might be influencing production, and so I suggested that any changes in practice would need to be evaluated by multivariate experiments with a considerable cost increase in research expenditure, as these experiments would have to be on a sufficiently large scale to obtain enough data from recaptured fish for statistical adequacy.

As at the other stations we discussed the need to understand the inherent appetite rhythm of the fishes, and I introduced the principle of the Aquasmart feeder. There was much discussion of this, with general approval of the idea, but some scepticism. There was the problem of stress, and reduced feeding, but I pointed out that the Aquasmart system was able to act as a stress indicator too. There were questions about whether such feed schedules could be operated with ITUMIC feeders. They should be operable with any type of feeder, but the precise schedule would depend on the information that came back from the fish, and the schedules would have to be modified iteratively.

In contrast to the other stations, this unit has a research programme, using computer models to predict the consequences of physical change in river systems on the fish. The reason for this work is the need to rehabilitate rivers damaged over a long period by channelling and scouring through use for timber floating, which has now ceased (all timber is carried by road or rail now). Some of this work is carried out in experimental flumes, whose physical configuration can be changed to mimic different shapes of flow channel, and different degrees of shelter. There is a proposal to instal more behaviour flumes, and I encouraged the researchers to visit the University of Glasgow's field station at Rowardennan, Scotland, to see the experimental flume there before they finalise their plans. (The Rowardennan flume is supported at c.1.5m above ground level and is made of perspex, so that the observers can record fish responses to environmental changes at the level of the fish, rather than only from above, as in the present flumes at Kainuu.)

Also, there have been stocking experiments in lakes with whitefish, trout and Saimaa salmon. These have included assessments of interactions between fishes in lakes, again using computer modelling. There are data sets since 1973. There have been changes in exploitation pressure as a consequence of increased trawling for vendace, which are a forage fish for trout. As a consequence of the work here, there is a proposal to introduce pike-perch as an alternative predator species to trout, to eat smelt rather than vendace. Pike-perch have been stocked as fingerlings at 100,000 - 300,000 per year into Oulujärvi. There have been marking problems for distinguishing the stocked from the natural production: the favoured method has been mass marking with fluorescent pigment, but mortalities have been quite high. The best effective

treatment gave 90% survival. I suggested that they might consider tetracycline otolith markers as an alternative.

Incubation of pike-perch is in fry tanks. First feeding would be better if its frequency was increased and ration decreased, and it would be improved if the flow pattern was changed to distribute the food better. There were problems with feeding at a slightly later stage: salmon food had been tried, but many individuals did not feed, and then became prey themselves for their larger brethren. Pike-perch did not like the texture of the pellets, but preferred fresh smelt (not frozen). I suggested that they when they had estimated the likely annual quantity of feed that would be needed, they should take their problem to a food manufacturer, and get the manufacturer to make up special batches of food of differing texture, shape, colour and pellet size for experimental testing. From conversations later at Jyväskylä, I understand that such collaboration may be possible with VTT Helsinki.

Some PIT-tagging of adult pike-perch (mean weight 640g) was carried out in September 1996, at 8°C, but mortalities were high in December-January. It is not known why. Was this a handling problem? It is very important that this should be resolved, as every hatchery is equipped with PIT-tags and sophisticated detection boards form which measurements of individually recognisable fish can be transferred directly into a computer. The PIT-tags are to be used in the pike-perch broodstock programme, and also in the behavioural experiments planned for the experimental flumes (see below). The tags have been injected into the body-cavity: Antti Soivio suggested that they should be injected into the muscle just below the dorsal fin.

4. GENERAL COMMENTS

The structure of the administration in FGFRI and its place within the Ministry of Agriculture was explained to me at Taivalkoski. Aquaculture production and aquaculture research are governed by the Ministry of Agriculture. So, for example, the genetics researchers are answerable to a head office director and not in direct contact with the producers who need their services directly, which seems too far from the user groups. It seems that there is a communication problem here.

I was very impressed with the conscientious way in which all the rearing facilities were managed, and with the very good appearance of the fishes there. It is clear that the managers take pride in meeting their production targets. However, it did seem unfortunate that the people who had the responsibility for producing the fishes did not seem to know how well their products were contributing to the overall goals of the programme. I understood from several of them that the monitoring of performance after release was the reponsibility of another branch of FGFRI, but that they did not hear about the success of their fish in the wild.

It seems that the producers in the hatcheries are not incorporated into the general planning and decision making processes. It would seem desirable that when a management programme is planned, all levels in the process from policy makers to researchers and fish husbandrymen should take part in the discussion, so that all levels of expertise are tapped at once, and all the players are fully aware of what will be done, how, and why. Thereafter, the present communication problems might be overcome by the appointment of a professional communicator within FGFRI - perhaps a competent technical journalist, developing an in-house newsletter - to act as an efficient channel of communication between the producers and the researchers?

I sense that there is another problem: the emphasis within conservation here is on genetics - which is excellent - but, except at Kainuu, there is little mention of the complementary component of habitat conservation. For fishes which are being released to the wild, with the opportunity to reproduce there, it is important to ensure sufficient diversity of habitat to permit the retention of genetic diversity within the wild stock. Apparently this deficiency is because habitat conservation is the responsibility of the Ministry of the Environment, and maybe there should be stronger liaison between the ministries on conservation problems.

Also there was concern that the emphasis within the Ministry of Agriculture was too much on economics and not enough on biology: targets are set with economic objectives, and not with biological requirements sufficiently clearly in mind.

There is no individual marking of broodfish, although the stations have supplies of PIT tags, and their use is planned. These should be brought into use as soon as possible, as otherwise there is no record of which individuals have been paired together in any one year. Care is taken at Taivalkoski to retain 40 individuals from each pairing for ongrowing as future broodfish: but without marking either the parents or the progeny, pedigrees are unknown, the performance of the progeny of known parents is unknown, and future genetic conservation is compromised.

At each of these hatcheries I have commented on the lack of use of appetite information from the fish in designing feeding schedules, and have explained the rationale behind the Aquasmart techniques. It is the principle of these techniques that is important, and while I must emphasise that I have no personal financial interest in the Aquasmart company, I do recommend that their European technical staff be consulted over the development of appropriate feed control systems in the Lappland hatcheries.

Getting the practice of light control right in the rearing regimes is particularly important in relation to making successful releases of fish into the rivers. For example, wild salmon smolts migrate out of the mouth of the Tornionjoki into the Bay of Bothnia in late May and early June when the water temperature there is c.10°C. These timing and temperature conditions are used as indicators of when to release reared smolts into the Tornionjoki, and winter rearing schedules have been geared to them. Since fish in the wild are assumed to have little or no exposure to light while under the ice, the hatchery smolts are reared in total darkness during the winter to slow down the smolting changes.

While this practice might be appropriate for the particular group of smolts that is released at the river mouth, it is unlikely to be so for the majority on the Tornionjoki, which are released as groups at several different places up to 300km upriver from the mouth. It is not known how long it takes for wild smolts on the Tornionjoki to reach the sea. Elsewhere in the world it would take them several weeks to cover such a distance, starting with short nightly displacements of only 1-200m. On this evidence, 14cm smolting salmon released at Muonio, say, should enter the river no later than mid-April, and probably much earlier, if they are to reach the mouth by the end of May.

These fish would have to be released under the ice at temperatures close to 0°C. It would be unwise to slow down their development during the winter prior to release.

There is another problem implicit here. Developmental timing of salmon is finely adjusted genetically to the habitat in which the fish are developing. Since the precise origin in the Tornionjoki of the individual broodfish at the hatcheries is not known, the expected migratory timing of their progeny is also not known. For those whose parents carried gene combinations appropriate to habitats near the river mouth, smolting changes would be expected to occur relatively late in the spring. So for these also, it would be unwise to slow down their development during the winter prior to release, since if released in June they would not be ready to move out.

Currently it is being assumed that the smolt migration is completed in the spring throughout the Tornionjoki. Has this been established? In several other systems it is known that juvenile salmon migrations begin in the autumn, these migrants eventually moving into the sea in spring as smolts. Could it be that in the rivers of northern Finland, where seasonal light signals throughout the winter may be obscured by ice and snow, that it is the autumn photoperiod cues that occur before the ice forms that are the important ones for juvenile migrants? Does the bulk of the downstream migration occur here in autumn, so that smolting fish are overwintering in the lower reaches of the river, close to the Bay of Bothnia? If so, upriver releases of juvenile fish should be made in autumn before the ice forms. Knowledge is needed of the actual movement patterns of salmonids throughout these rivers.

It will take time to obtain such information at the level of detail necessary to plan efficient release tactics. In the interim period, it would be wise to test the relative success of autumn releases (at all present release sites) against that of the current practice of releases at break-up of the ice. Such autumn releases would overcome the present lack of information on the nature of the light patterns experienced by the fish in the wild during the winter, and of the influence of these light patterns on the development towards smolting and migration.

It is particularly important that fish being released should be motivated to disperse away quickly from the release sites, to avoid the predators which learn to accumulate at regular release points at this time. The principal predators at the present release time in late May are pike *Esox lucius* and burbot *Lota lota*. These fish aggregate under the ice near the shoreline in winter and spring. So it would be wise to avoid shorelines as release sites, and choose instead mid-river locations. Provided that the salmon smolts to be released had active sheltering responses (as they should have if reared in tanks with underwater covers) earlier mid-winter releases under the ice in mid-river would provide protection from such predators. The precise timing of under-ice releases is not so critical as those of releases into open water, since the fish will be protected there until they are ready to move downstream. Similarly, care should be taken to determine the distribution of likely predators in the autumn, and the location of precise release sites chosen to minimise vulnerability of fish released at this time.

Similar arguments are applicable to the river releases of other species which migrate down-river in the spring, such as the trout moving into lakes, to secure their homing. So the rearing practices for overwintering trout also should be considered in relation to their release sites and times.

My general impression is of an ambitious production programme, run by dedicated and enthusiastic staff in very fine facitilies, which is achieving its defined targets well, but which still has a little room for tightening up its efficiency. Questions could be asked profitably about whether the level of biological insurance in the system is appropriate, and might not be reduced, so permitting the managers the opportunity to hold fewer fish, but achieve the same numerical targets with biologically better products. Within that framework, there are some relatively simple techniques which could be tested to establish whether the present successful production processes could be made even more successful.

5. SUMMARY OF RECOMMENDATIONS

General

1: Incorporate appetite rhythms into feeding regimes at all stations.

2: Compare scatter feeders with drip feeders wherever possible.

3: Monitor light intensity patterns throughout the year in wild fish habitats and in rearing tanks.

4: Determine the time of downstream migration of wild salmonids in different parts of the northern rivers.

5: Evaluate the relative success of release programmes.

6: Test the suitability of releases before the ice forms in autumn.

7: Test the suitability of under-ice releases.

8: Review mesh size regulations in the fisheries.

9: Include all levels of staff in management programme planning.

10: Appoint an in-house professional communicator.

Tornionjoki

1: Reduce egg holding to 1.2×10^6

2: Use underwater covers in tanks to provide shelter.

3: Test differential efficacy of releases of parr and smolts, and of smolts at different sites.

Muonio

1: Introduce natural lighting into the rearing halls.

2: Mark stocks differentially at release into appropriate tributaries.

3: Reduce egg holding.

4: Improve feeding schedules.

5: Restrict sales of stock to specific release localities to protect genetic integrity.

6: Test efficacy of stocking.

Inari

1: Cut off street lighting outside rearing hall.

2: Open blinds on windows.

3: Review lake stocking programme for trout, to protect genetic integrity.

Sarmijärvi

1: Test alternative incubation regime using covered EWOS incubators.

2: Test first-feeding of fry in EWOS troughs before transfer to parr tanks.

3: Test underwater covers in tanks.

4: Test sparge inflows to increase water velocity in parr tanks.

5: Seek statistical advice for sample sizes at monitoring.

6: Reduce total numbers of fish being reared.

7: Review lake stocking programme for trout, to protect genetic integrity.

Taivalkoski

1: Consider replacing robot feeders, to allow greater feeding flexibility.

2: Test supplementary hand-feeding of brook charr in summer.

3: Fertilise single egg batches with fresh milt from single males.

Kainuu

1: Compare return rates of Iijoki salmon to Kiimingijoki and Iijoki estuaries.

2: Open blinds on doors of parr rearing hall.

3: Test sparge flows to increase water velocity in parr tanks.

4: Test underwater covers in parr and 1+ tanks.

5: Test tetracycline marker for pike-perch.

6: Test increased frequency and decreased dose for first-feeding pike-perch.

7: In collaboration with a food manufacturer (or VTT Helsinki), test different types of pellets for pike-perch fry.

8: Evaluate reasons for PIT-tag failures in adult pike-perch.

9: Before building new flumes visit Glasgow University to see flume design there.

6. ACKNOWLEDGMENTS

I am most grateful to Prof. Antti Soivio for managing the logistics of these visits, and to Ari Savikko at Tornionjoki, Rainer Määttä at Muonio, Petri and Sirkka Heinimaa at Inari, Jaana Kauttu at Sarmijärvi, Pentti Pasanen and Vesa Määttä at Taivalkoski, and Pekka Hyvärinen and Risto Kannel at Kainuu for the time they gave to explain the details of their production objectives, facilities, fish, successes and problems. I thank Ari Huusko also, for explaining some of the environmental and behavioural research work being carried out at Kainuu in parallel with the production programme there. Rainer Määttä drove us from Muonio to Inari, and Sirkka Heinimaa shared the driving of her car with Antti Soivio over the remaining 1500km of the visits: I thank them for their expert care.

MUISTIO

Riista- ja kalatalouden tutkimuslaitoksen pohjoisten kalanviljelylaitosten viljelytoiminnan palauteseminaari

Aika ja paikka: 1.12.1998 Kemi
Läsnäolijat liitteessä

1. Kokouksen avaus.

Kai Westman avasi kokouksen ja kutsui seminaarin sihteeriksi Petri Heinimaan. Westman kertoi prof. J.E. Thorpelta (Glasgow:n yliopisto) tilatun arvioinnin taustoista ja tilaisuuden tavoitteista. Tarkoitus on, että jatkossa myös vesiviljelyn muitakin toimintoja arvioidaan vastaavalla tavalla ulkopuolisten asiantuntijoiden toimesta.

2. Käytiin lävitse prof. Thorpen esittämät suositukset kohdittain. Kunkin suosituksen osalta käytiin asiaa selventävä ja täydentävä keskustelu sekä arvioitiin mahdollisuuksia tutkia tai korjata toimintatapoja.
Ohessa esitetään suositukset (kursiivilla) yhteenvedon mukaisessa numerojärjestyksessä.

YLEISTÄ

1. *Otettava huomioon kalojen luonnollinen ruokailurytmi ruokinnassa ja ruokintajärjestelmien ohjelmoinnissa kaikissa laitoksissa.*

Esimerkkinä kalojen oman ruokahalun huomioon ottavista ruokintajärjestelmistä oli Aquasmart-järjestelmä, jota on kokeiltu Tasmaniassa lohikasseissa. Yleisenä ongelmana on ruokintajärjestelmien tunteettomuus kalojen ruokailuhalukkuudelle. Oikea ruokinta vaatii seurantaa emokalanviljelyssä ja poikastuotannossa (kalojen käyttäytymisen seuranta). Ruokintajärjestelmiä tulisi kehittää jäljittelemään eri lajien luontaista ruokailuaktiviteettia. Tervon kalanviljelylaitoksen ruokinta-automaatiossa otetaan huomioon ruokinnan hämäräpainotteisuus, samoin osassa RKTL:n poikaslaitoksia.

2. *Vertailtava levittävien ja pudottavien ruokinta-automaattien toimintaa kaikissa laitoksissa missä mahdollista.*

Ruokinnan tärkeyden vuoksi päätettiin asettaa vesiviljelynkehittämishanke, jossa arvioidaan laitosten ruokintalaitteiden ja järjestelmien käyttö sekä annetaan suosituksia ruokinnan ja ruokintaohjelmien kehittämiseksi. Tiedonkulkua kalanviljelylaitosten ja henkilöstön välillä tulee parantaa.

3. *Seurattava valon voimakkuuden muuttumista vuoden eri aikoina kalojen luonnollisilla elinalueilla ja viljelyaltaissa.*

Käynnistetään kehittämishanke valo-olosuhteiden selvittämiseksi (asioina mm. valaistus luonnossa ilmassa, lumen ja jään alla, viljelytiloissa, emokalojen ja poikasten viljelyssä ja työskentelyn vaikutus). Kootaan yleiset periaatteet kalojen ja valon välisestä suhteesta ja toimitetaan se kaikille laitoksille. Eri näkemyksiä valoon liittyen käsiteltiin vilkkaasti.

4. *Selvitettävä luonnon lohikalojen alasvaelluksen ajoittumista pohjoisten jokien eri osissa.*

5. *Arvioitava eri istutusohjelmien tuloksellisuus.*

6. *Selvitettävä syysistutusten tuloksellisuutta.*

7. *Selvitettävä jäänalusistusten tuloksellisuutta.*

8. *Tarkasteltava käytössä olevia verkkojen silmäkokosäädöksiä.*

Suositukset 4-8: Otetaan yhteys RKTL:n Kalantutkimuksen istutustutkimusohjelmaan kysymysten ottamiseksi huomioon tutkimushankkeissa.

9. *Otettava mukaan kaikki henkilöstötasot kalakantojen hoito- ja istutusohjelmien suunnitteluun.*

Parannetaan tiedottamista vesiviljelyn suunnittelemista istutustoimista. Pyritään parantamaan tiedon siirtymistä kalantutkimuksesta viljelyhenkilöstölle.

10. *Hankittava talon sisäinen ammattitiedottaja kalantutkimuksen ja vesiviljelyn yhdyshenkilöksi.*

RKTL:een on palkattu ammattitiedottaja. Parannetaan vesiviljelyn osalta laitoksen sisäistä tiedottamista. Tärkeätä olisi myös lisätä tutkimustulosten popularisointia.

Laitoskohtaiset suositukset:

TORNIONJOEN KALANVILJELYLAITOS

Todettiin arviointiraportissa voimakkaasti korostettu tarve kehittää palautteen saamista kalantutkimuksesta viljelylle.

1. *Vähennettävä haudottavaa mätimäärää 1,2 miljoonaan mätimunaan*

Toiminnan mitoitus on jo tällä tasolla.

2. *Käytettävä vedenalaisia varjoja altaissa tarjoamassa kaloille suojapaikkoja.*

Tornionjoen laitoksella on kokeiltu vedenalaisia varjoja, jotka toimivat hyvin pikkupoikasten suojapaikkoina häiriötilanteessa, mutta vaelluspoikasaltaissa suuren vedenkorkeuden vuoksi varjot eivät toimineet.

3. *Vertailtava joki- ja vaelluspoikasten istutusten ja eri paikkoihin tehtyjen istutusten tuloksellisuutta.*

Välitetään näkemys kalantutkimukselle otettavaksi huomioon tutkimushankkeissa.

MUONION KALANVILJELYLAITOS

1. *Päästettävä luonnonvaloa viljelytiloihin.*

Tehdään valokoehanke. Siirrytään valojaksossa eri kalakantojen paikalliseen luonnonvalorytmiin. Samaa asiaa yleissuosituksissa, kohta 3.

2. *Merkittävä eri sivujokien kalakannat erikseen istutuksia varten.*

Viljelyssä käytetty taimenkannat ovat paikallisia mutta istuttajia voidaan vain neuvoa sopivan kalakannan käyttöön eri istutuskohteissa. Pyritään vaikuttamaan kalatalousviranomaiseen neuvonnan ja tiedottamisen tehostamiseksi.

3. *Vähennettävä haudottavaa mätimäärää.*

Meritaimenen mätimäärä on ollut suuri koska poikasten syömäänopettamisessa on ongelmia. Näitä tullaan selvittämään yhteistyössä kalantutkimuksen kanssa.

4. *Parannettava ruokintatapaa.*

Kuormitussyistä laitoksen ruokintaa jouduttiin rajoittamaan vuosina 1997 ja alkuvuodesta 1998. Laitoksen kalastoa on vähennetty, jotta ruokinta voidaan järjestää tarkoituksenmukaisella tavalla. Todettiin, että lyhyet paastot voivat lisätä allaskohtaisesti poikasten kokojakaumaa.

5. *Rajoitettava istutuspoikasmyyntejä vain tiettyihin istutuspaikkoihin perinnöllisten ominaisuuksien suojelemiseksi.*

Istutuksissa käytetyt kalakannat ovat paikallisia mutta istuttajia voidaan vain neuvoa sopivan kannan käyttöön eri istutuskohteissa. Pyritään vaikuttamaan kalatalousviranomaiseen neuvonnan ja tiedottamisen tehostamiseksi.

6. *Tutkittava istutusten tuloksellisuutta.*

Välitetään tieto kalantutkimukselle. Nieriästä tehdään erillinen hankesuunnitelma.

INARIN KALANTUTKIMUS JA VESIVILJELY

1. *Sammutettava katuvalot viljelyhallien ympäriltä.*

On sammutettu.

2. *Avattava ikkunoiden valosuojat.*

Aloitetaan valokoe. Samaa asiaa yleissuosituksissa, kohta 3.

3. *Arvioitava uudelleen Inarijärven istutusohjelma erityisesti järvitaimenen osalta perinnöllisen monimuotoisuuden suojelemiseksi.*

Käynnissä on mikrosatelliittitutkimus, jossa selvitetään nykyisten emokalaparvien monimuotoisuus ja verrataan sitä luonnonkaloihin. Velvoiteistutuksissa istutetaan viimevuosia suurempi osuus järvitaimenen poikasista jokien alaosiin järven sijasta (kunkin joen omaa kantaa).

SARMIJÄRVEN KALANVILJELYLAITOS

1. *Testattava vaihtoehtoinen haudontatapa käyttäen peitettyjä EWOS-kaukaloita.*

Tehdään vertailu.

2. *Testattava poikasten syömäänopettamista EWOS-kaukaloissa ennen siirtoa altaisiin.*

Tehdään koejärjestely.

3. *Käytettävä vedenalaisia varjoja altaissa tarjoamassa kaloille suojapaikkoja.*

Selvitetään vuodenajat ja poikasten koko, missäpakoreaktio omaksutaan.

4. *Testattava tuloveden johtamisessa pystyputkea, jossa on useampia veden tuloaukkoja, parantamaan veden virtausnopeutta poikasaltaissa.*

Veden virtausnopeutta alkukasvatuksessa parannetaan.

5. *Hankittava tilastollista apua näytemäärien määrittämiseksi.*

Tarkistetaan onko laitoksen näytteenottokäytäntö mittaustyöryhmän ohjeiden mukainen.

6. *Vähennettävä viljeltävien kalojen kokonaismäärää.*

Kalastomääriä on jo vähennetty ja ne ovat nykyisin lähellä tarkoituksenmukaisia määriä.

7. *Arvioitavaa uudelleen Inarijärven istutusohjelma erityisesti järvitaimenen osalta perinnöllisen monimuotoisuuden suojelemiseksi.*

Sama toimenpide kohdassa Inarin kalanviljelylaitos, suositus 3.

TAIVALKOSKEN RIISTAN JA KALANTUTKIMUS

1. *Harkittava robottiruokkijoiden vaihtamista ruokintajoustavuuden parantamiseksi.*

Suositus on tullut vahingossa väärän laitoksen kohdalle, tarkoitettu koskemaan Tornionjoen kalanviljelylaitosta. Taivalkosken kalanviljelylaitoksessa kokemukset robotista ovat myönteisiä. Järjestelmää voidaan kuitenkin vielä parantaa. Pikkupoikasten ruokinnassa on käytössä asianmukainen automaattiruokinta.

2. *Testattava lisäravinnon antoa käsinruokinnalla puronieriälle kesällä.*

Laitoksella testataan ruokintaa. Selvitetään emokalojen geneettisen taustan mahdollista vaikutusta kasvuun.

3. *Hedelmöitettävä yksittäisten naaraiden mäti tuoreella yhden koiraan maidilla.*

Prof. Thorpen käsitys hedelmöitysmenetelmästä perustuu vanhaan videoon. Nykyisin hedelmöitys perustuu geneetikkojen ohjeisiin ja tehdään tuoreella maidilla.

KAINUUN KALANTUTKIMUS JA VESIVILJELY

1. *Vertailtava Iijoen lohen merkintäpalautustuloksia Kiiminki- ja Iijoen jokisuistoistutuksissa.*

Välitetään tieto kalantutkimukselle.

2. *Avattava ovissa olevat valosuojat poikashallissa.*

Ei syytä toteuttaa, sillä hallissa on käytössä astrokello.

3. *Testattava tuloveden johtamisessa pystyputkea, jossa on useampia veden tuloaukkoja, parantamaan veden virtausnopeutta poikasaltaissa.*

Vuonna 1999 mitataan altaiden virtausolosuhteita.

4. *Testattava vedenalaisia varjoja altaissa tarjoamassa kaloille suojapaikkoja poikasaltaissa.*

Asia selvitetään.

5. *Testattava tetrasykliini-värjäystä kuhan merkinnöissä.*

Välitetään tieto kalantutkimukselle.

6. *Testattava tiheämpää ruokintarytmiä ja pienempiä annoksia kuhien syömäänopettamisessa.*

Testataan tiheämpää ruokintatiheyttä kesänvanhojen poikasten ruokintaanopettamisessa. Jatkossa on tarve siirtyä vastakuoriutuneiden poikasten ruokintaan. Harkitaan planktonviljelmän perustamista.

7. *Yhteistyössä rehunvalmistajien kanssa (tai VTT Helsinki) testatkaa erilaisia pellettejä kuhan poikasten ruokinnassa.*

Prof. Thorpe lupasi selvittää aiheeseen liittyviä taustatietoja ja toimittaa ne Kainuun kalanviljelylaitokselle.

8. *Selvitettävä PIT-merkinnän epäonnistuminen emokuhilla.*

Kuhan punasolujen ionitasapaino häiriintyy herkästi ja palautuu hitaasti, mikä on saattanut aiheuttaa emokuhien kuoleman käytetysä lämpötilassa ja MS-222 nukutuksessa. Emokalamerkinnöissä siirrytään uhanalaisempien kantojen osalta yksilömerkintään mm. Taivalkosken kalanviljelylaitoksessa Saimaan kalanviljelylaitoksen kokemusten pohjalta.

9. *Ennen virtaustestiuoman rakentamista vierailtava Glasgow:n yliopistossa katsomassa siellä olevaa uomaa.*

Välitetään tieto RKTL:n kalantutkimukselle.

SEMINAARIN NÄKEMYKSET PROF. THORPEN LAITOSARVIOINNEISTA

Arvioinnilla saavutettiin hyvin asetetut tavoitteet, asioita tuli paljon esille ja arviointi synnytti eri vaiheissa rakentavaa keskustelua. Jatkossa vesiviljelyn laatujärjestelmään liittyvät auditoinnit tarjoavat menetelmän arvioida toimintaa ja sen tarkoituksenmukaisuutta systemaattisesti. Tutkimuslaitoksen nykyisessä organisaatiossa ei kaikilta osin ole riittävää yhteistyötä kalantutkimuksen ja viljelylaitosten välillä, mikä nousi toistuvasti esille arvioinnin yhteydessä. Prof. Thorpen käyntiajankohta ei ajoittunut parhaaseen ajankohtaan, sillä tuolloin varsin suuri osa henkilöstöstä oli poissa laitoksilta lomien ja matkojen vuoksi, minkä takia varsin pieni osa laitosten toimivaa henkilöä sai kontaktin arvioijaan.

LIITE: Palauteseminaarin läsnäolijat

Aika ja paikka: 1.12.1998 Kemi

Läsnäolijat:

Unto Eskelinen	Laukaan kalantutkimus ja vesiviljely, Laukaa
Petri Heinimaa	Inarin kalantutkimus ja vesiviljely, Inari
Sirkka Heinimaa	Inarin kalantutkimus ja vesiviljely, Inari
Hanna Iivari	Inarin kalantutkimus ja vesiviljely, Inari
Juha Iivari	Muonion kalanviljelylaitos, Muonio
Risto Kannel	Kainuun kalantutkimus ja vesiviljely, Paltamo
Matti Karjalainen	Taivalkosken riistan ja kalantutkimus, Taivalkoski
Pekka Kummu	RKTL/ Vesiviljelyn tulosyksikkö, Helsinki
Jarmo Louhimo	Laukaan kalantutkimus ja vesiviljely, Laukaa
Kati Manninen	RKTL/ Vesiviljelyn tulosyksikkö, Helsinki
Raimo Määttä	Kuusamon kalanviljelylaitos, Kuusamo
Pentti Pasanen	Taivalkosken riistan ja kalantutkimus, Taivalkoski
Markku Pursiainen	Saimaan kalantutkimus ja vesiviljely, Enonkoski
Juhani Rytilahti	Lautiosaaren/Simon kalanviljelylaitos, Keminmaa
Ari Savikko	Tornionjoen kalanviljelylaitos, Muonio
Antti Soivio	RKTL/Elinkeinokalatalouden tutkimuksen tulosyksikkö, Helsinki
Kai Westman	RKTL/ Vesiviljelyn tulosyksikkö, Helsinki

MEMORANDUM

Internal seminar on fish rearing at the Finnish Game and Fisheries Research Institute's northern fish farms

Date and location: December 1, 1998, Kemi, Finland
A list of seminar participants appears in the Annex.

1. Opening of the meeting.

Kai Westman opened the meeting and called on Petri Heinimaa to serve as secretary. Westman explained the background of the report commissioned from Professor J.E. Thorpe of the University of Glasgow and the objectives of the meeting. It is intended that other aspects of aquaculture be similarly evaluated by outside experts in the future.

2. The participants addressed Professor Thorpe's recommendations one by one. In the discussion of each recommendation, clarifications and supplementary information were provided and the possibilities for studying or improving the operations in question were considered.

The recommendations are presented below (in italics), numbered as they are in Professor Thorpe's summary.

GENERAL

1. *The natural feeding rhythm of the fish should be taken into account in feeding and in programming feeding systems at all aquaculture stations.*

An example of a feeding system that takes fish appetite into account was the Aquasmart System, which was tested in salmon cages in Tasmania. A general problem is the inability of feeding systems to sense when fish want to feed. Correct feeding demands careful monitoring in both brood fish rearing and juvenile production (i.e., monitoring of fish behaviour). Feeding systems should be developed such that they can imitate different species' natural feeding activities. The automatic feeding system at the Tervo fish farm, like those at some of the Institute's juvenile rearing farms, takes into account the importance of darkness in feeding.

2. *At all farms where it is possible, the effectiveness of spreader-type and shaker-type automatic feeding systems should be compared.*

Because of the importance of feeding, an aquaculture development project is to be set up in which use of the farms' feeding equipment and systems can be evaluated. Recommendations will be drawn up on how feeding and feeding systems could be developed. Communication between fish farms and their personnel will be improved.

3. *The effects of modifying the lighting at different times of the year in both natural spawning grounds and rearing tanks should be studied.*

A development project is to be initiated to study light conditions (e.g. natural outdoor light, light conditions under cover of snow and ice, light in farm conditions, light in brood fish and juvenile rearing, and the influence of handling and light). General principles about the relation between fish behaviour and light will be drafted and distributed to all the fish farms. Different perspectives on the effects of light were actively debated.

4. *The descent of natural salmonids should be studied in different parts of northern rivers.*

5. *The effectiveness of different stocking programmes should be determined.*

6. *The effectiveness of autumn stocking should be determined.*

7. *The effectiveness of stocking under ice cover should be determined.*

8. *The current regulations on the mesh size of gill nets should be examined.*

Recommendations 4-8: The Institute's Fisheries Research Profit Unit's Stocking Research Project will be contacted to ensure that these questions are addressed in the research project.

9. *All levels of personnel should be involved in planning fish stocks management and stocking programmes.*

Communications about the stocking activities planned by the aquaculture section will be improved. Efforts will be made to improve the flow of information from fisheries research to the fish farm staff.

10. *A professional, in-house Information Officer should be appointed to serve as liaison officer for fisheries research and aquaculture.*

The Institute has nowadays an Information Officer on staff. Internal communications concerning aquaculture will be improved. Wider diffusion of information about research results to the public is also important.

Specific recommendations concerning the individual fish farms:

TORNIONJOKI FISH FARM

Special note was taken of the evaluation's strong emphasis on the need to improve the flow of feedback from fisheries research to the fish farm.

1. *The quantity of eggs to be hatched should be reduced to 1.2 million.*

Hatching operations are already at this level.

2. *Underwater covers should be installed to provide shelter for the fish.*

Underwater covers were tried out at the Tornionjoki fish farm and were found to provide effective shelter for small juveniles when disturbed, but because of the depth of the water in the tanks where migratory juveniles are kept, the covers did not work there.

3. *The effectiveness of the stocking of parrs and smolts and also stocking of smolt to different sites should be compared.*

This recommendation will be conveyed to fisheries research to be incorporated in research projects.

MUONIO FISH FARM

1. *Natural light must be allowed to reach the fish rearing areas.*

A project in which the lighting will be tested will be carried out. The different fish stocks will be shifted to their own local outdoor light rhythms during various daylight cycles. The same issue was raised in the general recommendations, Item 3.

2. *Fish stocks from different tributaries should be tagged separately for stocking purposes.*

Brown trout used in fish farming are local, but the stockers can only be advised about which fish stocks to use at different stocking sites. Efforts are being made to persuade the fisheries authorities to provide information and advice more effectively.

3. *The quantity of eggs to be hatched should be reduced.*

Large quantities of sea trout eggs have been produced because difficulties have been encountered in start feeding of the juveniles. These problems will be studied in cooperation with fisheries research.

4. *Feeding methods should be improved.*

Feeding at the station had to be limited in 1997 and the beginning of 1998 because of environmental loading. The size of fish stocks at the station has been reduced so that feeding can be organised in an appropriate manner. It has been found that short fasts can increase the overall size distribution of juveniles by tank.

5. *Sales of juveniles for stocking should be restricted only to certain stocking sites to safeguard the genetic material of the fish.*

The fish populations used for stocking are local but stockers can only be advised about which fish stocks to use at different stocking sites. Efforts are being made to persuade the fisheries authorities to provide information and advice more effectively.

6. *The effectiveness of stocking should be studied.*

This information will be conveyed to the fisheries research unit. A separate project proposal will be drafted for Arctic charr.

INARI FISHERIES RESEARCH AND AQUACULTURE

1. *The street lights around the halls at the fish farm should be turned off.*

The lights have been turned off.

2. *The window shades should be raised.*

A light test will be conducted. See Item 3 of the general recommendations.

3. *Inarijärvi's stocking programme should be re-evaluated, particularly for protection of the genetic diversity of brown trout.*

A microsatellite research project is currently in progress in which the diversity of the present school of brood fish is being studied and compared with that of wild fish. To meet State stocking obligations, a larger proportion than previously of brown trout will be introduced in the lower part of the rivers instead of in the lake (from each river's own stocks).

SARMIJÄRVI FISH FARM

1. *Alternative methods of hatching using covered EWOS troughs should be tested.*

A comparison will be carried out.

2. *The effectiveness of training juveniles to feed in EWOS troughs before transfer to tanks should be tested.*

A test arrangement will be tried.

3. *Underwater covers should be installed in the tanks to provide shelter for the fish.*

A study will be carried out on the escape reaction of juveniles (at what size and which times of the year juveniles seek sheltered areas).

4. *Test sparge inflows to to increase water velocity in the juvenile tanks.*

The speed of water inflow at the juvenile rearing stage will be increased.

5. *Statistical assistance should be sought in determining sample quantities.*

Whether the farm's sample-taking practices are in accordance with the instructions of the measurement working group will be determined.

6 *The overall quantity of fish reared should be reduced.*

Fish stocks have already been reduced and are currently at nearly appropriate levels.

7. *Inarijärvi's stocking programme should be re-evaluated, particularly for the protection of the genetic diversity of lake trout.*

Same procedure in question as for Inari, Item 3.

TAIVALKOSKI GAME AND FISHERIES RESEARCH

1. *Switching from robot feeding to another system should be considered to improve feeding flexibility.*

This recommendation was accidentally directed at this station although it was meant to apply to Tornionjoki. Experiences at Taivalkoski with feeding by robot have been positive, although the system could be improved further. The appropriate automatic feeding system is in use for feeding small juveniles.

2. *Brook trout should be fed supplementary nutrients by hand in summer as a test.*

Feeding practices are being tested at the station. The possible effects of the genetic background of brood fish on their growth will be studied.

3. *The eggs of individual female fish should be fertilised with the fresh milt of a single male fish.*

Professor Thorpe's understanding of the fertilisation methods used is based on an old video. Nowadays fertilisation is based on geneticists' instructions and is done using fresh milt.

KAINUU FISHERIES RESEARCH AND AQUACULTURE

1. Compare return rates of *Iijoki salmon to Kiiminkijoki and Iijoki estuaries.*

This recommendation will be passed on to fisheries research.

2. *The shades on the doors to the halls in the juvenile rearing farms should be raised.*

There is no need to carry out this recommendation, as there is an astroclock in the hall.

3. *Test sparge flows to increase water velocity in the juvenile tanks.*

In 1999 the flow conditions in the tanks will be measured.

4. *Use of underwater covers in the juvenile tanks to provide shelter to the fish should be tried.*

This recommendation will be examined further.

5. *Use of tetracycline staining for tagging pike-perch should be tested.*

This information will be transmitted to fisheries research.

6. *More frequent feedings and smaller portions should be administered on a trial basis in training pike-perch to feed.*

More frequent feedings will be administered on a trial basis in training one-summer-old juveniles to feed. In the next stage the focus will need to shift to the feeding of newly-hatched fries. Cultivation of plankton will be considered.

7. In cooperation with feed producers (or with VTT, the Technical Research Centre of Finland, Helsinki), different kinds of pellets should be tested as feed for pike-perch juveniles.

Professor Thorpe has agreed to obtain background information on the subject and transmit it to Kainuu.

8. The reasons for the failure of PIT-tagging of pike-perch brood fish should be clarified.

The red blood cell ionic balance in pike-perch is disturbed easily and returns to normal slowly, which may have resulted in the death of pike-perch brood fish at the temperature used for tagging and during anesthetisation with MS-222. On the basis of experiences at the Saimaa Fisheries and Aquaculture, the more endangered brood fish stocks will now be PIT tagged individually f.ex. at Taivalkoski.

9. Before construction of a flow testing channel, the staff should visit the University of Glasgow to see the channel that has been built there.

This recommendation will be transmitted to the Institute's fisheries research unit.

THE SEMINAR PARTICIPANTS' ASSESSMENTS OF PROFESSOR THORPE'S EVALUATION WERE AS FOLLOWS

With this evaluation it has been possible to set appropriate goals, many issues were raised and constructive discussion was inspired at different points. In the future, audits of the aquaculture quality system will offer a means by which to evaluate operations systematically. In the current organisation of the research section, there is not always sufficient cooperation between fisheries research and the fish farms, a concern which repeatedly came to light in the evaluation. The timing of Professor Thorpe's visits to the aquaculture stations was not the best possible, because at that particular time a significant portion of the staff was away either for professional reasons or on holiday, which is why only a limited number of those working at the stations actually had contact with their evaluator.

ANNEX: Internal seminar participants

Date and Place: December 1, 1998, Kemi

Participants:

Unto Eskelinen	Laukaa Fisheries Research and Aquaculture, Laukaa
Petri Heinimaa	Inari Fisheries Research and Aquaculture, Inari
Sirkka Heinimaa	Inari Fisheries Research and Aquaculture, Inari
Hanna Iivari	Inari Fisheries Research and Aquaculture, Inari
Juha Iivari	Muonio Fish Farm
Risto Kannel	Kainuu Fisheries Research and Aquaculture, Paltamo
Matti Karjalainen	Taivalkoski Game and Fisheries Research, Taivalkoski
Pekka Kummu	Finnish Game and Fisheries Research Institute, Aquaculture Unit, Helsinki
Jarmo Louhimo	Laukaa Fisheries Research and Aquaculture, Laukaa
Kati Manninen	Finnish Game and Fisheries Research Institute, Aquaculture Unit, Helsinki
Raimo Määttä	Kuusamo Fish Farm
Pentti Pasanen	Taivalkoski Game and Fisheries Research, Taivalkoski
Markku Pursiainen	Saimaa Fisheries Research and Aquaculture, Enonkoski
Juhani Rytilahti	Lautiosaari/Simo Fish Farm, Keminmaa
Ari Savikko	Tornionjoki Fish Farm
Antti Soivio	FGFRI/Socioeconomic and Aquaculture Research Unit Helsinki
Kai Westman	FGFRI/Aquaculture Unit, Helsinki

Riista- ja kalatalouden tutkimuslaitoksen Pohjois-Suomen kalanviljelylaitosten emokalan- ja poikasviljelyn tunnuslukuja

Sirkka Heinimaa ja Petri Heinimaa, RKTL/Inarin kalantutkimus ja vesiviljely
Inari 23.3.1998

Taustatietoja Inarin, Sarmijärven, Muonion, Tornionjoen, Taivalkosken ja Kainuun kalanviljelylaitoksista professori John E. Thorpen tutkimuslaitoksen pohjoisten kalanviljelylaitosten toiminnan arviointia varten. Tilanne vuoden 1998 alussa.

Laitoksen perustamis- ja peruskorjausvuodet

	Perustaminen	Korjaukset ja laajennukset
Inari	1951	1967,1974-75,1979-80,1995-97
Sarmijärvi	1981	1989,1994-96
Muonio	1958	1971, 1982, 1992-93
Tornionjoki	1988	
Taivalkoski	1966	1990-97
Kainuu	1935	1989-1994

Allasyksiköiden tilavuus ja lukumäärä

	SISÄTILOISSA Allaskoko m²						ULKOTILOISSA Allaskoko m²					
Laitos	0.5-1	2-4	7-8	13-16	28-64	Yht. M²	4-7	24-63	75-250	272-850	500-2 300	Yht. m²
Inari	10	24	45	0	24	1 666	0	0	1	0	0	250
Sarmijärvi	0	33	23	0	0	316	0	0	30	0	0	6 000
Muonio	0	40	0	19	16	1 201	0	0	0	0	0	0
Tornionjoki	0	96	23	11	10	1 115	0	0	0	0	0	0
Taivalkoski	58	51	4	34	61	3 840	12	21	7	0	0	1 339
Kainuu	0	72	0	15	0	458	0	64	24	6	0	7 400

Kainuussa ja Taivalkoskella osa ulkolammikoista betonisia ja osa maapohjaisia, Sarmijärvellä ulkolammikot betonisia.

Vesitys

Inari	jokivesi
Sarmijärvi	järvivesi (pinta-, syvänne- ja alusvesi)
Muonio	järvivesi (pinta- ja alusvesi)- sekä ojavesi
Tornionjoki	järvivesi (pinta- ja alusvesi)
Taivalkoski	joki- ja pohjavesi (jokivedessä mukana järvivettä pinnasta)
Kainuu	järvivesi (pinta- ja alusvesi)

Viljelyveden lämpötila kuun 15. päivän keskiarvo sekä vuoden minimi ja maksimilämpötila

	Kuukausi													
Laitos	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	MIN	MAX
Inari	0.1	0.1	0.1	0.1	0.4	10.1	17.7	14.1	11.4	3.2	0.1	0.1	0.1	20.0
Sarmijärvi	1.6	1.7	1.8	1.7	2.3	11.7	16.6	14.4	12.0	4.2	1.9	2.0	1.5	18.2
Muonio	1.3	1.3	1.3	1.3	1.4	6.3	13.5	16.9	9.2	3.1	1.2	1.2	1.1	17.7
Tornionjoki	1.5	1.4	1.3	1.1	3.0	9.7	15.5	15.5	9.0	2.8	1.6	1.5	0.8	20.9
Taivalkoski	0.1	0.1	0.2	0.8	3.3	12.1.	13.7	12.2	6.8	1.5	0.4	0.1	0.1	16.8
Kainuu, alusvesi	1.7	2.0	2.1	2.1	3.0	11.4	13.9	16.1	12.0	5.0	1.3	1.9	0.5	20.0
Kainuu, pintavesi	1.0	1.0	1.2	1.3	3.1	12.3	17.4	18.0	12.0	4.8	0.9	1.1	0.5	21.6

Viljelyveden lämmitys/jäähdytysmahdollisuudet haudonnassa ja poikaskasvatuksessa

- Inarissa ja Sarmijärvellä ei mahdollista.
- Muoniossa lämmitysmahdollisuus haudonnassa ja poikasviljelyssä
- Tornionjoella lämmitysmahdollisuus haudonnassa ja poikasviljelyssä
- Taivalkoskella jäähdytysmahdollisuus haudonnassa ja lämmitys pohjavedellä
- Kainuussa lämmitysmahdollisuus haudonnassa ja poikasviljelyssä

Valaistus halleissa

- Keinovalo halleissa, valaistusrytmi automatiikalla paikallisen rytmin mukaan, Taivalkoskella ja Muoniossa poikaset työpäivän pituisessa valorytmissä.
- Sarmijärvellä yli 1-vuotiaat luonnonvalossa ulkolammikoissa, alle 1-vuotiaat tasaisessa hämärässä valossa hallissa.
- Kainuussa yli 1-vuotiaat luonnonvalossa ulkolammikoissa kotakatteisissa altaissa, halleissa paikallinen luonnonvalorytmi.

Kalojen ruokinta

Inari	Allaskohtainen automaattiruokinta (ITUMIC)
Sarmijärvi	Hallissa allaskohtainen automaattiruokinta ilman tiedonkeruuta, ulkolammikoissa käsinruokinta
Muonio	Allaskohtainen automaattiruokinta (ITUMIC)
Tornionjoki	Halleissa robottiruokinta tai allaskohtainen automaattiruokinta (ITUMIC)
Taivalkoski	Halleissa robottiruokinta tai allaskohtainen automaattiruokinta (ITUMIC)
Kainuu	Halleissa allaskohtainen automaattiruokinta, ulkolammikoissa automaattiruokinta (ITUMIC)

Laitoksessa viljelyksessä olevat lajit

Inari	Lohi, järvilohi, järvitaimen, nieriä, harjus, pohjasiika, muikku
Sarmijärvi	Järvitaimen, nieriä, harmaanieriä, pohjasiika
Muonio	Lohi, meritaimen, purotaimen, nieriä, vaellussiika
Tornionjoki	Lohi
Taivalkoski	Lohi, järvilohi, meritaimen, järvitaimen, purotaimen, nieriä, harmaanieriä, puronieriä, spleiknieriä, kirjolohi, harjus, vaellussiika, planktonsiika, peledsiika pohjasiika, muikku, made
Kainuu	Lohi, järvilohi, meritaimen, järvitaimen, purotaimen, kirjolohi, nieriä, puronieriä, harjus, vaellussiika, planktonsiika, kuha

Laitoksen tuotanto 1997

	Tuotanto kg	Emokalojen biomassa kg	Mädintuotanto spa litraa	Poikasten määrä vuoden lopussa 0-1-v.	2-v.	yli 3-v.
Inari	11 312	5 829	291	268 000	66 000	18 600
Sarmijärvi	32 546	6 908	628	530 000	96 000	97 000
Muonio	2 208	3 632	266	366 000	1 300	500
Tornionjoki	6 228	2 424	146	524 000	1 000	
Taivalkoski	9 333	34 139	2 376	90 000	40 000	4 200
Kainuu	15 000	2 821	135	378 000	10 700	240

Laitoksen lupaehdot

	Vedenkäyttö l/s	Lisäkasvu kg	Rehumäärä kg	Fosfori kg/a	Biomassa kg
Inari	500	40 000	56 000	360	
Sarmijärvi	kesä 500 talvi 350	40 000		270	
Muonio	130-200	4 800	8 000	35	
Tornionjoki	170	8 700	14 790	60	
Taivalkoski	1 100				
Kainuu	580-750	43 000	76 000	318	56 000

Haudonta ja poikaskasvatustulos (ongelmaryhmät)

Inari	Poikasten 1-kesän kasvatustulos vaihtelee järvilohella (30-78 %) ja taimenella (47-85 %)
Sarmijärvi	Taimenella poikasten 1-kesän kasvatustulos vaihtelee (26-77 %)
Muonio	Luonnosta hankituilla nieriäemokaloissa ongelmia sukutuotteiden tuottamisessa
Tornionjoki	Yksivuotiailla lohilla kidusongelmia talvella
Taivalkoski	Siialla ja lohella alhainen haudontatulos
Kainuu	Smoltti ja emokalatuotannossa vesihomeogelma.

Some basic information on the Finnish Game and Fisheries Research Institute aquaculture stations in northern Finland

Sirkka Heinimaa and Petri Heinimaa, FGFRI/ Inari Fisheries Research and Aquaculture
Inari Mars 23, 1998

Background information on the Inari, Sarmijärvi, Muonio, Tornionjoki, Taivalkoski and Kainuu fish farms for the evaluation of fish farming methods and practices in the northern Finnish Game and Fisheries Research Institute fish farms by Dr. John E. Thorpe. Situation in the early 1998.

Dates fish farms were initiated and reconstructed

	Initiation	Reconstruction
Inari	1951	1967, 1974 - 1975, 1979-80, 1995-1997
Sarmijärvi	1981	1989, 1994 - 1996
Muonio	1958	1971, 1982, 1992 - 1993
Tornionjoki	1988	
Taivalkoski	1966	1990 - 1997
Kainuu	1935	1989 - 1994

Volume and number of fish-rearing units

	INDOOR Size m²						OUTDOOR Size m²					
Fish farm	0.5-1	2-4	7-8	13-16	28-64	Total m²	4-7	24-63	75-250	272-850	500-2300	Total m²
Inari	10	24	45	0	24	1 666	0	0	1	0	0	250
Sarmijärvi	0	33	23	0	0	316	0	0	30	0	0	6000
Muonio	0	40	0	19	16	1 201	0	0	0	0	0	0
Tornionjoki	0	96	23	11	10	1 115	0	0	0	0	0	0
Taivalkoski	58	51	4	34	61	3 840	12	21	7	0	0	1339
Kainuu	0	72	0	15	0	458	0	64	24	6	0	7400

Some of the outdoor ponds in Kainuu and Taivalkoski are concrete and some earthen in Sarmijärvi the only outdoor ponds are concrete.

Water supply

Inari	river
Sarmijärvi	lake (surface and hypolimneon)
Muonio	lake (surface and hypolimneon) and brook water
Tornionjoki	lake (surface and hypolimneon)
Taivalkoski	river water (contains surface water from lake) and groundwater
Kainuu	lake (surface and hypolimneon)

Water temperatures (average) for the 15th day of the month and (year minimum and maximum)

Fish farm	Month I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	MIN	MAX
Inari	0.1	0.1	0.1	0.1	0.4	10.1	17.7	14.1	11.4	3.2	0.1	0.1	0.1	20
Sarmijärvi	1.6	1.7	1.8	1.7	2.3	11.7	16.6	14.4	12.0	4.2	1.9	2.0	1.5	18.2
Muonio	1.3	1.3	1.3	1.3	1.4	6.3	13.5	16.9	9.2	3.1	1.2	1.2	1.1	17.7
Tornionjoki	1.5	1.4	1.3	1.1	3.0	9.7	15.5	15.5	9.0	2.8	1.6	1.5	0.8	20.9
Taivalkoski	0.1	0.1	0.2	0.8	3.3	12.1.	13.7	12.2	6.8	1.5	0.4	0.1	0.1	16.8
Kainuu, hypolimneon	1.7	2.0	2.1	2.1	3.0	11.4	13.9	16.1	12.0	5.0	1.3	1.9	0.5	20.0
Kainuu, surface	1.0	1.0	1.2	1.3	3.1	12.3	17.4	18.0	12.0	4.8	0.9	1.1	0.5	21.6

Feasibility of warming and cooling water used in hatching and juvenile rearing

- Inari and Sarmijärvi: not feasible
- Muonio: warming feasible
- Tornionjoki: warming feasible
- Taivalkoski: warming and cooling (of water used in hatching) feasible through use of groundwater
- Kainuu: warming feasible

Light rhythm

- Inari: light rhythm in doors nearly the same as local natural light rhythm out doors
- Sarmijärvi: under 1-year-old fish exposed to steady dim light in doors and over 1-year-old fish exposed to natural light outdoors (ponds sometimes covered by ice)
- Muonio: light rhythm for juveniles same as length of working day; brood fish kept under local natural light rhythm in doors
- Tornionjoki: light rhythm for 1-year-old salmon same as length of working day; smolts kept under local natural light rhythm and salmon brood fish under Baltic Sea light rhythm
- Taivalkoski: light rhythm for juveniles same as length of working day; brood fish are kept under local natural light rhythm in halls.
- Kainuu: over 1-year-old fish kept in outdoor ponds under cover, in doors under local natural light rhythm

Feeding of fish

Inari	Automatic feeding system (ITUMIC)
Sarmijärvi	Automatic feeders in doors in hall and manual feeding outdoors
Muonio	ITUMIC
Tornionjoki	Robotic feeding and ITUMIC systems in doors
Taivalkoski	Robotic feeding and ITUMIC systems in doors
Kainuu	ITUMIC system in doors and outdoors

Farmed fish species

Inari	Salmon, landlocked salmon, brown trout, Arctic charr, grayling, whitefish, vendace
Sarmijärvi	Brown trout, Arctic charr, lake trout, whitefish
Muonio	Salmon, brown trout, Arctic charr, whitefish
Tornionjoki	Salmon
Taivalkoski	Salmon, landlocked salmon, brown trout, Arctic charr, lake trout, brook trout, splake charr, rainbow trout, grayling, whitefish, peled whitefish, vendace
Kainuu	Salmon, landlocked salmon, brown trout, rainbow trout, Arctic charr, brook trout, grayling, whitefish, pikeperch

Production in 1997

	Production kg	Biomass of brood fish kg	Egg production eyed eggs litres	Number of juveniles at the end of the year		
				0-1 years	2 years	over 3 years
Inari	11 312	5 829	291	268 000	66 000	18 600
Sarmijärvi	32 546	6 908	628	530 000	96 000	97 000
Muonio	2 208	3 632	266	366 000	1 300	500
Tornionjoki	6 228	2 424	146	524 000	1 000	
Taivalkoski	9 333	34 139	2 376	90 000	40 000	4 200
Kainuu	15 000	2 821	135	378 000	10 700	240

Production licences

	Waterflow l/s	Annual growth kg	Amount of dry feed kg	Phosphorus kg/a	Biomass kg
Inari	500	40 000	56 000	360	
Sarmijärvi	summer 500 winter 350	40 000		270	
Muonio	130-200	4 800	8 000	35	
Tornionjoki	170	8 700	14 790	60	
Taivalkoski	1 100				
Kainuu	580-750	43 000	76 000	318	56 000

Problems in egg and juvenile production

Inari	First-summer rearing survival varies in landlocked salmon from 30% to 78% and in brown trout from 47% to 85%
Sarmijärvi	First-summer rearing survival varies in brown trout from 26% to 77%
Muonio	Arctic charr brood fish caught outdoors have problems in maturation
Tornionjoki	One year-old salmon have gill problems during coldwater season
Taivalkoski	Whitefish and salmon show low survival during hatching
Kainuu	Smolts and brood fish have water fungus problems