

CENTRE FOR ENVIRONMENT, FISHERIES AND  
AQUACULTURE SCIENCE

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# TROUT PRODUCTION

## 1998 SURVEY OF TROUT PRODUCTION IN ENGLAND AND WALES

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As a result of the inspection and monitoring programme undertaken for MAFF and WOAD under the European Council Directive 91/67/EC, all but three registered salmonid farms in England and Wales were visited by the CEFAS Fish Health Inspectorate during the first 6 months of 1999. The data presented in the following report was obtained from all of these sites where the owners were willing to provide data.

A total of 290 salmonid farm sites were visited from January-June 1999. Of these, 12 sites failed to sell any fish during 1998. Four sites refused to supply details, there were four ownership changes where accurate details of production were unavailable and there were five new registrations. The data included in this report therefore represents the production from a total of 278 registered salmonid farms in England and Wales.

### Rainbow trout production

A summary of the production details for all sites farming rainbow trout is presented in Table 1. The sites are grouped according to regional divisions of the Environment Agency, to allow comparison with previously published data. Sites are classified into one of four different categories as follows:

- 1) Sites that did not produce any rainbow trout during 1998
- 2) Sites that produce rainbow trout for the table market only

- 3) Sites that produce rainbow trout for restocking fisheries and/or for ongrowing

- 4) Sites that cater for both table and restocking/ ongrowing markets.

The total annual production of rainbow trout for the table market in 1998 was 6980 tonnes from 125 farm sites. This figure is slightly lower than that for 1997 (7102 tonnes). A total of 193 farms produced rainbow trout for restocking fisheries or ongrowing purposes, this repeated a 9% reduction in sites since 1997. These sites together produced 3433 tonnes during 1998, of which 2957 tonnes were restocking trout and 476 tonnes were fingerlings or yearlings for ongrowing. This figure represents an 8% increase on the total restocking and ongrowing production recorded for 1997 (3188 tonnes).

The overall rainbow trout production (combining table and restocking/ongrowing figures) for England and Wales in 1998 was 10,413 tonnes, a small increase on the 1997 figure of 10,290 tonnes.

Table 2 provides a breakdown of trout production where farms are classified according to their scale of production. Data for brown trout production are also included because the majority of brown trout are produced from sites also farming rainbow trout.

Half of the trout farms in England and Wales are in the 0-10 tonnes category but their combined output only accounts for 3.5% of total production. There has been a

**Table 1. 1998 Rainbow trout production by Environment Agency Region for England and Wales**

Environment Agency Area	Number Of Sites				Production			
	No Production	Table Production	Restocking / Ongrowing Production	Both (Table & Restocking)	Total number of sites	Table (tonnes)	Restock/ Ongrowing (tonnes)	Fry (thousands)
Anglian	0	1	4	6	11	31	362	807
North West	1	1	7	10	19	276	118	633
Northumbria	1	1	3	0	5	15	45	0
Severn Trent	1	1	9	3	14	31	376	368
Southern	3	8	15	6	32	1,714	193	852
South West	0	7	14	19	40	620	731	780
Thames	0	3	9	7	19	536	374	1,811
Weksh	1	5	18	11	35	532	238	4,418
Wessex	1	10	21	10	42	2,171	601	11,759
Yorkshire	1	6	11	10	28	1,053	394	10,404
<b>Totals</b>	<b>9</b>	<b>43</b>	<b>111</b>	<b>82</b>	<b>245</b>	<b>6,979</b>	<b>3,432</b>	<b>31,832</b>

**Table 2. Analysis of rainbow trout and brown trout production according to region and scale of farm output. (The number of farms involved in each size class are given in brackets)**

Environment Agency Area	Production according to farm output category (tonnes)				
	0-10	11-50	51-100	101-200	>201
Anglian	11 (10)	90 (4)	100 (1)	198 (1)	0 (0)
North West	12 (9)	160 (7)	138 (2)	132 (1)	0 (0)
Northumbria	19 (4)	49 (2)	0 (0)	0 (0)	0 (0)
Severn Trent	25 (8)	147 (5)	71 (1)	0 (0)	265 (1)
Southern	43 (18)	240 (11)	60 (1)	0 (0)	1,601 (5)
South West	89 (21)	329 (13)	85 (1)	854 (6)	0 (0)
Thames	30 (8)	139 (6)	233 (3)	305 (2)	248 (1)
Weksh	57 (24)	274 (12)	158 (2)	105 (1)	217 (1)
Wessex	77 (25)	385 (15)	618 (9)	125 (1)	1,586 (3)
Yorkshire	20 (12)	173 (6)	476 (7)	354 (3)	525 (2)
Totals	383 (139)	1,986 (81)	1,939 (27)	2,073 (15)	4,442 (13)
% Total Production	3.5	18.3	17.9	19.2	41.0
% Farms involved	50.5	29.5	9.8	5.5	4.7

17% reduction in the numbers of registered small farms during 1998 and a small increase in the slightly larger (11-50 and 51-100 tonne) farms. The biggest farms (those producing over 200 tonnes annually) account for over 40% of total trout production but form less than 5% of the total number of trout farms in England and Wales. The Wessex area contains the highest number of farms (53) and produces the most trout of any region (26%) in England and Wales.

### Production of other farmed salmonids

The 1998 production information for brown trout and atlantic salmon is summarised in Table 3. Of the 278 registered salmonid farms producing fish during 1998, 65 sites produced brown trout in addition to rainbow trout and 18 sites produced brown trout only (a total of 83 sites – an increase of 9 sites from 1997). This represents an increase in the number of sites producing brown trout back to the 1996 levels (in 1997, 74 brown trout sites were recorded). Seven farms produced both trout and Atlantic salmon and 16 sites concentrated on producing salmon alone. Only 10 sites recorded brook

trout (*Salvelinus fontinalis*) production in 1998 – 33 thousand were produced for ongrowing by two sites and 8.8 tonnes was produced for the restocking market, both an increase on last year.

Commercial units that supply farms in Scotland produced the majority of salmon smolts. A total of 2.2 million smolts were produced from six sites, a reduction on last year. In addition, six Environment Agency salmonid rearing sites operated during 1998 to produce fry and juvenile salmon for specific river stock enhancement programmes. These sites together produced 203,000 salmon smolts, 170,000 salmon fry and 95,000 sea trout fry. The numbers of salmon produced by the EA sites has continued to decline while the numbers of sea trout has increased from last year. This suggests a change of emphasis from salmon to sea trout. The overall decrease in production from these sites suggests that the emphasis of salmon stock management is still moving away from stock supplementation towards habitat improvement programmes. While the emphasis on brown trout stock management may be returning to stock supplementation.

**Table 3. 1998 production of brown trout and Atlantic salmon in England and Wales**

Environment Agency Area	Brown trout				Atlantic salmon			
	Total number of Sites	No. of sites with active production	Restocking / Ongrowing (tonnes)	Fry (thousands)	No. of sites	Post Smolts (tonnes)	Parr / Smolts (thousands)	Fry (thousands)
Anglian	7	2	6	0	2	0	70	0
North West	9	4	48	14	7	0	1,382	5,072
Northumbria	3	1	8	0	1	0	405	0
Severn Trent	13	7	101	1,655	2	0	119	20
Southern	22	18	37	82	2	0	0	685
South West	11	5	6	0	1	1	0	0
Thames	13	9	45	0	2	0	23	0
Weksh	18	15	41	10	7	1	505	103
Wessex	21	13	56	146	1	0	11	0
Yorkshire	14	9	102	2,107	2	0	849	0
Totals	131	83	450	4,014	27	2	3,364	5,880

**Table 4. 1998/99 eyed ova production from sites holding broodstock salmonids in England and Wales (not including sea trout and salmon produced from wild broodstock by the EA)**

Environment Agency Area	Rainbow trout			Brown trout			Salmon
	All Females (thousands)	Mixed Sex (thousands)	Triploid (thousands)	All Females (thousands)	Mixed Sex (thousands)	Triploid (thousands)	Mixed Sex (thousands)
Anglian	0	0	0	0	0	0	50
North West	500	102	0	0	350	0	0
Northumbria	0	0	0	0	20	0	0
Severn Trent	250	260	0	0	270	0	0
Southern	430	3	150	0	131	20	0
South West	650	20	1,913	0	5,510	0	0
Thames	7,720	60	1,240	90	575	0	0
Welsh	30	1,860	0	0	339	0	12
Wessex	18,540	624	985	189	256	293	0
Yorkshire	4,621	61	315	11	1,082	0	0
Totals	32,741	2,990	4,603	290	8,533	313	62

## Ova production

The recorded figures for salmonid ova produced over the period running from late 1998 through to early 1999 from sites holding broodstock are summarised in Table 4. The majority of rainbow trout eggs produced were all-female. Production of this type of egg totalled 33 million eggs, of which just over one million were sold to other sites. These figures are a reduction of 20% from the 1997/98 season (40.7 million eggs) but a return to 1996/97 levels. Mixed-sex rainbow trout egg production was increased threefold from the 1997/98 totals (just under 3 million from 788,000 in 1997/98) and a return to the levels produced in 1996/97. The recorded production of rainbow trout triploid eggs was 4.6 million, which is an increase from the 1997/98 level of 1.7 million, the levels for the previous year were also surpassed.

The majority of brown trout ova produced were mixed-sex and production totalled just over 9 million ova, a threefold increase on last years figures, while 376,000 were sold to other sites. A total of 290,000 all-female brown trout ova were produced, a threefold increase on the 1997 levels. Triploid ova production was recorded

as 313,000 – a 40% increase in production for the second successive season. This represents a large increase in the production of brown trout eggs from the levels in the past few years, it is also interesting to note that the level sold to other sites has decreased only slightly from the previous year.

Only 62,000 salmon eggs were produced by commercial salmon rearing sites and a further 259,000 eggs were produced for Environment Agency stock enhancement programmes, a large reduction from last years level. In addition, 44,000 eggs from salmon broodstock obtained from the Rivers Itchen, Seiont, Tywi and the eastern Cleddau were laid down by commercial hatcheries, in co-operation with the Environment Agency, and reared to produce parr for local stock enhancement schemes. A further 288,000 salmon eggs were laid down by commercial hatcheries from wild salmon broodstock.

The majority of rainbow trout ova were produced from farm sites in the Wessex region while farms in the South West region produced the highest numbers of brown trout ova.

## 1998 SURVEY OF TROUT PRODUCTION IN NORTHERN IRELAND

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DANI inspect all fish farms twice per year under Council Directive 91/67 and Fisheries Act (Northern Ireland) 1966. During inspections the data summarised in Tables 1 and 2 was collected.

In addition to table production 60 tonnes of Rainbow trout and 95 tonnes of Brown and migratory trout were produced for restocking. Ova and fry/fingerlings surplus to requirements are exported.

**Table 1. Rainbow trout table production**

Production	No. of sites	Total production (tonnes)	Number employed (including hatcheries)		Sites not producing
			Full-time	Part-time	
0-9tonnes	8	51	8	3	-
10-24tonnes	8	188	12	11	2
25-49tonnes	5	232	8	4	0
50-99tonnes	5	480	6	4	-
100-199tonnes	2	248	5	2	-
Total	28	1,199	39	24	2

**Table 2. Ova production**

No. of Hatcheries	Rainbow trout	Brown trout	Migratory trout
7	14,000,000	-	-
2	-	1,300,000	-
7	-	-	210,000

## 1998 SURVEY OF TROUT PRODUCTION IN SCOTLAND

*Unfortunately the Scottish production figures for 1998 were not available at the time of going to press. They will be published in the January 2000 edition.*

## SUMMARY OF TROUT EGG IMPORTS INTO THE UK IN 1998

### England and Wales

The following data are supplied from CEFAS, Fish Health Inspectorate, Weymouth from their import monitoring programme.

Rainbow trout egg imports into England and Wales during 1998 totalled 38.4 million, a decrease on the number of eggs imported the previous year (44.3 million eggs).

**Table 1. Number and source of rainbow trout ova imported by month in 1998**

Month	Northern Ireland	Isle of Man	Denmark	South Africa	Total
January	780,000	2,079,000			2,859,000
February	600,000	2,650,000	900,000		4,150,000
March	270,000	2,075,000	2,050,000		4,395,000
April		100,000	3,225,000		3,325,000
May		420,000			420,000
June	30,000			7,416,000	7,446,000
July	30,000			8,580,000	8,610,000
August	195,000			750,000	945,000
September	220,000			787,000	1,007,000
October	248,000	1,573,000			1,821,000
November	325,000	1,556,000	200,000		2,081,000
December	300,000	535,000	500,000		1,335,000
Total	2,998,000	10,988,000	6,875,000	17,533,000	38,394,000
Total %	8	28	18	46	100

### Scotland

*Scottish ova import figures for 1998 were not available at the time of going to press.*

## EUROPEAN TROUT PRODUCTION

The latest production figures for rainbow trout released by the Federation of European Aquaculture Producers (FEAP) on its website (<http://www.fishlink.com/feap>) are given in Table 1 below for 22 European countries. The figures for large rainbow trout are for fish in excess of 1 kilo in weight and include both fresh-water and sea-grown (salmon trout) production.

Total European production for 1998 is estimated to be just over 307,500 tonnes with Italy as the leading producer at 49,000 tonnes closely followed by France at 48,000 tonnes. UK production, estimated at 15,825 tonnes in 1998, ranked ninth in the league of European trout producing countries.

**Table 1. European production of portion-sized (P) and large (L) rainbow trout for the period 1994-1998**

Country	1994	1995	1996	1997	1998
Austria	3,500 P 350 L	3,500 P 350 L	3,000 P 400 L	3,000 P 400 L	3,000 P 400 L
Belgium/Luxemburg	500 P 300 L	600 P 200 L	700 P 100 L	700 P 120 L	700 P 100 L
Cyprus	-	98 P	110 P	105 P	90 P
Czech Republic	650 P	645 P	647 P	499 P	550 P
Denmark	32,400 P 7,000 L	34,000 P 7,000 L	30,000 P 7,000 L	29,300 P 7,000 L	30,000 P 13,000 L
Faroe islands	452 L	452 L	63 L	100 L	100 L
Finland	16,600 L	17,300 L	18,000 L	16,500 L	17,000 L
France	34,000 P 8,000 L	42,000 P 8,000 L	48,000 P 8,000 L	42,000 P 8,000 L	40,000 P 8,000 L
Germany	23,500 P 1,500 L	23,500 P 1,500 L	23,500 P 1,500 L	23,500 P 1,500 L	23,500 P 1,500 L
Greece	1,943 P	2,455 P	2,500 P	2,500 P	2,300 P
Iceland	330 L	379 L	728 L	580 L	180 L
Ireland	754 P 616 L	1000 P 300 L	1000 P 300 L	1,000 P 300 L	1,000 P 300 L
Italy	47,000 P -	49,800 P 500 L	49,000 P 500 L	51,000 P 1,000 L	48,000 P 1,000 L
Netherlands	200 P	200 P	200 P	200 P	200 P
Norway	15,500 L	13,000 L	20,000 L	34,000 L	40,000 L
Poland	4,500 P	4,679 P	5,800 P	6,500 P	8,000 P
Portugal	1,164 P	1,500 P	1,500 P	1,500 P	1,500 P
Spain	22,000 P 750 L	18,000 P 750 L	24,000 P 1,000 L	25,000 P -	26,000 P -
Sweden	180 P 6,000 L	174 P 5,772 L	150 P 6,000 L	200 P 6,500 L	300 P 5,000 L
Turkey	6,977 P	6,977 P	8,000 P	18,000 P	20,000 P
UK	14,989 P 659 L	11,000 P 659 L	14,000 P 750 L	14,300 P 800 L	14,875 P 950 L
<b>Totals portion size</b>	194,257	200,128	212,107	219,304	220,015
<b>Totals large size</b>	58,057	56,162	64,341	76,800	87,530
<b>Grand total</b>	<b>252,314</b>	<b>256,290</b>	<b>276,448</b>	<b>296,104</b>	<b>307,545</b>

## FISH HEALTH CONTROLS: THE ACTIVITIES OF THE FISH HEALTH INSPECTORATE IN ENGLAND AND WALES 1998

By: Alasdair Scott, CEFAS Weymouth Laboratory, Barrack Road, The Nothe, Weymouth Dorset DT4 8UB

### Introduction

The work of the Fish Health Inspectorate at CEFAS Weymouth, from the advent of the single market in Europe in 1993 to the end of 1997, has been described in previous issues of Trout News (December 1996, June 1997 and July 1998).

This report aims to provide an update of the Inspectorate's work during 1998, illustrating how the Inspectorate performed with respect to targets set for each of the major areas of activity, and outlining the current status of notifiable diseases of fish in England and Wales.

### Inspection programmes

Details of the number of inspections carried out in each category of work during 1998 are shown in Table 1. The table does not show any detail of the shellfish inspection programme, which is reported annually in Shellfish News<sup>(1)</sup>.

The salmonid programme, which previously required the inspection of all registered salmonid farms twice per year, with samples being taken from half of the sites each year, was changed during the year. As a result of Commission Decision 98/45 EC, the requirement to inspect non-broodstock sites has been reduced to once per year. Broodstock sites are classed as all those rearing

eggs. The reduced inspection programme was completed as planned, though the number of samples taken was significantly less than half the number of sites, largely due to changes in the farm register since 1993, when the monitoring programme was established. During 1999 there will need to be some re-arrangement of the sampling periods for individual farms as a result of the changes in the inspection programme.

The number of samples taken on suspicion of notifiable diseases during routine farm inspections (10), and the number of disease outbreaks reported by farmers (15), were somewhat higher than the total of 17 recorded in 1997.

The inspection programme for coarse fish sites required a single site inspection on all registered farms each year, with samples taken from 25% of sites for SVC testing. The four year SVC testing programme was completed with all farm sites testing negative for the disease. Investigations relating to the discovery of SVC in ornamental carp imported from China, and into coarse fish mortalities, which resulted in the collection and testing of samples from a total of 161 sites, again placed pressure on resources available for routine farm inspections.

All Inspectorate duties relating to the control and eradication of notifiable diseases, and investigations of disease outbreaks, were completed to target. All

**Table 1. Number of tasks, by category, undertaken by the Fish Health Inspectorate in 1998**

	Site type		
	Salmonid	Coarse	Total
Farm inspections (no samples)	314	134	448
Routine sampling and inspection	138	44	182
Inspection and sampling on suspicion	10	2	12
Notifiable disease re-tests and contact tests	17	18	35
Reported disease outbreaks & mortality investigations	15	147	163
Import checks: sampling	3	20	23
inspection/physical checks	12	7	19
Export certification	2	97	99
Farm registration visits	6	16	22
Site disinfection visits	11	5	16
Wild fish monitoring	27	1	28
Other visits/inspections	23	8	31
		Total	1,078

<sup>(1)</sup> Copies of Shellfish News and back copies of Trout News are available from the CEFAS Lowestoft Library

essential duties in respect of farm registration, import licensing, and the issue of movement documents and health certificates were similarly met in full.

## The status of notifiable diseases in England and Wales

**VHS and IHN.** All registered farms sites continue to test negative for these list II viral diseases. The 27 tests on samples of wild salmonid fish in 1998 also proved negative for these diseases.

**BKD.** Two new cases of BKD on trout farms were discovered in 1998, the first detected during a routine farm inspection, and the second during subsequent contact testing. The second, a major restocking site, was subsequently cleared and disinfected under CEFAS supervision, and controls for the disease lifted from the site. Despite these cases, there was a continued reduction in the number of sites designated for BKD in 1998 from 12 to 9, as 3 sites successfully completed a programme of negative testing for this disease. Four of the nine designated sites continued to test positive in 1998. Testing of wild salmonids for BKD continued in 1998 with 27 samples taken, none of which tested positive.

The isolation of BKD from only one river during the three year wild fish monitoring programme, and the continued fall in the number of infected farm sites, supports the contention that the disease has a limited distribution, and that controls to prevent its spread from infected sites remain valid. In order to improve our understanding of the disease, the Inspectorate continues to provide samples of fish for research on the disease at the CEFAS Weymouth Laboratory.

**IPN.** The voluntary retest programme at the single salmon hatchery site designated for IPN continued during 1998 with negative results, and it is hoped that controls on the site may be lifted in 1999.

**Gyrodactylosis.** All salmonid samples taken from both farmed and wild fish were screened for and tested negative for *Gyrodactylis salaris*. Other gyrodactylid species of lesser concern continue to be found on both farmed and wild stocks.

**SVC.** Of the 45 farm sites routinely sampled, only one tested positive (see below), while re-tests on 17 sites were all negative for SVC in 1998. Of the 145 investigations into disease outbreaks in fisheries holding SVC susceptible species, none were positive for SVC.

The re-testing programme on designated sites resulted in 10 sites testing negative for a third year and having their designations revoked. In addition, a designation placed on suspicion in 1996 was also revoked in 1998. This left a total of 14 sites designated for SVC at the end of 1998.

A programme to screen imports of ornamental fish resulted in the surprising discovery of SVC in carp from China. This led to a temporary ban on trade from China, and resulted in a major programme of contact chasing by the Inspectorate that covered importers, wholesalers and retailers of ornamental carp throughout England and Wales. SVC was confirmed at one wholesale site during this programme. This was cleared and disinfected under CEFAS supervision. Several other wholesalers opted to destroy stock and disinfect sites as a precautionary measure. The single fish farm site found SVC positive in 1998, was infected following contact between farm origin and Chinese origin ornamental stocks. This illustrated the need for, and value of, the import check programme.

## Import/Export trade

There continued to be a large demand for licences to import fish from countries outside the EU, with 592 licences issued in 1998. This was however a significant reduction on the 1997 figures due to changes in the licensing scheme for temperate ornamental species.

**Table 2. Imports and exports of fish monitored by the Inspectorate in 1998**

<b>A. Import licenses by category for trade from non-EU countries</b>	
Tropical species (annual licence)	185
Koi and goldfish (annual licence)	164
Specified Purpose (individual consignment)	171
Human consumption	73
Total	593
<b>B. Movement documents for EU trade</b>	
Import documents received/checked:	
Salmonid eggs	93
Turbot (for direct consumption)	120
Coarse fish	50
Shellfish	22
Others	57
Total	342
<b>C. Export documents issued:</b>	
Salmonids	8
Ornamental fish	121
Shellfish	63
Total	192

Table 2 gives details of the number and type of import licenses issued, and the number of movement documents issued for exports, by fish type.

The major import trade continues to be in tropical ornamentals, goldfish and koi from outside the EU. Imports from within the EU were predominantly salmonid eggs for aquaculture, and turbot for direct consumption.

Fish exports were largely of ornamental species traded within the EU, though there were a small number of salmonid egg exports.

The illegal import of coarse fish for introduction into fishery waters remained a significant concern for the Inspectorate in 1998. Positive steps have been taken to develop an intelligence led approach to combating this problem, in collaboration with other agencies, such as the Environment Agency, Customs and the Police. The HOTLINE number established to collect any information that callers believe could help prevent illegal imports, or other breaches of the fish health legislation remains in operation. The number is 01305 206681.

### **Import of Live Fish Act 1981 Keeping Licences**

From 1 November 1998 the Inspectorate took responsibility for assessing applications to keep non-native fish (as listed in the new Prohibition of Keeping of Live Fish (Specified Species) Order 1998) on fish farms. This Order places additional responsibilities on

those keeping species such as Brook trout and Landlocked salmon in farms or other waters. An advisory leaflet on the new legislation, with full details of the Order and the species affected is enclosed in this edition of Trout News. Further information is available through CEFAS Weymouth (01305 206673/4), or MAFF (0171 238 5931)

### **Conclusions**

The Fish Health Inspectorate carried out the majority of its functions successfully in 1998, despite staff shortages, the additional workload arising from investigations into the SVC outbreak and secondment of Inspectors to Scotland to assist with the ISA surveillance programme.

The Inspectorate continued its review of operating procedures in 1998. This has helped the Inspectors adopt a more consistent approach to all aspects of their duties, and also ensure that a clear, consistent and efficient means of addressing matters where law enforcement is required, is put in place.

It is hoped that the main benefits arising from this procedural review will be in respect of the detection and prevention of illegal imports. It has however lead to the implementation of a new procedure for checking those movement, mortality and veterinary medicine records which fish farmers are legally required to keep. I hope to report on the quality of farm movement records in the next edition of Trout News.



## **THE FISH HEALTH INSPECTORATE & YOU**

### **STANDARDS OF SERVICE – CITIZEN'S CHARTER PERFORMANCE RESULTS**

by Debbie Murphy, CEFAS Weymouth Laboratory, Barrack Road, The Nothe, Weymouth, Dorset DT4 8UB

### **Introduction**

The Fish Health Inspectorate aims to provide an efficient, quality service. Our standards of service have always been high and we are constantly looking for ways to improve them. Under the terms of the Citizen's Charter we are required to publish an annual summary of the results of our performance against the standards set. The results are reported in the MAFF publications

'Trout News' and 'Shellfish News', which are sent free to all registered fish and shellfish farmers. A copy of the results is sent separately to all fish and shellfish import licence holders.

The following report shows the performance achieved against our target of 100%, for the period 1st April 1998 to 31st March 1999.

Achieved in  
1998-99

## Correspondence

The Inspectorate's target is to reply to all letters and complaints, within 10 working days of receipt. **98.8%**

## Import Licence Applications

The Inspectorate has undertaken to issue import licences within 10 working days of receipt. **99.8%**

## Deposit Licence Applications

The Inspectorate issue crayfish, lobster and mollusc deposit licences, these are not currently covered by our Citizen's Charter Statement, but it is currently our aim to issue them within 10 working days'. **100%**

## Movement Document Applications

The Inspectorate has agreed to respond to all requests for movement documents, provided 5 working days' notice is given. **100%**

## Fish and Shellfish Farm Applications

### Registration visits

The Inspectorate has undertaken to visit all potential farmers Within 10 working days of receipt of their application. **57.2%**

### Registration administration

The Inspectorate aim to complete the administrative action within a further 10 days from the date of the visit. **100%**

## Notifiable Diseases

Respond immediately to a notification of suspicion of infectious salmon anaemia (ISA), infectious haematopoietic necrosis (IHN), viral haemorrhagic septicaemia (VHS), gyrodactylosis caused by G. salaris, bonamiosis and maritelliosis. **100%**

Respond to other notifiable diseases within 2 working days. **100%**

## Reporting of Test Results

The Inspectorate must report all negative test results within 5 working days of the full results becoming available and give a verbal report within 1 working day where a notifiable disease is found. **86.9%**

## Visit Reports

The Inspectorate has agreed to provide a follow up letter within 10 working days to advise the farmers in writing of any points raised during the visit. **82.4%**

## Overall Results

The overall compliance rate with our set targets. **93.6%**

The total correspondence received and recorded by the Inspectorate was 1726. Our performance fully met or approached our targets in most areas. We will continue to strive to achieve all our standards in 1999/2000.

## Customer Care Helpline

The purpose of our work is to prevent the introduction and spread of disease into and within England and Wales. This involves implementing European Community Fish Health Directives and administering and enforcing national legislation. In carrying out this work our main

aim is to ensure that you receive a high quality, cost effective service so that your compliance costs are kept to a minimum. The best way for us to measure our performance is to receive feedback from people who require our service. To help us achieve this we have set up a Customer Care Helpline on 01305 206673/4 where all complaints will be recorded and, thoroughly and impartially investigated. Our helpline staff can assist the customer to formulate the complaint and will explain in full our complaints procedure. They will also aim to send a reply within 10 working days and to ascertain whether the customer is satisfied with the outcome.

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## FARMED FISH QUALITY CONFERENCE BRISTOL, APRIL 1999

Alasdair Scott, CEFAS Weymouth, Barrack Road, The Nothe, Weymouth Dorset DT4 8UB

When I first saw the programme for this conference, organised by University of Bristol Veterinary School, and sponsored by Trouw, I had very mixed views on attending. The idea, to bring together representatives of all parts of the farmed fish industry from hatchery manager to supermarket buyer to discuss fish quality, was excellent. I was unsure, however, if the various groups would perceive common problems and means of addressing them, or take a very parochial view of their own problems. I am pleased to report that the conference proved an eye-opener to many participants and seemed to be valued by all who took part.

With representatives from 18 countries, covering fish farmers, feed companies, veterinarians, processing plant operators, packers and supermarket representatives, and talks ranging across all these disciplines, this was no mean achievement. That most of the participants worked in the salmonid, and particularly Atlantic salmon, industries was probably a key to the success of the meeting.

The 3-day meeting covered six main themes, the first being a general overview of fish quality considerations.

Professor John Sargent from the University of Stirling gave the first talk on the nutritional value of fish. He stated that wild fish are extremely valuable from a nutritional standpoint, being an excellent source of protein, iron, selenium and iodine. The flesh of oil-rich fish is an exceptionally good source of the very low chain polyunsaturated fatty acids (PUFAs) which are known to be beneficial in respect of cardiovascular and inflammatory disorders. Fish farmers should aim to maintain and exploit this high nutritional status in their fish production. While artificial diets do not produce the same flesh quality in farmed salmon as we find in

wild fish in respect of PUFAs, the oilier nature of the farmed fish results in a higher intake of beneficial PUFAs from eating farmed fish.

As aquaculture expands the supply of fishmeal, which contains oils with high ratios of beneficial PUFAs to non-beneficial FAs, cannot be maintained. There is therefore a need to source oil from vegetable seed sources. Prof Sargent showed that the use of seed oils such as soya or palm oil could detrimentally alter the PUFA ratios in farmed fish and significantly lower their nutritional value. While alternatives such as linseed or rape oil were better suited for use in fish feed, their supply was much more limited than that of soya or palm oil. If the nutritional status of farmed salmonids is to be maintained near that of wild fish, then there must be sparing use of vegetable seed oils.

The second speaker, Ian Johnson from the Gatty Laboratory, St Andrews, spoke about muscle structure in salmonids and how it could affect quality parameters such as texture and flesh colour. Muscle growth in fish is very different from that in mammals in that the number of muscle fibres within the muscle is not fixed from birth. While human muscles grow only by increases in fibre size (hypertrophy), a fish muscle can grow by both hypertrophy and recruitment, the laying down of new muscle fibres. In salmon there is an 18-fold increase in muscle fibre numbers in the anterior myotomes from 10,000 to 180,000 between the fry and smolt stages.

There is evidence that the roles of recruitment and hypertrophy in determining actual muscle structure can be influenced by photoperiod, temperature, diet, exercise, and genetic make-up. Both the texture and perceived colour of fish flesh are significantly affected by muscle

fibre density. So while this research is still at an early stage, it raises the possibility that in future farmers could, through manipulation of their rearing environment or genetic make-up, produce fish of optimum flesh texture to suit particular markets or products.

Karl Shearer from Seattle then spoke about the effects of diet composition and feeding regime on the composition of cultured fish. He concluded that protein content and amino acid profiles are fixed for a given size of fish, except for a small free amino acid pool. Ash content and elemental profile are also fixed unless the diet is nutrient deficient. Only fat content and fatty acid profile vary significantly, with the moisture content expressed as a percentage of body weight, varying inversely with the fat content.

Fish fatty acid profiles as discussed earlier reflect dietary fatty acid profiles. Nutrient imbalance in the feed may impair growth but lead to excess fat deposition. Withholding feed, even for an extended period prior to harvest, is a poor strategy for reducing fat levels to improve product quality (in addition to its dubious position with regard to fish welfare). The best strategy for obtaining a desired body composition appears to be the use of feeds with optimal dietary protein/energy balance, together with genetic selection of the stock.

Ole Torrissen from Bergen then discussed the texture and technological properties of fish, with reference to smoked Atlantic salmon fillets. He discussed how the recent development of objective measures of fish flesh texture could be used to determine factors impacting on the quality of salmon fillets for smoking or after smoking. The industry wish to improve yields of fillets, reduce processing losses, and gain an understanding of the cause of losses to gaping of fillets, and variations in flesh texture and means to extend shelf life of their products. As ever, the solution to these problems is not simple. For example, the yield of fillets is increased with increasing fish size and increase in dietary fat level. High fat levels, however, cause softening of the flesh and increase problems with fillet gaping. Consumers also have an aversion to fatty food, though in taste tests they actually prefer the taste of fattier fillets. Resolving the single issue of optimum fat level is therefore not as simple as it may initially seem.

John Springate then gave a talk on flesh colour in salmonids, which covered the substances producing colour in salmonids and other organisms, the potential sources of these pigments as feed components, and their measurement in fish flesh, particularly using colour card systems. He emphasised strongly the value of pink flesh as a marketing tool for salmonids and commented that improvements in the understanding of how to obtain uniform and accurate colour in fish flesh would be a major factor influencing any future expansion of the salmonid market worldwide.

Having discussed what goes to make a salmonid fish in these early talks, we then went on to find out how to make them taste good. Lisbeth Johansson from Uppsala spoke of her work with taste panels to investigate the eating quality of rainbow trout. They concluded that whether cooking in a conventional or microwave oven, trout tasted best when they were cooked until their internal temperature reached 55°C. Any increase in internal temperature led to a decrease in tenderness, juiciness, flavour and surface moistness of the fish. They did, however, recommend cooking until the internal temperature reaches 60°C in order to ensure that bacteria are killed. They found that starvation of fish, even on time-scales associated with normal pre-harvest practice, caused a reduction in freshness and taste, and also became less juicy if starved until lipid content started to be reduced. Not surprisingly, storage of fresh chilled or frozen fish reduced their eating qualities in respect of all the measured parameters.

The talks then moved to some of the problems faced in farming, handling and processing fish. First, Tony Laidler of Marine Harvest McConnell spoke about microbiological problems associated with the harvest and processing of salmon. He explained that spoilage organisms and human pathogenic bacteria posed significant problems to an industry in which long shelf-like products such as gravadlax and cold smoked salmon were produced, and that contamination of fish with such organisms could take place at about any stage in their harvest and processing operation. He illustrated how the HACCP concept is being used to control the risks from microbiological hazards in processing plants. While pointing out that salmon have not been implicated in any food-poisoning problems, he did illustrate that bacteria such as *Listeria monocytogenes* had been found in salmon during and after processing, and that persistence of this bacterium in biofilms in processing plants presented a significant problem which the industry must address. He stressed the need for research on plant disinfection and/or identifying the underlying causes of biofilm production and *L. monocytogenes* persistence.

Following bacteria we heard about contamination of food fish with veterinary medicine and vaccine residues. Peter Southgate of the Fish Vet Group spoke about the risks of such contamination and the regulatory framework within the EU for preventing contaminated fish reaching the human food chain. He pointed out that the level of variation in medicine use between countries, and in the abilities of different countries to detect and monitor for the presence of veterinary medicine residues, were a major concern. Fish farmers and vets need to be aware of the risks that residues may be present in treated fish, in adjacent untreated fish through water and feed contact, in farms downstream of a farm under treatment, and in potable water supplies affected by farm-sourced residues.

The final theme for this first session was the ethics of farming fish. Martin Cooke of Tesco Store Ltd gave a very clear talk on the retailer's position. He described ethical considerations as the cornerstone to exchange, affecting employment, trading, animal husbandry and environmental matters. While the retailer's aim is to provide a variety of high-quality, low-cost fresh products, they must take account of how that food was produced in each of these four areas of concern. Using the salmon industry as his example, he illustrated that as an employer of people in rural areas it was at an ethical advantage. From a trading viewpoint the quality, availability, low cost and increased consumption make salmon a success, but to protect the quality image, supermarkets were quick to ensure that they did not take stock from sites affected by the ISA outbreak.

Where animal welfare is concerned, Tesco expect to see fish produced in conditions that satisfy FAWC's "five freedoms": freedom from thirst and hunger, discomfort, pain, injury or disease, fear and distress, and freedom to express normal behaviour. They are acutely aware that welfare issues are often raised against the individual animal that was not protected, as opposed to recognising that the vast majority are well cared for. The industry must always be aware of this problem.

Increasing environmental awareness or concern among customers means that the impact of fish farming on the environment must be addressed, understood, and improvements made wherever possible, if its ethical position is to be maintained. Mr Cooke suggested that the production efficiency of salmon farming must be ethically robust, when a single 100m polar circle cage producing 250 tonnes of harvest size fish equates to the production of 6250 lambs on over 500 hectares of land. The industry, however, needs to be able to prove that such an amazing feat can be achieved in a humane and ethical way.

Tony Wall of the Fish Vet Group then spoke about pre-slaughter management and slaughter techniques and the need to balance product quality with satisfactory animal welfare. He stressed that pre-slaughter starvation should ideally be for the purposes of gut evacuation only, but where control of growth rates are required, then this should not be achieved by total cessation of feeding. Pre-slaughter stock densities should not be allowed to increase to a level at which the fish are stressed. During crowding, oxygen levels should be monitored and maintained, and crowding should not be prolonged or significant physical damage to the fish may result. Chilling and anaesthesia were discussed as means of reducing pre-slaughter stress, and the conclusion was that prior to slaughter fish should be rested, fasted, show no external damage, no muscle bruising and contain no residues. The slaughter process should be efficient, rapid, cause minimal pain and fear and increase product quality. A very difficult task.

The use of percussive stunning and exsanguination in the salmon industry was seen as an appropriate means of slaughter, but there exists no such efficient means of dealing with smaller species such as trout, eels and flatfish at present. The use of CO<sub>2</sub> narcosis, electric killing and suffocation in air or ice slurry were discussed. None of these methods were wholly acceptable, either on welfare or product quality grounds, and there is a clear need for R&D to establish alternative methods.

The second session covered the effects of husbandry on fish quality. Ian Michie of Marine Harvest McConnell spoke about the causes of downgrading in salmon farm production, and opened a few eyes to the scale of the problem. Downgrading can occur at the primary or secondary processing levels, and in MHM's case affected some 13% of their 1998 Scottish production of around 30,000 tonnes. Downgrades at primary processing were due to maturation colour changes (25.2%), mechanical damage at harvest (19.8%), misshapen fish (19.3%), "lice damage (13.1%), and other causes such as lesions, damaged operculae, etc (22.5%). Losses due to maturation effects can be up to 50% of the value of the fish. Misshapen fish typically have fused vertebrae often with surrounding cartilaginous growths which further reduce fillet quality. Losses attributed to lice not only cover direct lice effects such as haemorrhaging lesions, and loss of condition, but also physical damage which occurs during treatment, particular abrasion damage to eyes. Losses at secondary processing are mainly due to: flesh colour (39%) typically due to paler bellies and backs than fillet middles (striping); gaping of fillets (38.4%) due to rigor or soft flesh; and blood spots (18.6%) which reflect poor exsanguination and are a particular problem in smoked fillets. Financial losses are magnified in this case because the problem does not become apparent until the end of the processing cycle.

The next speaker, Dr Richard Alderson of Alderson Aquaculture, looked at the role of genetic selection in determining quality and, in particular, championed the need to maintain the eating qualities of farmed fish. He illustrated how selective breeding aimed at increasing the growth rate, meat yield, percentage of lean meat, and feeding efficiency of pigs had been very successful, but at the direct cost of the eating qualities of the pork they produced. Both meat texture and flavour are inferior to those of older breeds, despite the fact that one of the major determinants of flavour, intra-muscular fat levels, is highly heritable and therefore easily selected.

Comparing salmon farming to pig farming, Dr Alderson pointed out that there is great scope for selective breeding in a species so newly introduced to commercial culture, and that there had already been significant improvements made in respect of growth rates. With large cost savings to be made by the industry with every

improvement in growth rate, there is little wonder that such breeding programmes are in place. Breeding for improved disease resistance and fish appearance is also underway. There is clear scope to include eating quality as a criteria in such breeding programmes.

Dr Alderson illustrated the value of good flavour in a food product by reference to recent changes in the tomato trade. He contrasted the now standard high growth rate, high yield tasteless supermarket varieties with those re-introduced to the market by the likes of Marks & Spencer which have a greater variety of size, texture, colour and, above all, good flavour. The varieties are on sale for 4 to 6 times the price of the mass-produced varieties, even though their production costs are only double. Dr Alderson suggested that the lesson learned by some tomato producers, that flavour determines the ultimate value of food, is one which the salmon industry should note. Acceptance by the customer is a most important quality trait.

Three papers on feeding and nutrition were presented in this session. Dr Paul Morris of BOCM. Paul looked at nutrition and body composition. In a rapid-fire talk he reiterated much of Dr Shearer's earlier talk and presented results of several experiments, including those on the manipulation of fish composition by pre-harvest fasting. The take-home message was that while pre-harvest starvation does allow some manipulation of body composition, it does not make economic sense. In selecting a feeding regime, farmers should: know the aim of their production; buy and feed food of a composition which will give the production aim with continuous feeding; and monitor body composition throughout the growing period rather than do so as a last resort before harvest.

Dr David Nickell of Roche Products Ltd spoke about pigmentation regimes. He stressed how pigmentation can be affected by many factors, including pigment type, species and strain of fish, fish growth rates, maturation status, slaughter weight, fish health, feeding regime and pigment dose among others. To produce pigmentation to the required level and maintain it to harvest by the most economic route requires that a controlled pigmentation regime is put in place. Given the importance of colour in the marketing of salmon, it was important that producers do not compromise the pigment quality of their products.

Dr Remi Baker of MHM spoke about dietary micro-nutrients with particular emphasis on vitamin E on which he has worked extensively. Vitamin E is a powerful anti-oxidant which helps prevent the breakdown of protein and lipids in fish flesh, hence increasing its shelf life and maintaining its fresh colour. In addition, it has been shown that high vitamin E levels impart a high flavour score on poultry in taste tests, and could perhaps do equally so in fish. Other micro-nutrients such as vitamin C and carotenoids may also have anti-oxidant roles which could increase shelf life, as could certain fatty acid types which may impart storage quality benefits to the product.

Changing direction somewhat, Dr Tom Pottinger (IFE Windermere) spoke about the effects of husbandry stress on flesh quality. He discussed physiological changes occurring in fish as a response to either short-term (acute) or long-term (chronic) stresses. These include: reduced glycogen levels and increased lactate levels (especially in response to acute stress); mobilisation of lipids from muscles; decrease in muscle carbohydrate; alteration of muscle pH; depletion of muscle ATP; and a change in water holding capacity of muscle.

These have been shown to result in reduced meat quality in other products, though not so clearly in fish. Some research has suggested that chronic stressors such as high stock density and prolonged starvation do not affect flesh quality, and nor do acute stresses such as pre-slaughter crowding, slaughter and transport. Other studies, however, have shown clear evidence of problems, such as the more rapid and stronger rigor observed in Atlantic salmon stressed prior to slaughter and a decrease in fillet tensile strength from salmon stressed pre-slaughter.

Dr Pottinger emphasised that the development of reduced stress methods of dealing with fish prior to slaughter would have product quality benefits. They clearly also have wider benefits in terms of fish welfare.

*(The remainder of Alasdair Scott's Conference report will be published in the January 2000 edition of Trout News – Ed.)*

# THE USE OF IMMUNO-MODULATORS AGAINST DISEASE AND STRESS IN TROUT

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## Introduction

Immuno-modulators are substances which play a valuable role in aquaculture by improving the non-specific immune response to a range of pathogens. They are also effective in enhancing the response in fish which have a weak or developing immune system, as for example, in larval fish.

Aquaculture Vaccines Ltd has recently launched AquaVac Ergosan, an immuno-modulator which is a completely natural product and as such is an accepted feed ingredient. Ergosan is produced from marine algae and contains two active ingredients, alginates and polysaccharides which are known to strengthen the full range of material defence systems in fish. Alginates stimulate the active transfer of oxygen across cell membranes, allowing the cells to perform at a higher metabolic rate, enabling them to perform their role more effectively. This enhances both the fish's resistance to infection and ability to repair damaged tissues as well as increase the response to vaccination.

## Stress modulated disease resistance

Stress has been defined (Bly, *et al.*, 1997) as the reactions of the body to deleterious forces (stress factors) that tend to disturb normal physiological equilibrium (homeostasis). Stress factors may result in either acute or chronic changes in physiology and can impact on all the systems within the fish. Immuno-suppression can occur and is often associated with acute and chronic disease problems. However the effects can go well beyond specific mortality, with stress-related depression in growth and condition factor causing significant damage to the productivity of fish populations.

The active components of Ergosan alleviate stress-related losses in several different ways. They increase the metabolic activity of lymphocytes and macrophages and production of cytokines and lysozymes. The product also increases the activity of cells involved in skin integrity and mucus production. These reactions are likely to alleviate the impact of external 'stressors' such as poor water quality. This will reduce the chance of a stressful event leading to immuno-suppression chain reactions that cause disease outbreaks. The fish's enhanced defence systems reduce the likelihood of exposure to pathogens developing into disease following environmental stress.

There are many potentially stressful procedures carried out during farming operations including transportation and grading. During transport, fish are subjected to high levels of stress, which can include starving, crowding, handling, temperature fluctuations, water quality deterioration and introduction to a new environment. These stressors can frequently lead to the onset of disease. Fish infected prior to transport may well be healthy 'carriers' of pathogens. This means that the immune system is able to contain the infection. However, if the system is suppressed by stress, the 'dormant' pathogen has the opportunity to develop, multiply and start causing disease.

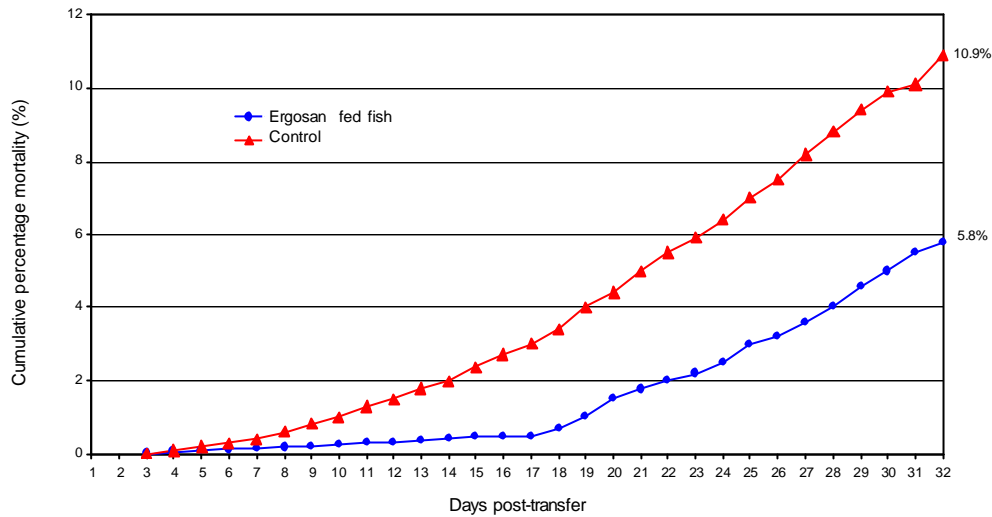
Ergosan is recommended for use prior to these predictable but potentially stressful farming operations. Trials using Ergosan at 0.5% in the feed for 5-7 days prior to pre-transportation starvation have been carried out in trout and other species of marine and fresh-water fish. Figure 1 shows the results of one such trial on the mortality of treated and control fingerling rainbow trout following transportation. Mortality rates are significantly reduced, the fish settle into their new environment quicker and return to full feeding faster. There is also a smaller reduction in condition factor and a lower incidence of transfer-related pathologies or disease outbreaks. Hatcheries should feed Ergosan as a matter of routine before moving or selling in order to maximise the quality of their juvenile fish.

## Alleviation of stress-induced disease syndromes

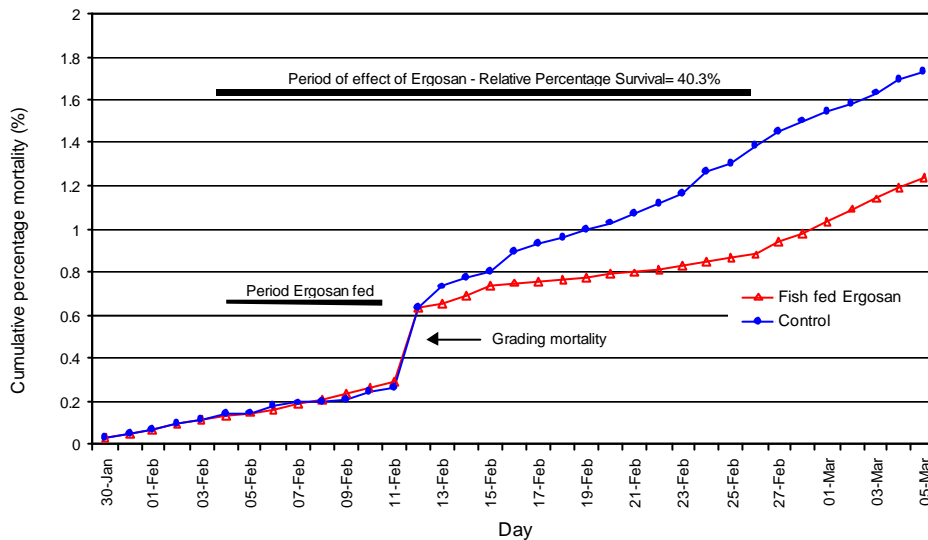
Ergosan can be used for the alleviation of stress-induced disease syndromes, such as Rainbow Trout Fry Syndrome (RTFS) caused by *Flavobacterium psychrophilum*. Stress is an important factor in the precipitation of this disease. Ergosan may be included in the feed prior to expected stressful husbandry manipulations such as grading and vaccination as well as transportation in helping to reduce mortalities from RTFS (Figure 2).

## Prevention of predictable disease outbreaks

'Prevention is better than cure' and all farmers are well aware of this laudable objective. However, despite following good husbandry practices (such as total vaccination strategies for the most serious diseases and



**Figure 1.** Graph showing the effect of Ergosan on reducing post transfer mortality of rainbow trout fingerlings (100/lb. or 4.5 g approximately). Data collected from Day 3 after transfer



**Figure 2.** Graph showing the effect of Ergosan on the reducing mortality of rainbow trout infected with RTFS

other disease prevention strategies), farmers still encounter predictable disease problems in their stocks. These disease cycles are often well established on the farm and associated with seasonal fluctuations in water quality, temperature and stocking densities or fish movements (harvesting or fry intake). Examples of these are Proliferative Kidney Disease (PKD), coldwater disease and Viral Haemorrhagic Septicaemia (VHS) in trout.

In addition to these specific pathologies, there are many 'syndromes' that may result from a combination of secondary pathogens and environmental and husbandry stressors that arise which can cause long term chronic damage to the performance of fish and the profitability

of farming operations. Ergosan has also been successfully used to treat secondary infections such as Columnaris and Whitespot in trout infected with PKD.

### Healing and recovery from disease and physical damage

The economic impact of disease and damage to farmed fish normally extends beyond the losses and costs associated with the acute outbreak. Stress and disease will affect the performance of farmed fish for many days after the event has apparently passed. During this time, the fish are susceptible to the same or other pathogens and they will have reduced growth rates and conversion

rates. The management of fish after treatment and disease or trauma is a critical factor in maintaining profitability.

Ergosan will speed up the recovery process and enhance the resistance of fish to reinfection during this phase. The active stimulation of the immune system will counter the effects of the disease and the side-effects associated with treatments. The enhanced activity of skin and mucus cells will accelerate the healing process of any wounds or lesions. This reduces the opportunity for secondary infection and also reduces the osmotic stress on the fish.

Antibiotic therapy often fails to completely cure and control bacterial infections in fish. Parasite treatments remove some forms of parasite but still leave damaged fish. Such treatments are often stressful to administer and there is normally a need for repeat treatments to clear all stages of the parasite from the environment. The infection and destruction of parasites make the fish prone to secondary infection. There are no effective treatments for viral infections.

Given this scenario it is clear that in the event of any disease outbreak, the rapid recovery and strengthening of natural defence systems is paramount in re-establishing the good health of the fish population. Ergosan should be used in conjunction with or following any specific treatment administered to fish. Trials carried out to date have shown that following treatment with Ergosan at 0.5% for up to 10 days fish return to and maintain a healthy condition much more rapidly than untreated fish.

## **Increased response to vaccination (vaccine adjuvant effect)**

Ergosan increases the fish's immune response to vaccination. The response of fish to vaccines can vary according to its health and previous exposure to the disease as well as with the specific characteristics of the vaccine. The 'adjuvant' approach has two purposes. Firstly, to increase the absolute response to the vaccine and secondly, to provide interim protection if the fish are infected during the immune induction period. The oral range of vaccines employs Ergosan as an adjuvant to improve the level and duration of protection in the fish. Oral vaccines are normally used to booster vaccinated fish which are in the environment where the disease is prevalent. Therefore both the specific and non-specific properties of Ergosan are very valuable in developing and maintaining strong immunity in the fish.

Currently a range of protection studies are underway to evaluate the level of protection induced by this approach. Field studies with trout, salmon and sea bass have shown that the interim effect is strong. Fish given Ergosan at 0.2% in the feed for the first five days of the vaccination programme concurrent with the vaccine develop immediate protection as opposed to those fed the unadjuvanted oral vaccine which experience a thirty day lag phase before they develop full immunity.

For further information contact Aquaculture Vaccines Ltd at the address given in the front of this article or by phone: 01799 528167, fax: 01799 525546, email: vaccines@avl.co.uk Web site: www.avl.co.uk

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## **GROWTH RATES OF TRIPLOID RAINBOW TROUT OVER THE SPAWNING SEASON**

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### **Introduction**

Over the past 20 years or so there has been considerable interest by fisheries biologists in the application of genetic engineering by the manipulation of chromosome sets to various fish species. Much of this work has focused on the induction of triploidy, where physical shocks utilising heat or high hydrostatic pressure applied to eggs soon after fertilisation causes retention of an extra set of maternal chromosomes. Triploidy has now been experimentally induced in over 40 species of fish, many of which include commercially important salmonid species like Atlantic salmon, brown and rainbow trout.

### **Effects of triploidy**

Triploids differ from normal diploid fish in three fundamental aspects:

- Firstly they contain three sets of chromosomes instead of the normal two sets as in diploid fish. This means they contain one third more genetic material and therefore potentially more heterozygous (genetically more variable).
- Secondly to accommodate the extra chromosome set individual cells are larger in volume but this is compensated for by a reduction in cell number in all the tissues and organs of the fish.

- Lastly triploids are sterile. This is because the extra chromosome set creates an imbalance in chromosome pairing during the special (meiotic) cells divisions in which eggs and sperm are produced in the gonads.

Given these fundamental differences it is perhaps surprising to find that a remarkable similarity exists between diploids and triploids in terms of their biology and physiology. Developmental rates are generally similar and morphologically they appear identical to diploids although some abnormalities have been demonstrated such as lower jaw deformities in triploid Atlantic salmon. Numerous studies have shown that despite an increase in cell size triploids do not grow larger than diploids due to a compensatory reduction in cell number and growth rates are little different. The main effect of triploidy, which confers the greatest advantage to farming these fish, occurs during the spawning season and to understand this the differences in sexual development between male and female triploids needs some explanation.

### Sexual development of triploid fish

Although no viable eggs or sperm are produced the degree of gonadal development is quite different between the two sexes which has important repercussions in terms of growth during the normal spawning season. In female triploids egg production is almost totally suppressed and the ovary remains diminutive throughout life. More importantly because steroid hormone production, which is associated with egg development within the ovary, is also totally suppressed, female triploid salmonids do not display secondary sexual characteristics and therefore continue to feed and grow throughout the spawning season. In male triploids the development of germ cells is also arrested at the pre meiotic stage but because of the vast number of cells involved the testes develop to near normal size. In addition the cells responsible for steroid hormone production (the interstitial cells within the testis) remain unaffected and consequently male triploids develop full secondary sexual characteristics (black coloration, kype formation etc) including suppression of feeding and growth. The main growth advantages resulting from triploidy can therefore be expected to occur during the first and subsequent spawning seasons.

### Growth rates

The following growth studies concentrate on the second year of production covering the first spawning season when most rainbow trout are expected to spawn. The graph in Figure 1 shows growth rates of mixed-sex populations of a winter spawning (Butley) strain of rainbow trout in which diploid and triploid fish were reared separately in tanks. Although growth rate of

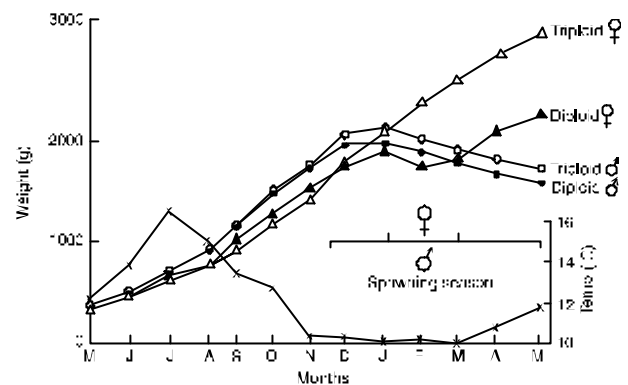


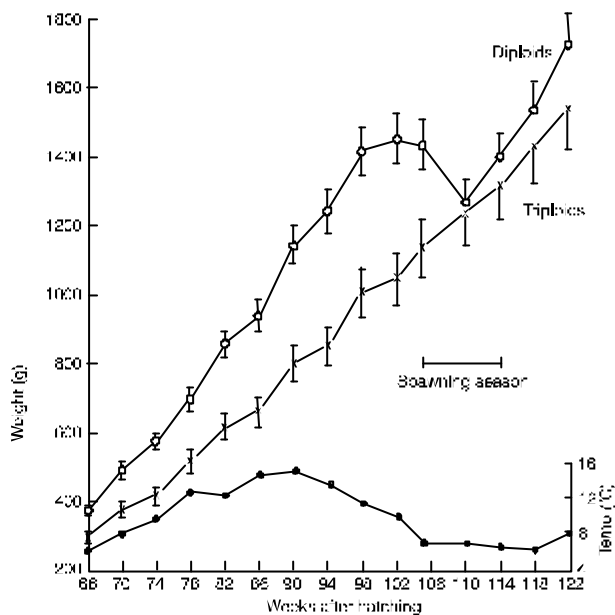
Figure 1. Growth rates of mixed-sex populations of diploid and triploid rainbow trout

both populations of male trout was initially superior over the seven month period leading up to the start of spawning (horizontal bar defines the period over which male and female populations were spawning i.e. spermiating or ovulating) growth steadily declined thereafter. Growth rate of diploid and triploid females was also similar prior to the spawning period but as a result of ovulation in the diploids and the consequent removal of eggs these fish rapidly lost weight. Although females quickly resumed growth after spawning, the uninterrupted growth of triploid fish resulted in a weight increment of some 800 grams above that of the diploids.

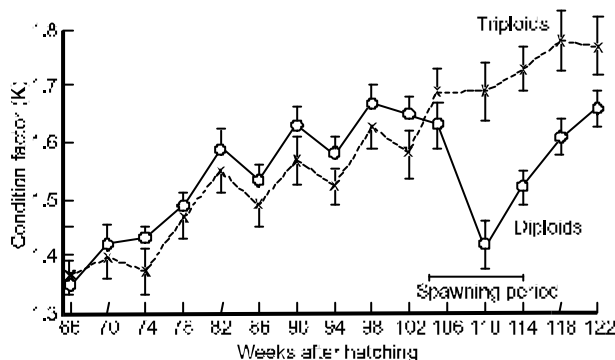
This experiment illustrates the poor growth that can be expected from male fish where growth cycles extend into the reproductive period (quite apart from the loss of flesh quality) and the commercial consequences that may accrue where supposedly all-female stocks become contaminated with male fish.

Figure 2 shows growth rates of an Autumn spawning (Caribou) strain of rainbow trout in which female-only populations of diploids and triploids were reared together in the same tank. The better growth of diploid fish in this experiment may be due to competitive effects since some studies have suggested that triploids are less aggressive and therefore not as effective in competing for food. In spite of the usual loss in weight as a result of spawning, diploid fish remained heavier and put on weight faster during the post spawning recovery period, although continued growth of the triploids had considerably reduced the weight difference.

Figure 3 illustrates the changes in condition factor of fish in the last experiment which is calculated as weight over the length cubed ( $W/L^3$ ). Typically triploid fish have a lower condition factor, being longer or leaner for their weight than diploids. Condition plummets in diploid fish with the removal of eggs but is quickly made up during the post spawning recovery period.

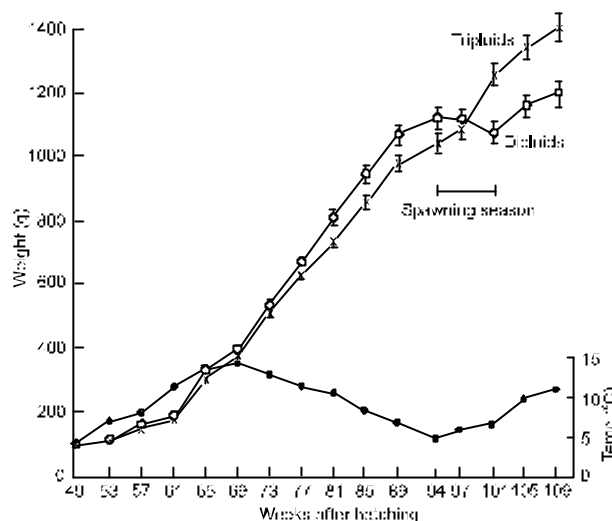


**Figure 2. Growth of female diploid and triploid trout reared together. Vertical bars are + standard error of the mean (SEM)**



**Figure 3. Changes in condition factor between diploid and triploid trout**

Figure 4 shows growth rates of another winter spawning (Winthrop) strain in which female-only populations of diploids and triploids were reared separately. Although the rates of growth was again better in diploids leading up to the spawning period the differences were much smaller than in the previous experiment. Consequently triploid fish gained a greater advantage over diploids during the spawning season ending up nearly 300 grams heavier. This is a smaller weight gain than that shown in the first experiment due to the prevailing low water temperature which had clearly depressed growth preventing triploid fish from realising their full growth potential at this time.



**Figure 4. Growth of female diploid and triploid trout reared separately**

## Conclusions

Farming sterile female triploid trout should eliminate the problems of poor growth and flesh quality associated with sexual maturity which is inevitable when large fish are required in value added products where production cycles may extend over a two year period or longer. To obtain the maximum growth advantage it is desirable to rear triploid females in isolation which in practical terms means achieving as high a rate of triploidy as possible and ensuring that 'all-female' stocks are not contaminated with male fish. The use of hydrostatic pressure in preference to heat shock in inducing triploidy has increased the efficiency of the process in recent years, leading to more consistent levels of triploidy in fish available to farmers. For pan-sized fish of between 300-400 grams where grow-out cycles of less than a year are common, the use of triploids confer no advantage and do not warrant the extra cost of their production.

Triploids are also useful in other areas of commercial production. For example they are proving highly successful in trout fisheries, particularly those in which angling is permitted throughout the winter months. This effectively removes the problem of spawning fish which was one of the main obstacles to all year round angling. Sea water culture of trout is another area which benefits from the use of triploids. The ability of salmonids to regulate salt intake (osmoregulate) is severely impaired during the period of sexual maturity when mortality rates are significantly increased. Again the use of sterile triploid females are helping to reduce losses and improve the profitability of this area of production.

# FERTILISATION PROCEDURES FOR USE IN ALL-FEMALE BROOD PRODUCTION

Stephen Baynes, CEFAS Conwy Laboratory, Benarth Road, Conwy, North Wales, LL32 8UB

## Introduction

When all-female production became common in the mid-eighties we tried to develop procedures to make the use of masculinised genetic females simpler. The testes from masculinised genetic females often have to be excised from the fish to be used for fertilisation. The degree of hydration is less than in testes from normal males and consequently the milt is so thick that sometimes it cannot even be poured from a container. This has made artificial fertilisation more awkward and less effective than farmers would like. We have recommended dilution of the suspension of spermatozoa from 'reversed testes' with 'Modified Cortland extender' (see below for the formulation) that not only improves the efficiency of fertilisation, but also allows storage of the diluted milt for a day or two in a refrigerator. However, the composition of the extender is too complicated for easy production and so a series of trials was carried out to identify a simple extender which would be as effective in aiding fertilisation. It was also an aim that the materials used would be readily available to anyone, not just a pharmacist, and so make the extender much more economical to produce.

At the same time as recommending the Modified Cortland extender we also suggested the use of a buffered sodium chloride fertilisation diluent. This is beneficial at fertilisation since it keeps yolk from broken eggs in solution and avoids blockage of the egg micropyle, which would otherwise prevent sperm entry. It also overcomes the inhibition of spermatozoan motility that occurs in the milt and extender. The buffer (which stabilises the pH) that had been used in this diluent was not readily available to most farmers and so an alternative compound that would work in conjunction with the new extender was needed.

This article summarises the outcome of the trials and it is hoped that it will provide a reminder that fertilisations with reversed milt can be obtained relatively easily using these simpler procedures.

## Modifications to the extender

To simplify the Modified Cortland extender, the compounds used to buffer the pH (sodium hydrogen carbonate and sodium dihydrogen orthophosphate) were omitted together with glucose, which can promote microbial contamination. The concentrations of the other components were varied and, in all, ten solutions were used in the experimental formulations together with Modified Cortland, which acted as a control. All were

tested for their influence on sperm activation, motility, and egg fertilisation rate. The results from five of these compounds, when compared with Modified Cortland solution and the use of non-extended sperm, indicated that there were no differences in percentage rates of fertilisation. The non-extended milt was more difficult to use and mix with the eggs than the extended milt, but the fertilisation rates were as good. For ease of preparation and use we therefore recommend the simplest formulation tested, which was just potassium chloride (chemical formula KCl) at a concentration of 10 grams per litre, made up in tap water. Potassium is important because it inhibits the activity of the sperm, before it is added to the eggs. Potassium chloride is sometime available in health-food shops and supermarkets as an alternative to the normal salt, sodium chloride.

## Use of extender solution

The following procedure is recommended for collecting and extending the milt from masculinised genetic females.

The testis should be removed as soon as possible after killing the fish, otherwise the sperm may die because of a lack of oxygen. It should be wiped clean of blood with absorbent tissue and then cut open with several cuts made with a sharp blade. Put the cut testis into a plastic or glass pot, preferably on an ice/water mixture at 0°C (do not use ice straight from a freezer as this may be below zero and freeze the milt). Allow the milt to drain from it for about 20 minutes and add an approximately equal volume of extender solution at the same temperature and mix thoroughly. The extended milt can be treated like normal milt and used straight away or kept for about 24 hours in a refrigerator at 5°C or below. If stored for use the following day the testis itself should be discarded and the depth of extended milt in the container should be no more than 5 mm deep to allow adequate oxygen exchange for the sperm to respire.

## Fertilisation solution

Sodium bicarbonate (chemical formula  $\text{NaHCO}_3$ ) was found to be a suitable fertilisation solution for use with the sperm extender which gave as good results as the buffered sodium chloride that had been suggested originally. The solution is made up by dissolving 10 grams of sodium bicarbonate in 1 litre of tap water. In use, the volume of fertilisation solution required should be enough to just cover the eggs so that they can be readily mixed. A large excess of solution does reduce the efficiency of fertilisation.

## Fertilisation procedure

Eggs should be stripped “dry” according to normal hatchery procedure into separate bowls and if they appear to be of good quality then they may be combined into one large container ready for fertilisation. The eggs should be kept cool and out of direct sunlight during collection. Immediately prior to fertilisation sufficient fertilisation solution (sodium bicarbonate) at the same temperature should be added to just cover the eggs. Now add the extended milt, which should be used at the rate of 2 mls per 10,000 eggs using a plastic dropper pipette. Immediately after adding the milt the eggs should be stirred gently, but thoroughly by hand for a few seconds to ensure mixing. This is essential when fertilising large quantities of eggs at a time as sperm activity is maintained for only about 30 seconds.

If milt is used straight from the testis, i.e. not diluted with extender solution, then one good sized testis per 50,000 eggs should be used. It may be easier to cut the testis open in the bowl of eggs to which the fertilisation solution has been added. Again mix the eggs and milt together quickly to ensure thorough mixing which is particularly important in this case because of the thick consistency of milt straight from the testis.

## Testing for sperm motility

If there is some doubt over the ripeness of the testis that is being used it may be desirable to check that the sperm is active. This can be done using a microscope at a magnification of x 100. A small drop of milt, the size of a pinhead, is placed on a microscope slide and covered with a glass cover slip. When viewed under the microscope this will be seen as a very dense suspension of inactive spermatozoa. Focus on the edge of the sperm mass and add a small drop of fertilisation solution to the edge of the cover slip. This should activate the spermatozoa, which will begin to swim vigorously in more or less straight lines for about 30 seconds in a good sample. If the swimming is mostly around in tight circles the sperm is less good and best used immediately without storing. If there is little or no swimming, the milt sample should not be used, as fertilisation will be poor.

A haemocytometer slide or a cavity slide are the most convenient microscope slides for testing activation in this way. However, plain slides can be used if the cover slip is supported just above the slide on two additional cover slips; the fertilisation solution can then be introduced at the edge into the gap.

## Egg fertilisation check

An assessment of the fertilisation rate can be made on eggs the following day (ideally around 15 hours after fertilisation at 10°C). Add about 20 eggs to a clearing fluid composed of equal parts of glacial acetic acid, methanol and distilled water. After a few minutes in this

solution it is possible to see the developing embryo. Focus on the white ‘pip’ (germinal disc) in each egg using a low-power dissecting microscope or a hand lens under bright illumination and look for cleavage lines that divide the germinal disc symmetrically into cells. A single white disc with no cleavage lines indicates the egg has not been fertilised. This has to be checked within 24 hours; after more than 1 day’s development the cells are so small it becomes difficult to see the lines even when the eggs have been successfully fertilised. The clearing fluid may be stored on the shelf.

## Some important points to note

1. Use only very darkly pigmented masculinised females that cannot be stripped by hand. Males showing poor secondary sexual coloration are more likely to contain unripe testes.
2. Ripe testes are white and soft. Unripe testes are grey in colour, firm to the touch and little or no milt exudes from them when cut open; they cannot be used and must be discarded.
3. Masculinised females appear to mature more slowly than normal males, which may lead to a shortage of ripe fish at the beginning of the spawning season. Several studies have shown that maturing female trout release a chemical (pheromone) via the urine which stimulate levels of sex steroids and milt production in male fish. Therefore in order to hasten/synchronise sexual maturity in masculinised fish include a few maturing females together with the males in the same tank.
4. Modified Cortland extender does have some advantage over the simplified formula if the testes contain a large proportion of immature sperm that do not activate initially. Storage in the extender does apparently increase the number of potentially active sperm and their motility. In all cases however it would be best to use only completely mature masculinised females at the time that eggs are being released. For those interested, the instructions for making Modified Cortland are given below:

Modified Cortland extender is made up by mixing two separately prepared solutions. The ingredients cannot all be mixed together without a precipitate forming.

Solution 1		grams/litre
Potassiumchloride	KCl	9.00
Sodiumchloride	NaCl	2.35
Sodiumdihydrogen orthophosphate	NaH <sub>2</sub> PO <sub>4</sub>	0.51
Magnesiumsulphate	MgSO <sub>4</sub> ·7H <sub>2</sub> O	0.29
Calciumchloride	CaCl <sub>2</sub> ·2H <sub>2</sub> O	0.29
Solution 2		
Sodiumhydrogen carbonate	NaHCO <sub>3</sub>	5.00
Glucose	C <sub>6</sub> H <sub>12</sub> O <sub>6</sub>	5.00

Both solutions should be made up in distilled water.

They can be made up in bulk and stored until required. Solution 1 contains only Inorganic salts and can be kept in a refrigerator for several weeks, or else frozen. Solution 2 contains glucose and must be stored frozen in order to prevent bacterial growth. The solution should not be mixed and then frozen because precipitation of some salts

may occur on thawing. Thawing of the solutions must be total to maintain the correct salt concentrations.

The complete extender is made by mixing 4 parts of solution 1 with 1 part of solution 2. It might be convenient to store measured aliquots such as 80 ml of solution 1 and 20 ml of solution 2: these can be mixed after thawing.

## NEW BROODSTOCK DIETS

John Williamson, Trouw (UK) Ltd, Wincham, Northwich, Cheshire CW9 6DF

### Introduction

Quality broodstock are essential for the future success of all fish farming activities, providing the required number of high quality juveniles. This article summarises the current knowledge available on broodstock nutrition and its influence on broodstock performance.

The limited number of published studies, have mainly focused on the relation between nutrition and egg quality, with an emphasis on: -

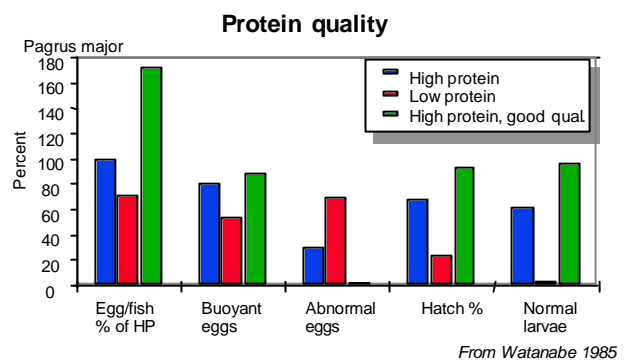
- Egg volume, size and quality.
- Fertilisation and hatching percentage.
- Development and survival in offspring.

Production of large parent fish is desirable, as large fish tend to produce more milt and larger eggs, which in turn may enhance fertilisation, and produce larger offspring with improved survivability. Most nutritionists agree that the nutritional requirements of broodstock are greater than those of 'production' fish. Nutrition is known to have a great effect upon gonadal growth and fecundity. Quality and quantity of feed, including the feeding regime are important factors for maintaining reproductive indices and increased fecundity. It is important to maintain an adequate food supply till vitellogenesis (development of the eggs) is complete. Any reduction in rations during the final stages can lead to reabsorption of oocytes and reduced fecundity. Obviously, good dietary palatability is important to ensure maximum feed intake, which is ensured by the careful selection of high quality raw materials. In addition, it is also important to ensure that the diet contains elevated levels of a number of important micronutrients.

### Protein

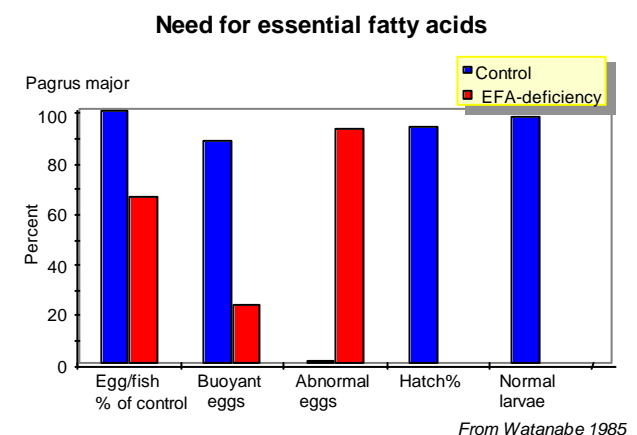
Research suggests that both protein level and protein quality are important factors determining egg production, egg and fry quality. In trials, a high level of

highly digestible protein resulted in improved fecundity, % hatch and larval quality.

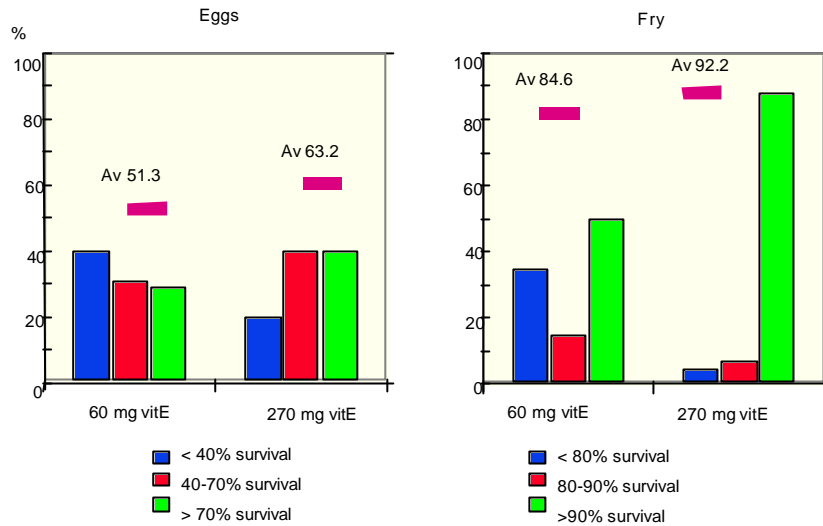


### Fatty Acids

The essential n-3 & n-6 fatty acids (EFA) are required for normal reproduction and egg development. EFA deficiency will also lead to deformations in juveniles. The importance of docosahexaenoic acid (DHA) (22:6n-3) has been highlighted because of the fundamental role DHA has during embryonic development particularly for the development of brain and nerve tissues. The effect of EFA-deficiency is much more pronounced in marine fish than in salmonids



### Vitamin E in salmon broodstock diets; effects on eggs and fry



Unpublished results from  
Inst. of Nutrition (Waagbø et al)

## Micronutrients

### Vitamin E

Vitamin E is important for the control of reproduction, testicular function, macrophage function and intra cellular oxidation in mammals. In fish, a deficiency will effect the number of spawning fish as well as egg and juvenile survival.

Studies with salmon have shown a clear effect of increasing vitamin E level on egg survival and fry survival in fish fed high dietary levels of highly unsaturated fatty acids (HUFAs) which suggests that the vitamin E requirement is higher during reproduction than for normal growth.

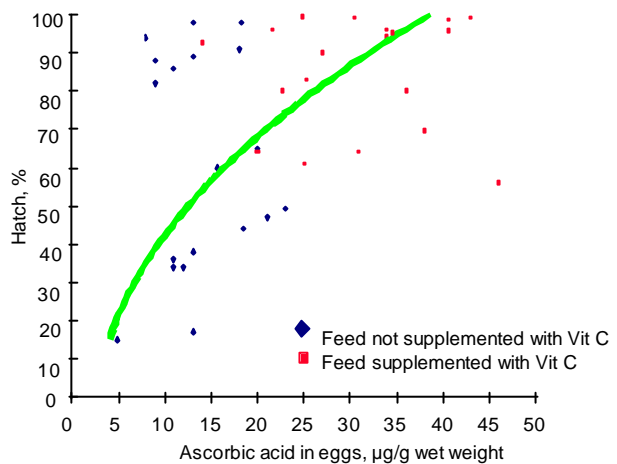
### Vitamin C

Teleost fish, like some mammals, including humans cannot synthesise, vitamin C (ascorbic acid) and must rely on an external dietary source. Vitamin C is important for the formation of bone and cartilage tissue, the function of the non-specific immune system and as an anti-oxidant. A deficiency will result in reduced growth, reduced egg production and reduced egg quality. Requirements for normal growth tend to decrease with fish age but increase during sexual maturation.

Studies with trout have shown that the hatch % is dependent on dietary (and thus egg) level of ascorbic acid.

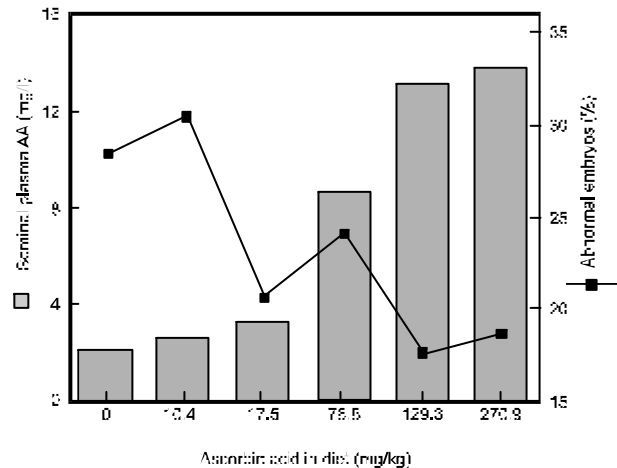
A more recent study has shown a similar relationship exists between dietary levels of ascorbic acid and normal sperm production in male rainbow trout. Low levels of ascorbic acid in seminal plasma of males during the breeding season, associated with corresponding low levels

### Effect of Vitamin C on egg quality in trout



From Sandnes et al. 1984

### Effect of Vitamin C on sperm quality in trout



From Ciereszko et al. 1999

in the diet, resulted in a high percentage of abnormal embryos in the offspring. In this case low antioxidant levels of ascorbic acid was implicated in damage to the sperm DNA since the abnormalities observed in the progeny were similar to those derived from sperm exposed to UV irradiation. This suggests ascorbic acid has a protective role against mutations to male germ cells during development in the testis of the fish.

### ***Vitamin A and Astaxanthin***

Vitamin A is important for vision, cell proliferation (growth) and the function of epithelial cells including ovarian, testicular, vaginal and corneal epithelium in mammals. A deficiency in parent animals can lead to reduced fertility and deformations in the offspring.

Next to nothing is known about the relation between broodstock nutrition and reproduction in fish with respect to vitamin A. The reason for this could be that vitamin A is stored in other forms than retinol (which is toxic) in the eggs. It is also suggested that the requirement for vitamin A can be covered by carotenoids and in particular astaxanthin.

In addition to being a pro-vitamin A, astaxanthin is also an effective antioxidant and it is suggested that astaxanthin participates in the respiration processes in eggs. It is uncertain if fish have a specific requirement for astaxanthin, but it has been shown that astaxanthin is effectively transferred from feed to eggs in salmonids and also in marine species. Positive effects of astaxanthin on egg quality have been demonstrated, and that supplementation of astaxanthin during start feeding has a positive effect on the growth and survival of juveniles.

### **Microminerals**

Supplementation of micro-minerals is required for normal reproduction but requirements above those needed for normal growth have not been established.

Based on these well-founded nutritional requirements, Trouw Aquaculture has a range of feeds designed specifically for broodstock fish. For best results these diets should be fed 8-12 months prior to spawning.

Further information can be obtained from Trouw Aquaculture UK on Tel: 01606 561090.

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## **POLICY MATTERS**

# **MAFF REVIEW OF FISH AND SHELLFISH CULTIVATION AND HEALTH**

Caron Montgomery, MAFF Chief Scientists Group, St. Christopher's House, Southwark Street, London SE1 OTE

## **Introduction**

This report summarises discussions which took place at a meeting held in London on 2/3 March, 1999 which formed an important part of a wide ranging review by MAFF of its R and D programme on aquaculture. The overall aim of the meeting was to provide a forum in which constraints and opportunities for the development of GB aquaculture could be discussed, and R and D needs and opportunities identified for the years 2000 - 2005.

## **Background**

MAFF is required to review its R and D programmes every 4-5 years. The review process helps develop future research strategy and ensures priorities are clearly identified and research properly focused. For aquaculture, MAFF has two principal policy aims; to encourage the development of a diverse, competitive and sustainable fish and shellfish farming industry and to safeguard farmed and wild stocks against disease.

Research is funded in support of these two priorities. MAFF last reviewed its aquaculture programme in 1994, and a joint MAFF/SOAEFD review of fish health was undertaken in 1995. The constraints and priorities considered in the current review would again include Scotland as well as England and Wales.

## **Terms of reference and approach**

The terms of reference for the review were:

- To identify the constraints to the further development of a competitive and sustainable aquaculture industry in Great Britain.
- To consider what research was required to support the Government's disease control policy for fish and shellfish including wild stocks.
- To assess the extent to which these constraints and requirements are being addressed by the current R and D programme (including Aquaculture LINK) and hence to identify gaps in the programme.

- To consider policy and scientific objectives and agree priorities for GB research for the period 2000 - 2005.

To help MAFF identify constraints and research priorities two assessors, Richard Slaski (aquaculture) and Patrick Smith (health), were commissioned in September 1998 to undertake a wide ranging survey of industry and the research community. Based on consultations with over 150 groups and individuals and the assessors' own personal views and experience, each prepared a report covering their area of remit which were widely circulated prior to the meeting. Over 50 industry and research representatives were invited to the meeting which was chaired by Mr Llewelyn, Head of Fisheries Division II, MAFF.

The meeting considered 5 aquaculture sectors namely salmon, trout, shellfish, marine fish and ornamentals but only the main issues concerning trout are included here. The report briefly describes the assessors' principal findings, the industry response to these reports and discussions on the R and D needs and opportunities for the next 5 years. The findings do not give MAFF or SOAEFD priorities for R and D but will help guide both Departments in developing their own strategies and requirements for research.

## Identification of constraints to trout aquaculture

The assessors considered trout to have less potential for growth compared with salmon which appeared to have considerable potential for expansion providing limitations on site availability could be overcome. Welfare, nutrition and product quality were the main concerns affecting the trout industry, with disease continuing to be the major constraint. Although the losses caused by disease were difficult to establish precisely, considerable gains in production could be made by reducing disease levels. The present rationale for legislation in controlling the spread of disease and protecting wild stocks could itself be a constraint on the industry particularly with respect to movement restrictions and slaughter requirements and also the lack of effective treatments due to restrictive licensing.

In response to the assessor's report Mark Davies for the BTA outlined the development strategy for the trout industry which had the ultimate aim of producing an additional 2,700 tonnes over the next 3 years. Four classes of constraints were identified:

- Structural, including the EU fish health regulations and UK legislative framework in which the industry had to operate, covering abstraction, effluent and welfare issues.
- Markets, including international competition and competition from other species especially salmon, and public concerns over environmental impact and animal welfare.

- Input constraints arising from water supply, feed stock quality and egg and fry supply.
- Production constraints, including disease, availability of treatments, lack of potential to diversify into other species, limited stock improvement to date and welfare.

## Identification of R and D needs

The assessors reports and discussions earlier had identified a number of constraints and opportunities that would require research if UK aquaculture was to expand. Eight priority areas under cultivation were identified of which three applied to the trout industry. Fish welfare was considered one area with a high priority where on going EU consideration of guidelines would require GB interests to be represented backed up by scientific knowledge. A wide but important field with a moderate to long term priority was the genetic improvement of farmed fish. This was considered essential in helping the long-term sustainability of any food producing sector. Nutrition was another medium to long term priority particularly in the replacement of marine-origin raw materials. This was probably mainly a feed company area of research but public funding could contribute to the difficult area of fish oil substitution for maintaining the nutritional value of fish to consumers.

For health aspects the assessor singled out three specific diseases that required research priority in the trout sector. These were PKD (life cycle studies and vaccine development), BKD (diagnostics development and presence of organism in wild fish) and white spot (vaccine development). PKD would be the subject of a MAFF sponsored workshop in the autumn, with the aim of improving co-ordination and prioritising research needs. In the assessor's view MAFF's current R and D programme was well focused and provided coverage of the major disease issues but there was a need for more epidemiological studies, risk assessment and life cycle studies.

The principal R and D issues and priorities presented by the industry were water and effluent management (supply, use and reuse, quality and treatment) and the following aspects of production:

- Stock quality and selection breeding programmes. Priorities here included dedicated selective breeding programmes for trout and egg, fry and fingerling production.
- Egg and fry supplies with a priority for year round supply.
- Optimising culture through a better understanding of the biotic requirements of fish. This would involve improved understanding of fish behaviour, physiology, on-farm welfare and stress in relation to culture conditions.

- Nutrition. This involved fish meal and fish oils with the aim of achieving rapid growth rate by investigating nutritional needs under different growing conditions.
- Product quality. Variations in flesh pigmentation still occur causing problems with processing. A more efficient way of achieving pigmentation was needed since this was a significant cost factor.

For fish health aspects, in addition to the specific diseases identified in the assessor's report the industry also included RTFS, VHS and IHN in their list of R&D priorities. For each, where appropriate, research on life cycle studies, fish health management, availability of medicines, development of vaccines and disease control measures would be required.

## Conclusions

This Review provided a useful opportunity to consider constraints on and opportunities for aquaculture in Great Britain which would help MAFF Policy customers identify R&D priorities. Particular points noted were:

- it would be helpful for all sectors to establish their own development strategies; MAFF was encouraged by the work already done by SSGA, BTA and the British Halibut Association and by the plans that were being developed for the shellfish sector;
- there was support for CARD (Committee on Aquaculture Research and Development), including use of sub-groups as appropriate;
- there was also support for LINK and that it had succeeded in directing Government funds towards industry priorities, in introducing new contractors and ideas to aquaculture R&D and in developing more rigorous and transparent systems for appraisal project proposals. The disadvantages had been the bureaucracy involved. MAFF and the other sponsors would now be considering future arrangements;
- there is a clear need, to involve the industry in the development of contingency plans for dealing with outbreaks of major diseases;
- research into one topic of major importance to the shellfish industry, shellfish hygiene, was now being undertaken by MAFF Food Hygiene Division, the responsibility for this would eventually pass to the new Food Safety Agency.

As far as research priorities were concerned, there seemed to be general agreement that MAFF's current programmes are on the right lines. More specifically:

- **Disease control** remained a high priority. For notifiable diseases, a particular priority was to establish the prevalence of the relevant pathogens in wild and farmed fish; this might then require a reappraisal of existing control policies. Another priority was the development of rapid, sensitive and quantifiable diagnostic methods. More generally, work was needed on pathogen life cycles; immunology and vaccine development, epidemiology and risk assessment; and coastal zone and catchment management in relation to disease control strategies;

- research was needed on the **environmental impact of aquaculture**. Particular priorities in England were the impact of trout farms on river systems, and how this might be alleviated, the role of shellfish production in coastal zone management and the impact of mussel seed exploitation. It would be important to involve other regulators, such as the Environment Agency and English Nature, in this work;
- research was needed into **fish behaviour**, both in order to improve welfare and with a view to optimising management systems;
- research on **fish cultivation** would continue to be funded principally through LINK or its successor. Topics for further research were likely to include genetic improvement of fish and shellfish stocks; flesh quality; fish nutrition; and the development of new species, possibly in relation to recirculation systems.

## Research priorities

There was general agreement that MAFF's current programmes were on the right lines. More specifically:

- **Disease control** remained a high priority. For notifiable diseases a particular priority was to establish the prevalence of the relevant pathogens in wild and farmed fish which may require reappraisal of existing control policies. Also development of rapid, sensitive and quantifiable diagnostic methods was required. More generally work was needed on pathogen life cycles, immunology and vaccine development, epidemiology and risk assessment, and coastal zone and catchment management in relation to disease control strategies;
- **Environmental impact** studies was a particular research priority in England in relation to trout farm discharges on river systems and how this might be alleviated. It would be important to involve other regulators such as the Environment Agency and English Nature in this work;
- **Fish behaviour** research was required to improve welfare with a view to optimising management systems;
- **Fish cultivation R and D** would continue with likely topics to include genetic improvement of fish and shellfish stocks, flesh quality, fish nutrition, and the development of new species possibly in relation to re-circulation systems.

## The way forward

MAFF will now reflect on the outcome of the review and prepare ROAME (Rational, Objectives, Appraisal, Monitoring, Evaluation) documents which will detail policy objectives and the requirements for research which will form the basis for calls for proposals over the next five years. Research on fish cultivation will continue to be funded principally through LINK or its successor.

# MAFF/BTA FUNDED RESEARCH

## LATEST ON TROUT RELATED LINK AQUACULTURE PROJECTS

Compiled by Dr Mark James of Link Aquaculture

The final round of LINK Aquaculture application assessments will take place in November 1999. By this stage, the programme will probably be supporting 35 projects with a total value of approximately £10 million pounds (including Government and industry contributions). Overall, the trout sector has fared well, with the LINK Programme Management Committee endorsing 7 projects directly related to trout, with a total value in excess of £2m. The British Trout Association has presented well justified priority areas for industry relevant research, many of which have been developed into collaborative research and development (R&D) projects through the LINK programme.

Pivotal to the success of collaborative approach to R&D is the desire of industry and scientific project partners to seek objective solutions to often complex problems with limited time and resources. LINK Aquaculture has demonstrated that commercially focused research can produce remarkable results of direct benefit to the industry. An equally important outcome from some of the Programme's most successful projects has been the desire of industry partners to contribute further, to less applied scientific studies. This commitment is borne of a confidence in the scientific community to deliver information that could profoundly influence the future competitiveness of aquaculture in the UK.

The trout farming sector, in particular, has a very healthy attitude to R&D conducted on its behalf and a refreshing desire on the part of individual farmers to actively participate in R&D projects – long may this continue.

Considerable progress has been made in a number of trout related LINK projects and what follows is a brief summary of this work:

### **Malachite Green alternative – TRT01**

*Project Leader: Mr Julian Braidwood  
(Vericore Ltd)*

*Sponsor: MAFF*

It is anticipated that this link project will result in Pyceze being brought to market very soon. An application for a provisional Marketing Authorisation for the treatment and control of fungal infections in eggs has been made and all outstanding questions have been answered. Vericore are hopeful of the MA being issued very soon. Similarly, the grant of an Animal Test Certificate to allow field trials in fish is expected imminently.

Both SEPA and the EA have indicated they should be able to consider discharge consent applications soon and Vericore therefore, expect to conduct further trials in fish and have product available this summer.

All work to date demonstrates that Pyceze is equivalent in efficacy for the treatment and control of fungal infections in eggs and fish to Malachite Green. Pyceze has the benefit of a wide safety margin when compared to negative controls; with, no mortalities in eggs attributed to treatment and no abnormalities in fish from treated eggs, monitored to swim up fry. Tolerance trials in fish also indicate a very wide safety margin.

Ecotoxicity tests show that Pyceze is environmentally sound and a favourable response is anticipated from SEPA and the EA.

Early indications are that Pyceze may have many other applications, for example, in controlling against Bacterial Gill Disease, RTFS and other bacterial infections. The product has the potential, therefore, to become one of the most useful medicines in managing the health of farmed fish.

*By: Ms Joanne Hardwick*

### **Identification and assessment of chemical control methods for Proliferative Kidney Disease (PKD) – TRT04**

*Project Leader: Dr Sandra Adams*

*(University of Stirling)*

*Sponsor: MAFF*

Significant progress has been made with the project and results of trials, in particular, results of field trials, are very encouraging.

Fourteen compounds have been tested for activity against PKX *in vitro*. All compounds tested showed positive activity against PKX *in vitro*, at a wide dose range. The results of *in vitro* testing were very promising, and short-term trials *in vivo* were undertaken to confirm results. Compounds were administered to PKD-infected rainbow trout at 5-10 times the recommended dose by manufacturers. Results of this investigation showed that seven compounds directly affected the parasite in host tissues, however, high doses administered also caused severe damage to host tissue.

Three field trials were carried out in 1998. Nineteen compounds were tested in a dedicated trial unit with endemic PKD. Field trials were designed to examine the effect of compounds administered orally in feed. Medicated feed was administered to experimental fish for five weeks, following detection of PKX using PCR. Groups were weighed and tissues were sampled weekly. Tissue was analysed by immunohistochemistry using the PKX specific monoclonal antibody. Results of trials indicated that two compounds reduced the proportion of fish manifesting kidney swelling and appeared to cause a delay in PKD infection. In further trials, it was found that experimental groups treated with two other compounds caused a fluctuation of infection and immunohistochemical analysis showed that parasites were directly affected by the chemicals.

In conclusion, from the nineteen compounds tested, two compounds showed an effect on the progress of PKD infection, while two compounds appeared to directly affect parasites. Detailed trials will be undertaken in 1999. Two compounds were selected from the four candidates to be further tested in more extensive field trials.

*By: Dr Sandra Adams*

### **Development of vaccination methods for the control of Bacterial Kidney Disease (BKD) in salmonids – SAL10**

*Project Leader: Dr Sandra Adams  
(University of Stirling)*

Significant progress has been made in the project with the standardisation of a BKD challenge, production of monoclonal antibodies to *Renibacterium salmoninarum*, development of methods to detect and identify the pathogen, and the preparation and testing of recombinant antigens.

The BKD aquarium facility at Stirling has been re-located, modernised and approved enabling BKD challenges and thus vaccine evaluation to be performed throughout the year. The challenge method has been standardised and a variety of rapid specific methods (both antibody and molecular based) to detect *R. salmoninarum* in fresh and fixed tissues developed and optimised.

Two fusion proteins have been prepared by Plymouth and are presently being evaluated as recombinant vaccines at Stirling. Initial trials with one of the vaccines indicated toxicity to the fish. Further processing of the antigen, however, enabled this vaccine to be utilised safely. The results from these trials will be available shortly. Two more fusion proteins are currently being prepared at Plymouth. In addition, the development of novel recombinant antigens is under way.

*By: Dr Sandra Adams*

### **Assessment of chemical and potential immunological control methods for *Ichthyophthirius multifiliis* – TRT06**

*Project Leader: Dr Rod Wootten  
(University of Stirling)*

*Sponsor: MAFF*

The characteristic whitespots of the protozoan *Ichthyophthirius multifiliis* in the epidermis of host fish are well known and the parasite causes high mortalities in both commercially reared food and ornamental fish. The control of this disease is notoriously difficult and since methods are rather ineffective, alternative treatment compounds are required. Researchers from the Institute of Aquaculture, University of Stirling, University of Plymouth, Vericore Limited (formerly Grampian Pharmaceuticals), the British Trout Association and the Scottish Salmon Growers Association funded under the LINK Aquaculture Programme have assessed the efficacy of eight anti-protozoal compounds. Four compounds tested *in vitro* have demonstrated degrees of effectiveness against the various stages of *I. multifiliis*. Two compounds are particularly promising as in-water treatments and one is 100% effective against all stages of the parasite. *In vivo* trials of both in-water and in-feed compounds are in progress but two of the in-feed compounds have been found to significantly reduce the number of trophonts on rainbow trout receiving medicated feed. Following the completion of the laboratory-based studies the efficacy of the most promising compounds will be assessed under field conditions. Research at the University of Plymouth is directed towards the *in vitro* culture of *Ichthyophthirius multifiliis*. The approach has been to design culture systems which best simulate the fish epidermis. This has included the building of complex fish cell layers in culture and introducing the infective stage of the parasite within the overlay media. Although the research is at an early stage, *I. multifiliis* has been shown to recognise and invade these cultured layers, the observed events corresponding closely to those recorded in the normal infection process of live fish. Potential applications of the current work include the development of a standardised approach to the screening of new drugs against ichthyophthiriasis and the investigation of parasite responses to immunological agents.

*By: Dr Andy Shinn*

### **Subcage collection and disposal of wastes from freshwater cage production of trout – TRT08**

*Project Leader: Mr Michael Aldridge  
(Drummond Estates)*

*Sponsor: NERC*

The project objectives are to evaluate the potential for the introduction of subcage collectors to prevent waste solid deposition in freshwater lakes, and the treatment of the collected wastes. As part of this project, therefore, it

was required that the nature of the solid wastes themselves was determined. Characterisation of the solid wastes produced by cage farms has now been completed, and it is clear that the particle sizes are small, with more than 90% of particles being <450 microns in diameter, and possessing a high organic content (>50% carbon by dry mass).

The waste collectors installed at the two sites have, to date, produced poor collection efficiencies, and work in the forthcoming year will be focused on attempting to improve our understanding of the flow of particles from the cages, and adjusting collector configurations accordingly. Monitoring of collector performance is to be increased in intensity during the summer period.

Field studies have not so far indicated any adverse effect upon water quality within the cages fitted with collector devices. Monitoring of water quality is to be maintained throughout the critical summer period, particularly with respect to dissolved oxygen levels through the cages. From laboratory trials of anaerobic digestors, it is clear that the waste from fish farms is highly digestible, and results confirm that +90% of BOD, +50% of COD and c. 50% of total solids are removed at mesophilic (35°C) temperature.

*By: Dr Liam Kelly*

### **Investigations into non-specific and acquired immune responses to rainbow trout fry syndrome (RTFS) with a view to disease control – TRT10**

*Project Leader: Professor Randolph Richards  
(University of Stirling)*

*Sponsor: MAFF*

The first 6 months of this new project has seen significant progress towards an improved understanding of the humoral response to immunisation with *Flavobacterium psychrophilum*. Additionally, the autoagglutinating properties of the bacterium have been studied

A series of experiments have been completed in which the antibody response in rainbow trout to immunisation with adjuvanted soluble proteins of *F. psychrophilum* and to whole inactivated and live cells have been examined. Humoral response to soluble proteins has been undetectable and variable but low antibody levels have been measured against dead whole cells. However, high levels of agglutinating antibody following immunisation with live cells have been demonstrated. It has also been shown that this trout gamma(I)globulin has considerable *in vitro* bacteriostatic activity against *F. psychrophilum*. These results have significant implications for vaccine development as they indicate that a protective antibody response can be elicited.

Autoagglutination is the capacity of bacterial cells to aggregate together in culture, a property which is frequently linked to virulence. It has been noted that the virulence of

*F. psychrophilum* in laboratory challenge trials is closely correlated with this ability. Amongst the Flavobacteriaceae the tendency to autoagglutinate appears to be directly proportional to the level of mucopolysaccharide which envelopes the cells. It is speculated that this exopolysaccharidic substance is required not only for the group's characteristic gliding motility but, for attachment to host tissues. It is therefore a good determinant of virulence and may be a useful candidate as an immunogen.

Further work is in progress focusing on characterisation of protein and lipopolysaccharide antigens of *F. psychrophilum* using Western blotting analysis. It is anticipated that once optimised this method will provide information on potential antigens for use in future putative vaccines. Additionally, passive immunisation studies will be carried out in rainbow trout fry to determine the *in vivo* effect of the anti *F. psychrophilum*-globulins.

*By: Dr Rachel Rangdale*

### **Automated humane slaughter of trout – TRT07**

*Project Leader: Dr Jeff Lines*

*(Silsoe Research Institute)*

*Sponsor: MAFF*

Concern within the industry that trout welfare may be compromised by some slaughter methods has prompted investigation into slaughter methods, with the aim of identifying and developing a demonstrably humane method which can be automated safely and economically. This work is supported by BTA, five major supermarket chains, Aquatess and the Humane Slaughter Association. We have tested a range of methods for stunning trout while monitoring welfare indicators such as swimming ability, sensibility, eye reflexes and whole body responses. The results suggested that, on welfare grounds, rapid stunning methods such as percussion and electric stunning are to be preferred to other methods such as killing in air, ice slurry or carbon dioxide. Quality assessments of these fish were then made by a group of fish buyers. This assessment included flesh texture, fillet haemorrhage, gaping and frame damage. For most of the stunning methods there was little difference in fish quality. However some quality problems were associated with the electrically stunned fish. This was an unwelcome find, though not altogether unexpected. The use of electricity to stun trout is attractive since it is system which could be relatively simple and cheap to automate. It can also be inherently safe since only low voltages are required. Investigations are therefore underway to examine a range of alternative electric stunning techniques in order to identify solutions to the quality problem. If no feasible solutions are found then other techniques for stunning fish will be investigated further.

*By: Dr Jeff Lines*

Summary information on all LINK Aquaculture projects, including latest programme news, can also be found on the LINK Aquaculture Website at: [www.linkaquaculture.co.uk](http://www.linkaquaculture.co.uk)

## INFORMATION FILE

### TROUT NEWS ON THE INTERNET

The internet has become an important communication medium for fish farmers throughout the world and to this end it has been decided to place Trout News on the

World Wide Web. Starting with the last issue (number 27, dated February, 1999) Trout News can be accessed on [http://www.cefasc.co.uk/trout\\_news.htm](http://www.cefasc.co.uk/trout_news.htm).

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### CODE OF PRACTICE ON THE RESPONSIBLE USE OF ANIMAL MEDICINES ON THE FARM

The Veterinary Medicines Directorate has issued the above code of practice which is available free to all users of animal medicines. The code provides general guidelines for the safe and responsible use of medicines and covers aspects of planning to prevent disease, authorised sources, correct administering and record keeping, precautions to be

taken, observance of withdrawal periods, storage and safe disposal of medicines.

Anyone requiring a copy or further information on the Code of Practice should contact Phil Davies at VMD, Addlestone, Surrey on direct dial 01932 338332.

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### MEASURES TO PROTECT NON-NATIVE FISH

Enclosed with this edition of Trout News is a copy of a leaflet prepared by CEFAS and the Environment Agency which gives full details of new measures introduced in November 1998.

The measures made it illegal to keep, or release certain non-native fish in any waters, including fish farms, in England and Wales without a licence.

# BRITISH TROUT FARMING CONFERENCE, SPARSHOLT 1999

Wednesday 1st, Thursday 2nd and Friday 3rd September 1999

## PROGRAMME

### Wednesday 1 September

All day Traders set-up

1900 Trouw Barbecue

### Thursday 2 September

0900-1000 Registration

Morning Chair: Niall Bromage, Institute of Aquaculture, Stirling

1005-1015 Welcome and Opening Address  
Tim Jackson, Principal, Sparsholt College Hampshire

1015-1040 European Trout Markets: The Danish Experience  
Vibeke Kristiansen, Kristiansen Fish Farms, Billund

1040-1045 Discussion

1045-1110 The Salmon Industry: are there lessons for trout?  
George Hide, Sparsholt College

1110-1115 Discussion

1115-1145 Coffee

1145-1210 Review of Fish and Shellfish Cultivation 1999  
Richard Slaski, British Halibut Association

1210-1215 Discussion

1215-1240 Trout and Charr: "I did it my way...."  
Philip Bowden-Smith, Caledonian Trout Company

1240-1245 Discussion

1245-1415 Lunch

Afternoon Chair: Christopher Saunders-Davies, Test Valley Trout Limited

1415-1440 The Future of the Pig Industry: are there lessons more for trout?  
James Miles-Hobbs, Andersons Farm Business Consultants

1440-1445 Discussion

1445-1510 The Trout Industry Review  
John Giles, Promar International

1510-1515 Discussion

1515-1545 Tea

- 1545-1610 Trout Farms – Drinking at the “Last Chance” Saloon?  
Mark Davies, Chairman, British Trout Association
- 1610-1700 Open Forum: The Trout Industry into the next Millennium
- 1900 BOCM Pauls Reception
- 1930 Conference Dinner  
Dinner Band: *Tipsy Tunes*

### Friday 3 September

- 0900-0945 Registration and Coffee
- Morning Chair: John Springate, F. Hoffmann La-Roche
- 0945-1030 The Buckland 1999 Lecture: Eel: The Eurofish  
Christopher Moriarty, The Buckland Professor 1999  
(*Members of the public are invited to attend the Buckland Lecture*)
- 1030-1035 Discussion
- 10.35-1100 French Caviar Makes a Comeback: recent progress in the development of sturgeon farming  
Alan Jones, Sturgeon SCEA & Ecloserie de Guyenne, SA
- 1100-1105 Discussion
- 1105-1135 Coffee
- 1135-1200 Suppliers’ Forum: Exciting new products  
Air Products, AVL, Aqua Systems, Ewos, Spirex Aquatech
- 1200-1205 Discussion
- 1205-1240 Typical Trout Production Problems in Ontario  
Hugh Ferguson, Institute of Aquaculture, Stirling
- 1240-1400 Lunch
- Afternoon Chair: Nick Read, Alderley Trout Limited
- 1400-1425 Notifiable Diseases: Implications for Trout  
Randolph Richards, Institute of Aquaculture, Stirling
- 1425-1430 Discussion
- 1430-1455 Review of Fish and Shellfish Health 1999  
Patrick Smith, Aquaculture Vaccines Limited
- 1455-1500 Discussion
- 1500 Tea and Close of Conference

For further details please contact Shaun Leonard, Sparsholt College Hampshire, Winchester, Hampshire SO21 2NF.

## EC RESEARCH PROJECTS

### PROGRESS IN AQUACULTURE R AND D PROJECTS SPONSORED BY THE EUROPEAN COMMISSION

Many aquaculture and related food science and technology research programmes are sponsored through the EC, but dissemination of the results from these programmes often remains below expectations. The purpose of this new section is to keep the fish farming industry updated on intermediate or final results of EC sponsored research programmes relating to salmonid fish. Most of the projects involve research scientists from different countries. The name, address and phone number of the principal researcher (i.e. the main contractor who also acts as the co-ordinator of the project), is given at the end of the text for each project. For more information on a particular project or the partners involved, readers should contact the appropriate co-ordinator directly.

#### **Minimising the interaction of cultured and wild fish: a comprehensive evaluation of the use of sterile, triploid Atlantic salmon**

This project was designed to evaluate the comparative biology of diploid and triploid Atlantic salmon. It was intended to inform the debate on the overall usefulness of sterile triploids for culture given the concern, on the one hand among fish stock managers, that escapes of diploid stocks from aquaculture operations are a potential threat to diminishing wild stocks and, on the other hand, the belief in the minds of fish farmers that triploids are more difficult to rear and will make their operations less efficient. Comparisons were made in a number of areas: performance in fresh and sea water culture, behaviour on release, product quality, potential for somatic growth, exercise physiology and disease resistance.

Performance trials in Ireland and Norway used mass spawned or family based groups respectively. Triploids were found to grow very similarly and to survive as well as diploids in fresh water. In sea water, triploids grew similarly to diploids but in two of four sea water trials suffered higher losses (ca 10 - 15%) than comparative diploids. Family differences were often as great as ploidy differences. Progressive cataract formation was seen at higher levels in triploids but skeletal deformity levels were generally low in the stocks used (Scottish

and Norwegian origin). The sterility of female triploids was confirmed. No commercial differences of any significance were seen in the flesh quality of diploids and triploids. Releases of triploid and diploid stocks were made in Ireland and Norway but significant recaptures were only made in Ireland. Here, fewer triploids returned after their release. Because triploids have larger muscle cells but fewer of them, they showed a reduced rate of fibre recruitment. This was compensated by an increase in muscle fibre hypertrophy so that overall muscle growth rates in triploids and diploids was similar. Triploids performed very similarly to diploids in a number of swimming tests. However, in a prolonged trial triploids volunteered a lower mean swimming speed than diploids. C start and muscle twitch contraction times were shorter in triploids. Non-specific and specific disease parameters varied with ploidy and family and no consistent pattern of inferior performance in triploids was noted. Similarly, no consistent differences were seen in the susceptibility of triploids during live agent challenges.

These findings confirm the general similarity rather than difference in the biology of triploids. If yields of triploids under farming conditions are lowered it is most likely to be a consequence of their poorer sea water survival. This aspect of their performance would need to be better understood and improved by management methods introduced before farmers could be entirely confident that yields of triploids could match those of diploids under all circumstances. Triploid female salmon remain immature during the farming cycle and could not successfully interbreed with normal fish.

The advantages and disadvantages of triploid use are presented alongside other impact minimisation options. Hopefully, this will enable policy makers to balance the costs and benefits of individual options in deciding the preferred option(s).

This project was carried out under the AIR (Agriculture and Agro-Industry Research) programme (contract CT 942216). Final Report (years 1994-1998). Project co-ordinator: Ray Johnstone, Scottish Office, Agriculture Environment and Fisheries Department, Fisheries Research Services, Marine Laboratory, Aberdeen, AB11 9DB. Telephone number 01224 295621.

## RESEARCH NEWS

The following abstracts of recent research work are taken from papers published in international scientific journals and aquaculture magazines:

### Food intake and utilisation in slow and fast growing strains of trout

Two rainbow trout strains differing in their growth performance were used to study possible interactions between genotype, dietary composition and feed level on their feed utilisation efficiency and voluntary feed intake. Two diets (35 and 45% of crude protein) and two feeding levels (to satiation or at a restricted level of 2% of body weight), were used. The two diets were distributed, in duplicate, for each strain, during a four month growth trial. At the end of the experiment the digestibility of the two diets was determined in each strain, using chromic oxide, as a marker, and an automatic system for the faecal collection. The body composition of both strains was also analysed. The final weight of fish of the fast growing strain, fed to satiation, was significantly higher than that observed for fish of the slow growing strain. No significant differences were found between the strains for body weight when a dietary restriction was made. Results observed for the feed-gain ratio were also similar between the two strains. The apparent digestibility coefficient (ADC) of dry matter and energy were significantly different between the two diets but similar for both strains. No significant differences were observed in protein digestibility in the diets, although one of the strains appeared to show a higher ADC for protein. Body composition as well as nitrogen and energy retention were similar for both diets and strains.

#### Reference

VALENTE, L.M.P., FAUCONNEAU, B. AND DOS SANTOS GOMES, E.F., 1998. Voluntary feed intake, feed and nutrition utilisation in slow and fast growing rainbow trout strains. *Aquatic Living Resources*, 11(2): 93-99.

### Male potency in rainbow trout

Individual male potency in rainbow trout was examined using the fertilization ability of fresh and cryopreserved sperm. One female and four males bearing genetic markers enabling determination of the progeny paternity were chosen as the source of gametes. Samples of eggs were inseminated with sperm from separate individuals or with pooled sperm. Genetic examination of the progeny obtained after fertilization of eggs with pooled milt showed differences in male potency. The proportions of offspring sired by four individual males after fertilization of eggs with the fresh milt were similar

to those obtained after fertilization with cryopreserved milt. These proportions did not correlate with the proportions of progeny resulting from fertilization of eggs when sperm was not pooled.

#### Reference

BABIAK, I., GLOGOWSKI, J., LUCZYNSKI, M., GORYCZKO, K., DOBOSZ, S. AND KUZMINSKI, H., 1998. The effect of individual male potency on fertilization ability of fresh and cryopreserved milt of rainbow trout, *Oncorhynchus mykiss* (Walbaum). *Aquaculture Research*, 29(5): 337-340.

### Field efficacy of fumagillin against PKD

Proliferative kidney disease (PKD) of salmonid fish is an internal parasitic infection with an, as yet, unclassified myxosporean parasite, the so-called 'PKX'. Malachite green and fumagillin are the only chemotherapeutants capable of controlling this disease. The efficacy of a single 10-day treatment of fumagillin, orally administered at 3 mg per kg body weight (BW) per day was assessed in 14 day field trials conducted during the summers of 1994 and 1995 in trout farms located in France and the United Kingdom (UK), using populations of juvenile rainbow trout, naïve to PKX infection. Each population was divided into a treated group and an untreated control group that were run in parallel. The first day of medication (DO) was determined by collection for examination of a random sample of 50 fish within each population prior to the medication. Depending on the frequency of the PKX cells in kidney imprints from these samples (2-8%, 10-30% or >30% frequency), fumagillin treatment was commenced at either 15-21 days, 7-15 days, or immediately after parasitic examination. Assessment of the treatment efficacy was based upon comparisons between treated and control groups of the distribution of renal hypertrophic lesions, final survival rates, total losses in body weight and food conversion rates (FCR). The tolerance to the product was quantitatively assessed by comparing the intermediate survival rates among groups on day 35; the end of a critical post medication period identified in previous studies. Most treated fish exhibited significantly fewer severe lesions (mean reduction in frequency of 59.1%). A mean relative percent survival (RPS) of 36.7% in PKD mortality was obtained. RPS was highest in moderate cases of PKD. The mean difference of overall survival rates was +7.8% in favour of treated fish. The mean reduction of weight

loss was 32% in treated fish compared to controls. An improvement of FCR was detected when a very severe PKD infection occurred in the farm. Overall, this study confirmed that fumagillin is a safe and effective treatment for PKD in salmonid fish when administered at 3 mg/kg BW per day for 10 days during the PKD incubation phase.

### Reference

LE GOUVELLO, R., POBEL, T., RICHARDS, R.H. AND GOULD, C., 1999. Field efficacy of a 10-day treatment of fumagillin against proliferative kidney disease in rainbow trout *Oncorhynchus mykiss*. *Aquaculture*, 171(1/2): 27-4

### Sediment effects on brook trout eggs

This study was designed to determine effects of different fine sediments (0.43-0.85 mm in diameter) on survival of brook trout (*Salvelinus fontinalis*) eggs during early developmental stages under laboratory conditions. Intragravel permeability and dissolved oxygen declined with increasing fine sediment amounts. Survival at each developmental stage generally declined with increasing fine sediment amounts, although not significantly for all stages. Differences in survival to emergence were not significant due to a large amount of variation in survival estimates. Survival of eggs and alevins declined linearly through time for all fine sediment treatments. In general, fry weight declined as the amount of fine sediment increased but fry length changed little. These results indicate that increased levels of fine sediment may reduce survival of brook trout through early development.

### Reference

ARGENT, D.G AND FLEBBE, P.A., 1999. Fine sediment effects on brook trout eggs in laboratory streams. *Fisheries Research*, 39(3): 253-262.

### Effect of timing and duration of feeding astaxanthin on pigmentation

The efficiency of pigmentation and the variation and development of fillet colour was assessed in rainbow trout fed astaxanthin (Ax) enriched diets at different stages of fry development and for different periods of time. Triplicate groups of 165 rainbow trout were fed a fish meal-based diet containing 31 mg/kg Ax at start weights of 6.5 ± 2 g (B), 120 ± 5 g (C) until reaching a market weight of 400 g. A control group received a diet without Ax throughout the experiment. The chromaticity of the dorsal and Norwegian Quality Cut (NQC) regions of the fillets were assessed at regular weight intervals by tristimuli colorimetry. The Ax concentration of the NQC region was determined by HPLC. The final flesh Ax concentration in the pigmented groups ranged from 5.5 ± 0.3 µg/g in group C

to 8.0 ± 0.5 µg/g in group B. There were large variations in fillet colour irrespective of the timing and duration of Ax intake and the variations were significantly higher in the dorsal muscle compared to that of the NQC. Inter and intra-fillet variations in pigmentation were reduced with increase in wet weight, irrespective of the duration of pigment intake. There appears to be an innate variation of 20-25% in flesh pigmentation in any one stock at a market weight of 400 g. Irrespective of the timing and duration of Ax intake, the initial development of colour was greater in the NQC region, followed by the muscle along the lateral line and dorsal region, respectively. Pigmentation of the NQC region occurred faster and remained at a higher level than that of the dorsal region.

### Reference

NICKELL, D.C. AND BROMAGE, N.R., 1998. The effect of timing and duration of feeding astaxanthin on the development and variation of fillet colour and efficiency of pigmentation in rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, 169: 233-246.

### Sludge treatment from land-based fish farms

This paper describes both an experimental and a commercial-scale system for sludge dewatering and stabilisation. In the experimental system, back-wash water from rotating disk microsieves was settled in a conical sedimentation tank which functioned well, commonly removing more than 75-80% of the solids, at an overflow rate of 1 to 2.7 cubic metres per hour. The hydraulic load was maintained low, so treatment efficiency was significantly positively influenced by inlet concentration and not inflow rate. Lime was added to the settled sludge which killed more than 99.9% of pathogenic viruses and bacteria within 7 days at pH 12. In the commercial system, a newly developed combined effluent treatment and sludge processing system was located in a large Norwegian salmon smolt farm. Four drum microsieves were used to separate particles from the primary effluent flow. The back-wash water, amounting to a maximum of 0.3% of the 30-35 cubic metres per minute primary flow, was dewatered using another drum microsieve. Dewatered back-wash water from this sieve was pumped to a sedimentation tank with a top surface area of 3.3 square metres and a volume of 5.5 cubic metres. This system produced on average 0.7 L settled sludge containing about 10% dry matter per kg of feed supplied. Sludge tapped from the bottom of the sedimentation tank was stabilised by mixing with lime. This system produced on average 0.7 L settled sludge containing about 10% dry matter per kg of feed supplied. After stabilisation, the stored sludge was diluted with cattle manure and spread on agricultural land. The primary treated effluent was discharged into the receiving marine water body where no settled solids were detected on the seabed at the outlet point. The running costs of

effluent and sludge treatment, including sieving, settling and stabilisation, amounted to US\$ 0.056 per smolt produced, or about 5% of the total production costs.

### Reference

BERGHEIM, A., CRIPPS, S.J. AND LILTVED, H., 1998. A system for the treatment of sludge from land-based fish-farms. *Aquaculture Living Resources*, 11(4): 279-287.

### Exposure of trout to diluted sewage plant effluent

Brown trout populations of numerous Swiss rivers are declining due, possibly, to sewage plant effluents. To investigate this brown and rainbow trout were exposed to 10% diluted sewage waste water over a period of 12 months. The effects were compared to trout kept in commercial tap water. The mortality rate was low and no pathogenic bacteria or viruses were recorded in exposed or tap water animals. Parasitological examination revealed a mild infestation with *Gyrodactylus* sp. in all groups. Macroscopically and histologically, only minor changes in gills, skin and kidneys of exposed animals were found when compared to fish kept in tap water. Degenerative and inflammatory lesions in the liver of exposed animals were the most prominent findings. Several brown trout caught in the River Langete showed marked proliferative, degenerative and inflammatory lesions of gills, liver and kidneys. The results do not suggest that waste-water effects would explain the decrease of fish populations. However, it is conceivable that the effluents in combination with other factors in the river enhances the development of changes.

### Reference

SCHMIDT, H., BERNET, D., WAHLI, T., MEIER, W. AND BURKHARDT-HOLM, P., 1999. Active biomonitoring with brown trout and rainbow trout in diluted sewage plant effluents. *Journal of Fish Biology*, 54: 585-596.

### Physiology and behaviour of triploid fish

Induced triploidy is widely accepted as the most effective method for producing sterile fish for aquaculture and fisheries management. Artificially produced triploids generally differ from diploids in three fundamental ways: they are more heterozygous, they have larger but fewer cells in most tissues and organs, and their gonadal development is disrupted to some extent. Despite these basic biological differences, triploids are similar in most respects to diploids when examined at the whole animal level. The only clear differences relate to the effects of impaired gametogenesis on the reproductive physiology and

behaviour of triploids, especially in females. Other apparent differences include reduced aggressiveness, occasional specific morphological abnormalities, and inferior performance when reared under suboptimal conditions. The causes of these latter problems are poorly understood but must be addressed if triploids are to be used more extensively.

### Reference

BENFEY, T.J., 1999. The physiology and behaviour of triploid fishes. *Reviews in Fisheries Science*, 7(1): 39-67.

### Photoperiod manipulation and productivity

The effect of varying photoperiod regimes on rainbow trout held in 6.5°C ground water between mid-November and March, was investigated to determine the impact on productivity. Fish subjected to a 16 hour photoperiod with extended feeding grew significantly faster and had a higher condition factor than fish subjected to a natural photoperiod, or to fish held on an increasing photoperiod regime or to fish on a constant 16 hour photoperiod but fed only during normal daylight hours. Fish on the 16 hour photoperiod also had a better feed conversion than fish on the other treatments. An economic analysis revealed that seasonally extending the photoperiod can be used as a management tool to increase farm productivity by approximately \$12 per cubic metre of rearing water volume at an initial stocking density of 15 kg/m<sup>3</sup>.

### Reference

MASON, E.G, GALLANT, R.K. AND WOOD, L., 1991. Productivity enhancement of rainbow trout using photoperiod manipulation. *Bulletin of the Aquaculture Association of Canada*, 91(3): 44-46.

### High dietary water content and growth

This study looked at the growth performance of rainbow trout fed moist pellets with varying water content utilising minced herring flesh. One-year old trout (initially 350-670 g) were fed for 15 weeks on diets containing various amounts of water (23-67%) achieved by replacing fish meal with Baltic herring. The growth of fish, whether measured as wet weight, protein or energy, was impaired when 50-55% dietary water was fed. The fish compensated for increasing dietary water content by consuming more diet so that the dry matter intake of the diets with 23 and 67% water were equal. Partitioning of growth into protein and lipid as well as protein and energy retention efficiencies were unaffected by dietary water. It is suggested that there is a metabolic cost of consuming more food when compensating for high dietary water content.

## Reference

RUOHONEN, K., VIELMA, J. AND GROVE, D.J., 1998., High dietary inclusion level of fresh herring impairs growth of rainbow trout, *Oncorhynchus mykiss*. Aquaculture, 163: 263-273.

## Vertebral column deformities in farmed trout

Fish are unable to synthesise ascorbic acid which must be added to the diet as vitamin C. Deficiency of vitamin C may cause physical deformities, reduced growth and reduced resistance to infection. Both glucan and chitin stimulate the immune response leading to a higher resistance to disease. This study looked at the effect on rainbow trout of diets given from first feeding to 6 months of age containing different levels of vitamin C or diets enriched in glucan or chitin on vertebral column deformities. At an average weight of 100 g the trout were X-rayed to determine the level of deformity. The investigation showed deformity levels, ranging from 8.9% to 12.5%, while the group fed the glucan-enriched diet had the lowest level of deformities (4.8%). In all groups examined, the deformities were spread over the whole vertebral column. The deformities in the group fed the low vitamin C diet were more severe than those found in the other groups. An outbreak of the disease rainbow trout fry syndrome (RTFS) caused by the bacterium *Flavobacterium psychrophilum* was observed in all groups during the investigation. The findings of deformities in all groups examined indicate a possible role of the bacterium in the development of the observed abnormalities. The lower level of deformities in the group fed the glucan-enriched diet might be caused by the ability of glucan to stimulate the immune response and increase the disease resistance of fish.

## Reference

MADSEN, L. AND DALSGAARD, I., 1999. Vertebral column deformities in farmed rainbow trout (*Oncorhynchus mykiss*). Aquaculture, 17(1 and 2): 41-48.

## Effect of supplemental dissolved oxygen on growth

The greatest limiting factor to productivity on trout farms with a limited water supply is dissolved oxygen concentration and many farms now utilise oxygenation or aeration systems to overcome this. This study looked at the effect on growth and food conversion as well as physiological and blood responses of rainbow trout acclimated to supersaturated (130%), saturated (100%) and low (65%) dissolved oxygen concentrations over a period of 10 weeks. Negligible effects on growth and food conversion was observed in fish reared at all three levels of dissolved oxygen. Acclimation to supersaturated dissolved oxygen resulted in lower blood haemoglobin, haematocrit, and total red blood cell

concentration. Within 6 h of a confinement challenge in their respective oxygen regime, fish acclimated to 10 weeks of supersaturated and low dissolved oxygen exhibited similar stress responses in duration and magnitude (plasma cortisol, glucose, osmolarity, blood lactate) compared to fish in saturated oxygen conditions which acclimated to the confinement stress. The stress of the challenge imposed an oxygen demand that was met by separate compensatory strategies to increase oxygen-carrying capacity in the blood. Fish in supersaturated and low oxygen conditions utilised cellular swelling as evidenced by the increase in mean corpuscular volume, and fish in saturated oxygen conditions responded with cellular recruitment as evidenced by the increase in total red blood cell concentration. The authors concluded that from the results presented, not only does excess oxygen fail to increase growth and improve performance capacity in cultured trout, but its usage results in an added and needless expense to the fish culturist's narrow profit margin.

## Reference

CALDWELL, C.A. AND HINSHAW, J., 1994. Physiological and haematological responses in rainbow trout subjected to supplemental dissolved oxygen in fish culture. Aquaculture, 126: 183-193.

## Remote weighing of fish

This paper describes the current status of the Remote Mass Measurement project which commenced in 1993 as a collaboration between the Institute of Aquaculture at Stirling and the BBSRC's Silsoe Research Institute, Bedford. The approach has been centred on the use of stereo video cameras and the principal considerations have been accurate, 'hands-off' measurement, achieved through low stress and low labour operations, and targeted on larger, offshore facilities and high value species. The intention has been to achieve an accurate measurement of mass to provide a valuable input to a range of activities, including monitoring growth, leading to enhanced ability for harvest planning and sales planning. In addition, improved data on size distributions could lead to a better ability to adjust husbandry particularly in terms of grading, feed quantity and fish size/pellet size match. In the case of salmon, size distribution patterns would also enable better prediction of future growth and percentage grilting. The use of box-truss shape analysis and mass estimation is described for Atlantic salmon, tilapia and Atlantic halibut. The future prospects for such systems and their development are discussed.

## Reference

ROSS, L.G., HOCKADAY, S., TILLET, R.D. AND CHAN, D., 1998. Remote weighing of fish: myth and reality. In: Proceedings of the British Trout Farming Conference, Sparsholt College, Hampshire, 2 - 4 September, 1988, pages 83-91.

## Nutrition in fish stress and disease

This article looks at the influence of specific feeding practices or feed types on ameliorating fish stress and disease. Examples of the beneficial effects of withholding or restricting feeding on pancreatic disease in salmon and RTFS in trout are given and the phenomenon of 'feeding stress' is explained. The beneficial use of vitamin C feed supplements during periods of fish stress or disease challenge is discussed and the concept of 'convalescent diets' explored where feeds are modified to include highly digestible or pre-digested protein, boosted vitamins and immunomodulators which place less demand on the digestive capacity of the fish and supports the immune system.

### Reference

SOUTHGATE, P., 1998. Can feeds be developed to cure stress and disease. *Scottish Fish Farmer*, 119 (September Issue), page 16.

## Performance of female triploid trout

The salmonid aquaculture industry has recently been investigating the benefits and drawbacks of sterile triploids. Although studies have shown that triploids should not be restricted by their altered haematology under optimal conditions, little is known about their performance in sub-optimal environments. This study focused on the performance (in terms of growth and survival) of female triploid rainbow trout in comparison to female diploids at chronic high temperatures. Triploid and diploid rainbow trout were reared in fibre glass tanks at  $21 \pm 1^\circ\text{C}$  for 23 days. At these chronic high temperatures, triploids had a significantly higher mortality rate in comparison with diploids: 68.5% of the triploids ( $N = 175$ ) died within three weeks at  $21^\circ\text{C}$ , while only 39% of the diploids ( $N = 167$ ) died in this time period. Diploids had larger fork lengths (by 4.8%), body weights (by 23.9%) and condition factors (by 10.3%) than the triploids by the end of the experiment. The cause of fish mortality in this experiment was likely to be multifaceted, and influenced, and/or directly caused, by the stress of the experimental protocol. However, it is evident from these results that triploid rainbow trout did not survive or grow as well as diploids in chronic high water temperature conditions.

### Reference

OJOLICK, E.J., CUSACK, R., BENFEY, T.J. AND KERR, S.R., 1995. Survival and growth of all-female diploid and triploid rainbow trout (*Oncorhynchus mykiss*) reared at chronic high temperature. *Aquaculture*, 131 (3/4): 177-187.

## Broodstock nutrition

This article covers practical trials with salmon, carried out in Norway, which demonstrated that feeding a formulated broodstock diet, as against a standard on-growing diet,

enhanced both survival and health of broodfish, increased the quantity and size of eggs produced and improved fertilisation and fry survival. Details of the timing and quantity of broodstock feed required for both salmon and trout broodstock are given as well as a breakdown of the main ingredients of the special diet and their value in improving gamete quality and fry survival.

### Reference

WILLIAMSON, J., 1998. Vital importance of broodstock nutrition. *Scottish Fish Farmer*, December Issue, page 19.

## Performance of native and hatchery-reared brown trout

This project looked at the effect of supplementary stocking a sub-Alpine reservoir in Norway with non-native and hatchery-reared brown trout (*Salmo trutta*) on subsequent growth and survival. The trout were marked by fin clipping and released as two year-old fish during the summer. Hatchery reared brown trout grew more slowly and had a smaller asymptotic length than native fish and also exhibited significantly shorter life spans than native fish. This category consisted mainly of individuals aged 2+ and 3+ years, and only 1.5% of the trout were aged  $\pm 5$  years. On the other hand the ages of the native fish sampled were between 2 and 8 years, and the most abundant age groups of trout were 4+ and 5+ years. It was suggested that these differences in life-history characteristics were related to adaptations by the native trout to the local environmental conditions. In the reservoir studied, which had a limited food supply as a result of water level fluctuations and high level of inter- and intraspecific competition, environmental effects were considered significant.

### Reference

FLOYSTAD, L., HEGGE, O., STAURNES, M. AND SKURDAL, J., 1999. Comparative life-history characteristics of native and hatchery-reared brown trout, *Salmo trutta* L., in a sub-Alpine reservoir. *Fisheries Management and Ecology*, 6(1): 47-61.

## Rainbow trout production in Canada

An overview of the status and future of rainbow trout production in Canada is presented based on a survey of all the provinces. Prevailing production methods are compared in the different regions and innovative approaches being applied on fish farms are highlighted. Environmental aspects of trout culture in Canada are outlined and appropriate approaches to handling wastes are described. The various products and markets are discussed and, on the basis of figures obtained from producers regarding costs of production and margins, some conclusions on the economics of trout culture are presented. Current trends in trout culture in Canada are explored for a glimpse into the potential and future of the oldest aquaculture industry in the country.

## Reference

HYNES, J., 1997. Rainbow trout production in Canada. Bulletin of the Aquaculture Association of Canada, 97(4): 10-14.

## Temperature effects on ovulating trout

Sexually mature female rainbow trout were held at temperatures ranging from 9 - 21°C for up to three months before the natural time of ovulation, in experiments conducted over three different spawning seasons. The majority of fish held at 9 and 12°C ovulated, while variable numbers were able to ovulate at 15 and 18°C. Only one fish ovulated at 21°C. Egg production was similar at 9, 12 and 15°C, but significantly lower at 18°C and near zero at 21°C. Egg survival to the eyed stage after incubation at 11°C was similar at 9, 12 and 15°C, and nil at 18 and 21°C. Histological examination of oocytes from fish held at 12, 15 or 18°C for one or two months showed no evidence of gonadal atresia (breakdown). Plasma levels of gonadotropin hormone were measured in samples taken 1, 2 and 3 months after introduction to temperatures of 9, 12, 15, 18 or 21°C, and all showed no differences between temperatures at any time. Plasma levels of testosterone (T) and 17 $\beta$ -oestradiol (E2) hormones were similarly unaffected. Repeat measurement of T and E2 in another spawning season also showed that holding temperature had no effect on plasma steroid levels. In contrast, in *in vitro* basal steroid production by isolated ovarian follicles was generally lower at 18°C than at 12 or 15°C. Follicles from fish held at 18°C for two months did not retain responsiveness to stimulation with steroid precursors or gonadotropin hormone, whereas those from fish held at 12 and 15°C did. These results indicate that elevated autumn holding temperatures for female broodstock have a deleterious effect on ovulation, egg production and fertility but have equivocal effects on endocrine parameters associated with yolk production. This suggests that the effects are directed on processes associated with final maturation and ovulation rather than yolk production.

## Reference

PANKHURST, N.W., PURSER, G.J., VAN DER KRAAK, G., THOMAS, P.M. AND FORTEATH, G.N.R., 1996. Effect of holding temperatures on ovulation, egg fertility, plasma levels of reproductive hormones and *in vitro* ovarian steroidogenesis in the rainbow trout *Oncorhynchus mykiss*. Aquaculture, 146(3/4): 277-290.

## Vitamin C and trout semen quality

During the reproductive season, rainbow trout spermatozoa are stored in the sperm ducts for several months. There is no sperm production at this time since spermatogenesis is completed before spawning. To learn more about characteristics of semen during such a long

storage, an analysis was made on changes in protein concentrations, anti-proteinase activity in seminal plasma and spermaspartate aminotransferase activity during an extended reproductive period during which fish were fed diets supplemented with various ascorbic acid concentrations. Seminal plasma protein concentration and anti-proteinase activity declined toward the end of the reproductive season. These phenomena may be related to oncoming proteolytic events leading to degradation of the sperm. Protein concentrations and anti-proteinase activities were strongly correlated within groups of different ascorbic acid supplementations and several sampling dates in most cases. Ascorbic acid deficiency resulted in a decrease in both parameter levels as compared to levels in groups with vitamin C supplement. These results support earlier studies suggesting a protective role of ascorbic acid toward maintaining sperm quality.

## Reference

CIERESZKO, A., LIU, L. AND DABROWSKI, K., 1996. Effects of season and dietary ascorbic acid on some biochemical characteristics of rainbow trout (*Oncorhynchus mykiss*) semen. Fish Physiology and Biochemistry, 15(1): 1-10.

## Therapeutic uses of hydrogen peroxide

Hydrogen peroxide (HP), a strong oxidising agent, should kill a number of bacteria, fungi and parasites on fish and is considered environmentally compatible because the primary decomposition products are oxygen and water. Its potential to kill disease organisms and to receive FDA approval, make it a great candidate for a fish disease therapeutant. With such interest being expressed in this chemical, the published uses of HP in aquaculture are reviewed in this article.

## Reference

MITCHELL, A.J. AND COLLINS, C.B., 1997. Review of the therapeutic uses of hydrogen peroxide in fish production. Aquaculture Magazine, 23(3): 74-79.

## Ozone and its use in aquaculture

Ozone has been used in a range of aquaculture applications related to disinfection and improving water quality. Ozone has seen wide use because it is a powerful oxidising agent that has a rapid reaction rate and few harmful reaction products. This paper reviews the application of ozone within aquaria and in aquaculture systems that use single-pass or re-circulated water. The issues and mechanisms required to use ozone are reviewed, with particular emphasis on the processes of ozone generation and gas-to-liquid absorption, the contact time for reaction, and the removal of residual ozone. In addition, the toxicity of ozone to humans and to aquatic organisms is discussed, as well as techniques to monitor or control ozone in both the gaseous and aqueous phases.

## Reference

SUMMERFELT, S.T. AND HOCHHEIMER, J.N., 1997. Review of ozone processes and applications as an oxidising agent in aquaculture. *Progressive Fish Culturist*, 59(2): 94-105.

## Ageing of trout semen during storage

This study investigated changes in the motility and fertility and biochemical changes in seminal plasma composition and sperm metabolism in rainbow trout semen during in vitro storage for 2 hours on ice (2 ml semen in a 2 cm diameter, 10 ml glass centrifuge tube). Semen fertility, motility rate and swimming velocity did not significantly change within 1 hour of storage but were significantly decreased after 2 hours. Motility rate was most affected by storage which was reduced by about 65%; swimming velocity decreased by 26% and fertilisation capacity by about 35%. The motility pattern of spermatozoa was not affected by storage. As a practical recommendation the data indicated that storage of untreated semen should not exceed 1 hour before use.

## Reference

LAHNSTEINER, F., WEISMANN, T. AND PATZNER, R.A., 1997. Aging processes of rainbow trout semen during storage. *Progressive Fish Culturist* 59: 272-279.

## Effect of sperm pooling on inbreeding levels

Based on computer simulations of cultured salmonid populations under selection, pooling of sperm of several males prior to fertilisation of eggs will lead to increased levels of inbreeding compared with expectations when all males fertilise equal shares of eggs. Single pair mating may produce less inbreeding than sperm pooling when the heritability of the trait under selection is low. Factorial matings, where each male fertilises an equal share of the pool of eggs, always produces less inbreeding than either sperm pooling or single pair matings.

## Reference

MCKAY, L.R. AND MCMILLAN, I., 1991. Effect of sperm pooling on inbreeding levels. *Bulletin of the Aquaculture Association of Canada*, 91(3): 16-18.

## Improving fin condition in trout

In two separate experiments, Bear Lake cutthroat trout (*Oncorhynchus clarki* Utah) fingerlings and domesticated rainbow trout fingerlings were reared for 10 and 6 months, respectively, in concrete raceways with or without (controls) cobblestone bottoms. Health/condition profiles (HCPs) were performed bi-monthly on 20 fish per treatment. Both species showed

significantly reduced fin erosion in cobble bottom raceways using fin scores from all eight fins of individual fish. Relative fin lengths (% of body length) showed that significant shortening of fins of control fish occurred on caudal and both pectoral fins for cutthroat trout and for right pectoral, both ventral, caudal, and anal fins of rainbow trout. Comparison of the two species showed that fin erosion was much more severe in rainbow trout. Overall, cobble substrates reduced fin erosion for both species, suggesting that natural bottoms are better for rearing than concrete bottoms.

## Reference

BOSAKOWSKI, T. AND WAGNER, E.J., 1995. Experimental use of cobble substrates in concrete raceways for improving fin condition of cutthroat (*Oncorhynchus clarki*) and rainbow trout (*O. mykiss*). *Aquaculture*, 130(2/3): 159-165.

## Estimating the economic value of improved trout fishing

Economic information that can be used to determine which management alternatives best meet public demands within limited budgets is important to resource management agencies. The objective of this study was to generate estimates of economic benefits of improvements on Wyoming trout fishing streams that could be used to evaluate different improvement projects. A mail survey was conducted to determine characteristics and preferences of anglers fishing Wyoming streams, and the contingent valuation method (CVM) was used to estimate economic benefits associated with fishing under improved conditions. Questions were associated with fishing for any or all trout species an angler might encounter on Wyoming streams. Benefits of improvement were based on CVM questions involving a hypothetical doubling of the chance of catching a large trout and a hypothetical increase in trout populations. Tourist and resident fishing licence subgroups were also analysed. Anglers in the tourist license group travelled long distances, spent more days fishing per trip, and had higher incomes than resident anglers. Consumer surplus estimates for the complete sample were US\$101/day for increased trout populations and \$132/day for doubling the chance of catching a large trout. Benefits for the resident angler for the large trout improvement and the population improvement were \$87/day and \$64/day respectively. Tourist angler benefits were estimated at \$227/day for the large trout improvement and \$131/day for the population improvement. The results of this type of study can be used within a framework of net present values to evaluate and prioritise potential improvement projects.

## Reference

DALTON, R.S., BASTIAN, C.T. AND JACOBS, J.J., 1998. Estimating the economic value of improved trout fishing on Wyoming streams. *North American Journal of Fisheries Management*, 18(4): 786-797.



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