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Articles, letters and news relating to trout farming are always welcome and may be included in future issues.

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TROUT PRODUCTION

The recent Foot and Mouth restrictions on farm access has meant that it has not been possible to complete the production statistics for 2000. These will now appear in the January 2002 edition.

ARTICLES

BRITISH TROUT FARMING CONFERENCE, SPARSHOLT 6-7 SEPTEMBER, 2000 - PART 2

Dick Lincoln, CEFAS, Lowestoft Laboratory, Lowestoft, Suffolk NR33 0HT

This report covers the presentations given on the final day of the Sparsholt Conference. My first report covering the first day's proceedings appeared in Trout News No. 31, July, 2000.

Wild fish stocks

Dr Heather Hall, curator of lower vertebrates at London Zoo (aquarium and reptile house) and co-ordinator for European aquarium conservation and breeding programmes for fish and aquatic invertebrates gave an overview of the status of wild fish stocks, briefly reviewed the assessment of endangered species and concluded with some specific examples.

The current status of wild fish stocks comprise approximately 10,000 freshwater and 14,000 marine species but it is estimated that there are still many thousands that have yet to be identified and described. Fishing represents the last major industry exploiting wild animals and forms a major food source for 200 million people world- wide. The world fishing fleet had doubled since 1970 and most stocks are declining or have collapsed indicating that the old adage 'the sea will feed the world' is no longer true. Subsistence fisheries are not monitored by the Food and Agriculture Organisation, she said, and there are a number of species where statistics are not collected at all. Global production from wild fisheries increased from 40 to 80 million tonnes between 1960 and 2000 for marine species and from 4 to 6 million for freshwater fish. Aquaculture over the same period increased from zero to 20 million tonnes.

To assess the endangered status of species the International Union for the Conservation of Nature and Natural Resources (IUCN) issues a Red List every 2 years in which a warning flag indicates when a species is becoming threatened. This body has no legislative capacity but simply issues a warning based on a series of criteria which assesses the level of threat. Four levels are identified: EW – extinct in the wild, CR – critical, EN – endangered, and VU – vulnerable. The EW category indicates that a species only exists in a captive situation and some of these are held at London Zoo.

The IUCN Red List currently lists 754 species of fish of which 118 are from the marine environment, 7% are categorised CR, 6% EN and 21% VU with 92 recorded extinctions. It is estimated that less than 10% of all fish species have been assessed.

Aquaculture, she continued, provided one fifth of the fish consumed by people and potentially constituted an important conservation tool although in the past it had been one of the major causes for the destruction of half the world's mangroves. To achieve a major positive contribution the economic viability of aquaculture operations should be established through pilot studies that use minimal numbers of wild stock. The source population must also be sufficiently well understood so that initial brood-stocks may be removed without damage. The reproductive biology of the target species also required careful study enabling the operation to rear a high percentage of young to market size at viable cost.

Measures are now being adopted world wide to limit exploitation rates. For example the international impact on subsistence fisheries has been addressed and the conservation of biological diversity is now respected. There are also measures now in place not to promote new trade in captured wild species that have not been exploited before.

Dr Hall concluded her talk with some examples of endangered species and the measures being taken to halt their decline. She began with the paddle fish (*Polyodon*

spathula) a freshwater species closely related to the sturgeon. This fish is now very vulnerable due to its limited range (only found in the Mississippi river) and over exploitation for its meat and caviar. The biology and movements of this little known fish is now under intensive study and currently large numbers are being reared for supplementation of wild stocks. Madagascan cichlids are another group of freshwater fish that are critically endangered with some species on the point of extinction due to habitat loss, over exploitation and competition from introduced exotic species such as tilapia. Cichlids command a high market value and therefore suitable for aquaculture production which may provide a safety net for these fish. A more familiar species, the cod (*Gadus morhua*) is currently on the endangered list because of the decline in wild populations together with other commercial species such as haddock and halibut also meeting red list criteria. Sharks have declined by 75% over the past 30 years due to over exploitation (700,000 tonnes caught annually with 125 countries trading in shark products), low fecundity and slow growth. A final example – sea horses (hippocampus species) had a particular interest for the speaker being associate director of project sea horse, an international team working on sea horse conservation. With an exploitation rate of over 10 million annually, mainly for the souvenir and traditional Chinese medicine trade, most species are now considered vulnerable. Sea horses inhabit shallow coastal areas throughout the world and are therefore vulnerable to subsistence fishing as well as presenting a large by-catch problem. Conservation programmes are now underway in Vietnam and the Phillipines where fishermen are turning to growing sea horses in cages using enriched artemia as a food source.

Elvers and Eels

Peter Neusinger was the next speaker from Western Aquaculture, one of around 25 small companies involved in the collection and export of elvers from the UK to Europe and China. His talk described the various operations involved in the harvesting, holding and transport of wild elvers to their final destination for on-growing.

Eel farming has developed slowly over the past 50 years due to the difficulty of artificially spawning eels so that elvers must be taken from the wild to obtain stock. The season for migrating elvers extend over a period of 6 months beginning in France in the autumn. Elvers enter the rivers on the west coast of Portugal followed by the south and north coasts of Spain and from south west France northwards along the west coast arriving in south west England by February and finally Scotland in May.

Elver collection
Several methods are employed; hand held nets, dip nets, traps of various types including pipe and funnel traps or whole sections of the river may be netted off. In England only hand netting is allowed but traps can be used in Scotland. The water temperature needs to be around 7-8° C before elvers begin migrating up river, utilising the tides to carry them inland before dispersing to the bank-sides to continue their journey. It is while the elvers are near the river bank that hand nets are used to scoop them up. Once caught they are held in trays with fine mesh bottoms and kept wet. He said the first hour of capture is crucial to the survival and quality of elvers. At this stage they are easily damaged by physical pressure during netting particularly if too much debris is picked up, therefore only a few are netted at a time and care is taken not to stock the trays too deeply. Freezing temperatures or too much bright sunshine must also be avoided.

Holding facilities
These consist of basic tanks with a plentiful water supply, sometimes with the addition of oxygen. From here elvers may be packed for onward transport, but usually buyers come to collect directly. If elvers are required for human consumption they must be packed hygienically. Throughout the holding period strict tank hygiene must be carried out and all mortalities removed quickly.

Transport
Road transport takes place in tanks with oxygen or a mixture of oxygen and air in combination with water re-circulation using a submersible pump for good mixing. The use of oxygen allows higher fish densities to be carried than formerly so that much smaller lorries or vans can be used. On arrival at the collection station dead or weakly swimming elvers at the surface are removed and discarded.

Packing
At this stage elvers are no longer handled directly but piped or siphoned from the tanks to avoid damage. Packing is carried out under a controlled temperature of 5-7° C during which elvers pass over a shoot, under a cooling shower and weighed into polystyrene boxes where they are held in thin layers. Water, ice, and oxygen are added before the box is taped up producing a package of between 4 and 5 kg net weight and measuring 70 x 50 x 25 cm. The boxes are transferred by road in refrigerated vans to an airport (London, Amsterdam or Brussels) for air freighting to farms in Europe (Spain, Portugal and Denmark) or to China. The boxes are designed to keep the fish in good condition for 40 hours providing ample protection for the 27 hour journey to Hong Kong. On average it takes 8 days from first catching the elvers to delivery in China from France and 4 to 5 days from UK operations. Speed, he said, was vital to success as the elvers are loosing weight and therefore quality all the while. Average survival rates of 98% are guaranteed on arrival.

On-growing

In China the farming operations are enormous while in Europe relatively small scale high tech re-circulating systems are used. In China a production cycle of 1-2 years is required produce eels of the desired weight of 150-200 gm. Most are for home consumption but some are re-exported to Europe but here generally larger eels of 500 gm. are required which are difficult to produce. In 1999 China purchased 110 tonnes of elvers and Europe 20 tonnes. The numbers required have fallen by half over recent years due to the greater efficiency of rearing farms. Prices for Atlantic elvers range from £80 to £230 per kilo and have reached £350 in the past. The elver trade, he concluded, is an uncertain business because the supply can be very variable. Systems must be very flexible and capable of expansion or contraction as required. Uses must be found for spare equipment which is why he has started farming catfish and tilapia. Current production runs to 1.5 tonnes for each with a projected 20 tonnes in future years.

The regulation of discharges

This paper provided a European perspective on the regulation of discharges from non-cage fish farms. The speaker, Iver Warrer-Hansen, has had a long involvement in this subject having started out at the Danish Water Quality Institute (now the Danish Aquaculture Institute) in the early 1970s, followed by a spell of salmon and trout farming in Ireland. His present position as adviser for Trouw Aquaculture involves hatchery design and production enhancement as well as water quality issues.

In 1995 the European Commission set out to review and restucture community water policy and in 1997 adopted proposals for a new Water Framework Directive which comes into force soon. This establishes a framework for community action in the field of water policy and implicit in the legislation is the requirement for an environmental impact assessment in which measures must be taken to ensure the water environment is protected from all intensive fish farming operations. Previous environmental legislation had been implemented in the light of subsidiarity, that is, within the competence of each member state which had led to a low degree of compliance in some countries. The new Directive will redress this problem.

The Fresh Water Directive covers 14 physical water parameters each with guide values laid down for salmonid and carp culture which must be complied with whenever possible, that is, measures must be introduced to discharge water to correct guidelines.

Legislation in E & W classifies rivers into five river ecosystems (REs) ranging from 1 (good) to 5 (bad) with accompanying criteria given for each class. Salmonid farming occurs on rivers with ecosystems 1and 2 with the Environment Agency determining the discharge parameters for each farming enterprise. In Scotland a similar classification divides rivers into A1 and A2, B,C, and D but with more strict discharge parameters for each particularly with regard to phosphorus.

The most recent legislation adopted for E & W is the Integrated Pollution Prevention and Control (IPPC) Act 1999. This determines appropriate controls placed on industry to protect the environment but fish farming is not covered in this new act.

From an EU point of view a most important organisation is the European Environmental Bureau (EEB). With its membership of 130 environmental organisations located in Brussels its purpose is to lobby and make recommendations. Other changes in legislation was a move towards charging for water but the speaker was unable to expand further having run out of time at this point.

A farmer's perspective of discharge regulations

Continuing the theme of water regulation Christopher Saunders-Davies of Test Valley Trout briefly reviewed the history of discharge regulation in the UK, outlined the current EA proposals and finally discussed alternative approaches that he considered may be more appropriate to a modern trout farming industry.

Trout farming emerged in the early 1970s and initially was virtually un-regulated. Cheap but inferior quality feeds produced poor conversion ratios of around 1:1.7 which often resulted in some of the worst quality discharges in the history of the industry. Eventually in the 1970s the Water Authorities brought in discharge regulations on an arbitrary basis which varied across the regions. By the end of the decade a framework for monitoring the major determinants – ammonia, biological oxygen demand (BOD) and dissolved oxygen (DO) evolved into a scheme which was reasonably responsible.

Because trout required good quality water farms were located on high grade 1A and 1B rivers and the values set were designed to maintain the quality of the receiving water, that is output was not to exceed input particularly for DO. With the reorganisation of the water industry and the advent of the National Rivers Authority, charging commenced (hitherto monitoring had been free of charge) based on water volume and quality. The general formula inpinged heavily on trout farming operations because of the large quantities of water used. Following negotiations fish farms were recognised as being low polluters but high volume users and consequently were placed in band G – the lowest band possible. More recently the Environment Agency moved fish farms from band G to band F on the basis of achieving a correct recovery of charges and avoiding cross subsidies from one type of discharge to another.

This was subsequently changed to band C because BOD was included in the regime of tests resulting in a further increase in charges of 600%. This move, which was carried out with a minimum of consultation, would clearly have rendered many trout farm operations non-viable and meetings were set up between the BTA, DETR, and DEFRA to resolve the situation. The present position is that although no immediate re-banding is pending an overall review is currently taking place.

BTA farm survey

In order to determine what risk, if any, modern trout farming has on the water environment and as an aid to discussions a survey was carried out in 1998 involving 52 farms, representing a total production of 6,258 tonnes. Over the two year survey period 1248 tests were completed on the key determinants (suspended solids, BOD, ammonia and DO). Of these 132 (11%) failed to reach the required standards resulting in 9 (5%) altered discharge consents.

A further survey carried out in 1998 looked at larger farms since it could be argued these represented a greater risk to the river environment. Four farms were monitored over a period of 3 years (1995-1998) covering a size range of between 200-500 tonnes and representing between 17-20% of production in E & W. Sampling carried out on the same determinants revealed that out of 174 tests 9 (5%) failed the standard for the period.

Both surveys demonstrated that fish farms were operating responsibly within prescribed limits, a fact accepted by the EA in recent discussions. Dissolved oxygen was considered the most important determinant, and taking dilution into account there were no major fluctuations. Failures were mostly with BOD by 2 or 3 ppm but this was not excessive taking into account the low sensitivity of the analytical procedure used (within + or – 1 ppm). In reality, he said fish farming is a continuous biological process in which large fluctuations do not occur.

Impact of Band C charges

The move to band C was considered highly detrimental and could result in the majority of trout farming businesses becoming unprofitable. The scheme currently proposed imposes a sliding scale of charges amounting to over £225 per tonne of production for small farms of less than 25 tonnes to £37 for farms in excess of 450 tonnes capacity. These charges for E & W represented a far greater cost than elsewhere in the UK. In Scotland, for example, discharge costs are 50% less and in the majority of EU countries there is no charging at all. In summarising these results he said there was a need for regulation but not to the extent of forcing the industry out of existence by such a dreconian system of charges.

An alternative approach

The speaker suggested a risk based approach was more appropriate to an industry which presented only a minimal threat of pollution to the environment. There was a move coming from industry towards Integrated Pollution Prevention and Control (IPPC) – an alternative approach to environmental protection involving a measure of self- regulation and monitoring which would be less costly. There would be an onus on industry to behave responsibly, be pro-active and comply to a set of general binding rules establishing the way farms operate. The parameters covered could be the same as those currently used but others may be better able to monitor the environment that were more affordable. The results should also be audited making them more demonstrable.

The establishment of self monitoring would incur costs. Larger farms would have a greater degree of monitoring than smaller units which would increase costs but this, he thought, would be acceptable. Cage farms in Scotland are presently regulated according to biomass and this could be another appropriate parameter for regulation as discharged waste is proportional to the amount of feed given which in turn is proportional to biomass. The tonnage of feed used forms the basis for regulation in the Danish trout industry which could be used in the UK. He finished on a cautionary note saying the trout industry needs to make its views known otherwise unacceptable regulation would be forced upon it.

Humane slaughter of trout

Dr David Robb from Bristol University reviewed the work being carried out at the Silsoe Research Institute, Bedford under the DEFRA Link aquaculture project (TRT 07) on the humane slaughter of trout. The project stemmed from the 1996 Farm Animal Welfare Council's (FAWC) report on the welfare of farmed fish. This recommended that farmed fish must receive the same considerations as for red meat and poultry, that is, there was to be no avoidable excitement, pain or suffering and stunning fish prior to slaughter must involve an immediate loss of consciousness. Further if fish were to be killed without stunning the method must result in rapid and irreversible loss of consciousness.

The aim of the project was to develop an automated device for the humane slaughter of trout. This involved (a) a review of slaughter methods in use and to identify and evaluate the welfare aspects of each; (b) determine which method was most acceptable; (c) design and test a device able to humanely stun trout beyond the point of recovery ie to kill and (d) to transfer the information to technology.

A literature review revealed a number of slaughter methods in use with many variations such as different temperatures and carbon dioxide concentrations. In order to evaluate these a demonstration workshop was

organised in which all the practical methods of slaughtering trout were demonstrated to the project participants. These included the following of which the first four methods are currently in use by the industry and the remaining six methods experimental:

Death in air
Death in ice
Carbon dioxide
Carbon dioxide + ice
Aqui-s anaesthetic
Percussive stun
Ikijime (spiking of the brain)
Head only electric stun
Whole body stun.

Each was scored on a 10 point scale with respect to welfare and flesh quality. On quality grounds few differences were observed between the different methods. All the current slaughter practices in use were considered poor on welfare grounds. Of the experimental methods electrical stun, particularly the whole body stun scored well on welfare but produced problems with flesh quality caused by haemorrhaging. Manual methods were slow to carry out and the amount of fish handling ruled these out. These results indicated electrical stunning was the best option and research focussed on the effects of different electrical parameters namely voltage (current), duration and frequency of alternating current.

It was found that increasing the voltage and therefore the current increased the time of recovery of breathing and therefore the time of return to sensibility. At high currents the fish were killed (ie stunned without recovery). Increasing the duration of the current increased the likelihood of killing fish while increasing the current frequency decreased the duration required. With respect to haemorrhages it was found that current strength and duration had little affect but increasing the current frequency greatly reduced the incidence of damage. This, he said, was due to the fact that muscle is not stimulated to the same degree at high frequencies while nerves are still affected.

The final step was development of a device that killed fish in large numbers. This is currently underway at Silsoe which will be a bolt on device consisting of a pipe through which the fish are pumped where the electrical current is received for about one minute before collection in a bin of ice slurry. The device will be affordable and efficient in humanely slaughtering portion size fish at the rate of 60 kg per minute. The electrical conductivity of water will also be taken into account at each trout farm from which the amount of current required will be determined. Such a device is currently on trial and should be available in the near future.

BKD wild fish survey

The final session of the conference, traditionally reserved for fish health issues, began with a paper by Edel Chambers of CEFAS, Weymouth on BKD wild fish survey. Her introduction included a brief history of the disease which was first described in Atlantic salmon in 1930 from the Aberdeenshire Dee. This was followed by other reports from America, in a Massachusetts trout hatchery in 1935, from the Pacific west coast in 1936 and British Columbia in 1937. Today BKD is present in every country except Australia and New Zealand.

The causative organism, *Renibacterium salmonimarum* is a small gram positive staining diplobacillus bacterium which lives primarily within the cells of the fish and may be transmitted both vertically (in eggs) and horizontally (by cross infection). The presence of the disease is revealed internally by grey lesions on the kidneys and externally in the later stages by bulging eyes, black coloration and lesions of the skin.

Isolation of the bacterium involves culturing the organism on agar plates but because of its intracellular life-style it is difficult to grow and detection may take up to 10 weeks. Another serological test involving the detection of fluorescent antibodies (ELISA test) is considered by many to be an improvement but both methods are not very effective. In spite of a comprehensive monitoring programme in E & W the presence of the bacterium has rarely been found in wild populations of fish leading to the conclusion that BKD is not widespread in the environment. In the absence of any treatment or vaccine the presence of BKD on fish farms is considered a significant risk to wild fish populations and it is therefore categorised as a List III notifiable disease in which movement restrictions apply. This has serious commercial repercussions for infected table farms and hatcheries and farmers are now challenging the wisdom of current policy she said. They argue that since BKD rarely kills fish they are able to live with the disease and because the existing detection methods are so ineffective it is possible that BKD is more widespread in the environment than currently proven.

New PCR detection method

To help answer this case a new, more sensitive molecular diagnostic test has been developed to detect the pathogen in very low numbers. The method known as Polymerase Chain Reaction (PCR) enables multiple copies to be made of a specific fragment of DNA from the bacterium, in this case a 358 base pair fragment of the P57 gene, which can then be easily analysed for the presence of *Renibacterium* in fish.

Wild fish survey

Once developed and validated the technique was applied to a wild fish survey. Sites were selected according to the following criteria:

1. Prestine river on which no fish farms exist and no recent history of restocking has taken place.

2. Rivers with fish farms currently negative for *Renibacterium solarum* (R.s.) and always have been.
3. Rivers with fish farms currently negative for R.s. but were positive in the past.
4. Rivers with a fish farm undergoing disinfection because of BKD.
5. Rivers with some fish farms positive for R.s. by culture methods of detection and have been for many years.

The fish species sampled were brown trout, rainbow trout, grayling, Atlantic salmon, pike and eel. Fish were sacrificed on site, the head kidney swabbed onto agar plates after which the whole fish was bagged and returned to the laboratory where kidney tissue was removed for DNA extraction.

Results

An eel mini survey carried out on one river accorded criteria 5 status above revealed one sample out of 46 (2.2%) was positive by PCR analysis representing the first ever recorded presence of R.c. in eel. Results for the other species surveyed showed that on rivers accorded criteria 1 and 2 status all samples proved negative. For criteria 3 and 4 rivers samples proved positive for only one species - brown trout in 2 out 140 (1.4%) fish sampled and 1 out of 88 (1.1%) fish sampled respectively. Two rivers tested with criteria 5 status both proved positive for grayling (20 of 172 (11.6%) and 12 of 116 (10.3%) fish sampled) and one river for salmon (4 of 49 (8.2%) fish sampled). These results suggested that the bacterium was not widespread in wild fish in E & W and where it was present it could be linked to the presence of fish farms and their R.s. status. Future work, she concluded, would concentrate on 10 fish farm surveys and include analysis of suspended solids in water and river sediments for the presence of R.s. using modified PCR techniques. The effect of smolting in infected salmon and sea trout would also be investigated as well as the ability of R.s,. to spread via nets, boots and vehicle tyres.

White spot treatment

This paper by Dr Andrew Shinn of the Institute of Aquaculture, Stirling has been reproduced in full later in this issue.

PKD overview

Steve Feist from CEFAS, Weymouth provided an overview of PKD research which summarised the key findings and recommendations of a workshop funded by DEFRA/CSG at the Weymouth laboratory in November, 1999. The recent discovery that the agent of PKD requires a bryozoan in its life cycle had provided a tremendous boost to the research, opening up several new lines of enquiry. Formerly known as PKX the agent has now been named *Tetracapsula bryosalmonae* from the appearance of the 4 celled spore that occurs within the bryozoan.

The main findings of the workshop involving the various interactions of *Tetracapsula*, bryozoans and fish hosts could be divided into the following five zones, each forming an area for further investigation:

Zone 1 - bryozoan phase. This involved the development of the parasite and release from a bryozoan host. The later stages of the parasite in the kidney tubules of fish had now been confirmed to enter the bryozoan but further research was needed to determine the numbers of tetra spores produced within the bryozoan, the relative infectivity of the various strains to fish, the viability of spores after release and the duration of their infective phase.

Zone 2 – parasite interactions with host fish, pathogensis and immunology. This was the most well documented zone in the life cycle of the parasite. It had not been possible to study the early stages of pathogenesis such as penetration of the fish host and the minimum infective dose required but this was now possible. He said there may be a link here with strawberry disease (reported in the July, 2000 issue of Trout News) but little is known about this and investigative studies were currently underway to determine if a parasite was involved. Immunology was an important area where more work is required, specifically on antibody production in both fish and parasite, the nature of the response and of the acquired immunity. Little was known of external influences such as the role of wild fish in the distribution of infection or the factors influencing infection rates and more epidemiological studies were required.

Control methods, particularly chemotheraputants targetting the infective stages and those within fish were required and in the long term the development of recombinant vaccines. Management options in preventing the excessive growth of bryozoans by water filtration or pond design may also prove effective.

Zone 3 – parasite interactions with bryozoan host. Virtually nothing was known about this area of the life cycle which raised a number of important questions. For example, is there a cellular response in the bryozoan and do different strains of the parasite have different pathogenicities? Does transmission occur directly between individual zooids of the bryozoan and what is the host specificity? Ecological factors was another important area of study such as determining the distribution of bryozoans and whether other alternative hosts exist for tetra capsules.

Zone 4 – fish phase, spore development and release. Requirements here involved developing culture methods for the parasite to determine its morphological development within the fish host to typical 'PKX' cells, the mechanism of their proliferation and migration through fish tissue. An understanding of the antigenic responses was also required to determine why rainbow trout are so susceptible to the parasite while other fish species appear relatively resistant.

In researching the gaps in the current knowledge of this parasite he said it was important that standardised procedures and techniques are developed. These were required, for example in bryozoan culture for studying host/parasite relationships and development stages where a ready source of parasites would be required (currently being undertaken at Reading University) and propagation of the parasite for standardisation of challenge methods.

Lactococcosis disease

The final speaker, Dr Chris Gould, a trout sector manager for Aquaculture Vaccines Ltd in Cambridge, gave an account of the bacterial disease lactococcosis. He said this world-wide disease had been spreading rapidly northwards in mainland Europe over the past few years and having reached Brittany it clearly posed a threat to the UK trout industry. Unbeknown to the speaker at the time, this disease had already arrived in the UK on a farm in the south of England (see January, 2001 edition of Trout News).

This disease, which is seasonal and occurs in both fresh and seawater, attacks at least 22 species of fish including yellowtail, sea bream, turbot, bass, tilapia, eel and trout. The agent involved is various species of streptococcal bacteria which are divided into two groups according to their temperature preferences. Warm water streptococcosis prefer a water temperature of 15°C and above and include *Lactococcus garvieae* of European rainbow trout, and cold water streptococcosis which occurs in water at 8- 12°C. Poor water quality often associated with over-crowding may increase the severity of the disease and losses can be substantial. It is estimated that $70 million a year is lost to the disease in Japan (yellow tail and trout), $10 million in the USA (tilapia) and $4 million in the Philippines (tilapia). Losses world wide are conservatively estimated at $200 milllion. The sources of infection may be from the environment in water and mud, from wild fish which can act as carriers and from contaminated diets.

Clinical signs

Both warm water (*Lactococcus garvieae) and cold water (Vagococcus salmoninarum)* lactococcosis occurs in Europe and was first reported in Italy in 1991, followed by Spain in 1995, Pays Basque in 1998 and Brittany in 1999. The clinical signs of the disease include erratic swimming, anorexia, dark body colour, exopthalmia, haemorrhaging, ulceration of the skin and head-up posture. Internally the clinical signs may include systemic septicaemia and haemorrhaging of the hind gut, heart, liver, spleen and swimbladder. In France *L. garviae* occurs when the water temperature reaches 15°C + between June and September in fish of 60 g + when mortality can be up to 50%.

Control methods

Chemotherapy involves the use of antibiotics such as oxytetracycline and amoxycillin but the benefits are short lived since re-infection may occur. Prevention by husbandry methods such as avoiding the entry of infected fish (carriers) and materials and by disinfection is more affective although both warm and cold water species of the bacterium are highly resistant. Vaccination has been carried out for many years with success using immersion, oral and injection routes. He said his company's experience against *L. gariae* using a bivalent vaccine had been quite encouraging but it was essential to protect fish before an outbreak of the disease. Protection is short lived and a booster vaccination would be necessary.

In the UK water temperatures would support both the warm and cold water bacterial species causing the disease. Potential routes of infection are birds, faeces of infected fish, water and equipment and vehicles from infected sites. The most important route however is via the carcasses of infected fish were bacteria on the skin and mucous may remain viable for 24 hours. It was therefore vital to avoid the entry of high-risk material onto UK farms. Farmers should disinfect and maintain good husbandry while processors should source their fish from abroad with care and ensure correct disinfection procedures are carried out on transport vehicles.

PHOTOPERIOD EFFECTS ON REPRODUCTION AND GROWTH IN RAINBOW TROUT

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Introduction

Of all the environmental variables the seasonally-changing daylength ('photoperiod') provides the most reliable and 'noise-free' information on time of year. It is therefore not surprising that many animals at middle and higher latitudes have evolved to use photoperiod to time seasonal functions such as reproduction and growth. This article summarises previous and current research aimed at determining how photoperiod can be used to manipulate reproduction and growth for the benefit of the trout industry.

Seasonality of reproduction in rainbow trout

The majority of rainbow trout strains farmed within the U.K. spawn naturally during mid-winter and early spring (November – March). The resultant seasonal availability of eggs has proved to be a major constraint for the trout farming industry, which requires an all-year round supply of eggs to ensure a consistent supply of market size fish. The market for out-of-season eggs is still largely supplied by egg imports[1,2]. Whilst imported eggs undoubtedly benefit the industry an over-reliance on imported eggs carries with it some risks, such as unexpected reductions in supply and the possibility of exotic disease. Consequently, there is a need for greater self-sufficiency in year-round egg production.

Artificial manipulation of photoperiod as a tool for spreading egg production throughout the year.

It is now well established that the primary environmental influence on the reproductive timing of rainbow trout and other salmonids is the seasonally-changing photoperiod[3]. Consequently, artificial manipulation of photoperiod provides a useful tool for spreading the production of eggs throughout the year. A variety of protocols have been used to advance and delay spawning time in salmonids, including compressing or expanding the natural seasonal photocycle into periods of less than, or greater than, one year, and exposing fish to combinations of constant long and constant short photoperiods[3,4] (Figures 1,2). These protocols advance or delay spawning time by re-setting an internal circannual (yearly) biological clock[5].

Recently, attention has focused on simple protocols involving continuous (24-hour) exposure to light, thus obviating the need for blackout covers and time clocks. This is achieved either by superimposing 24-hour artificial light on the natural light-dark cycle (the method currently used most frequently for trout) or by turning the lights on, shortly before dusk, and off, shortly before dawn. Initial experiments were conducted indoors with continuous artificial light superimposed over subdued ambient light entering the buildings via windows and/or plastic corrugated roofing. A fluorescent tube or tubes were suspended approximately 1 metre above the tanks, providing an intensity of around 1000 lux at the water surface. These experiments showed that exposing rainbow trout to continuous artificial lighting (superimposed on the natural daylength) throughout the year results in irregular/desynchronized spawning and a

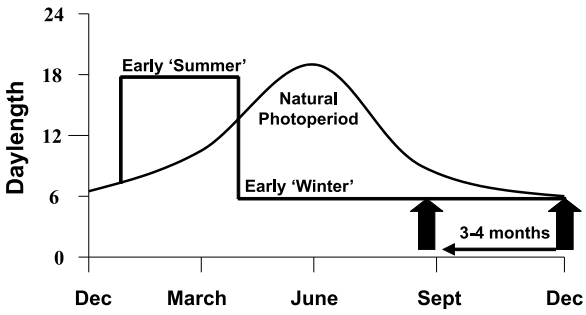

Figure 1. Spawning can be advanced by 3-4 months in a December spawning stock exposed to a combination of constant long and short photoperiods before these photoperiods would be experienced naturally. Arrows indicate spawning time

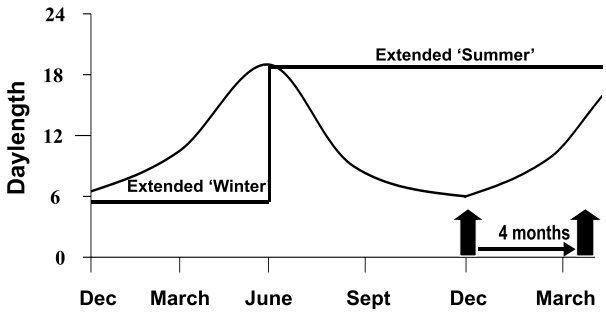

Figure 2. Spawning can be delayed by 1-4 months in a December spawning stock exposed to a combination of constant short and long photoperiods after these photoperiods would be experienced naturally. Arrows indicate spawning time

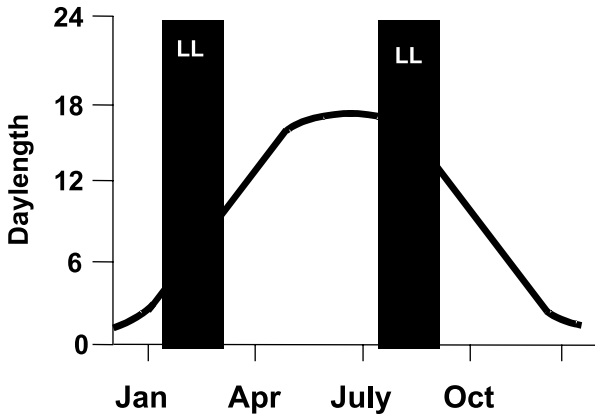

Figure 3. Protocols for advancing (LL, left) and delaying (LL, right) spawning in rainbow trout which spawn naturally in December (LL = 2 month period of continuous light superimposed on the natural photoperiod)

reduction in the proportion of fish attaining sexual maturity. However, exposing fish to shorter periods of continuous light superimposed on the natural daylength (Figure 3) enabled the spawning times of a large proportion of the broodstock to be altered, and resulted in relatively synchronized spawning. For example, spawning could be advanced by 5 months by exposing December-spawning trout (maintained in tanks supplied with river water) to continuous light for 2 months from mid-January to mid-March (Figure 4), and could be delayed by 1-4 months by exposing the same stock to continuous light for 2 months from mid-July to mid-September[5] (Figure 5). Moreover, experiments with normal males indicated that males and females respond similarly to continuous light (Figure 4), ensuring the availability of milt for the fertilization of out-of-season eggs.

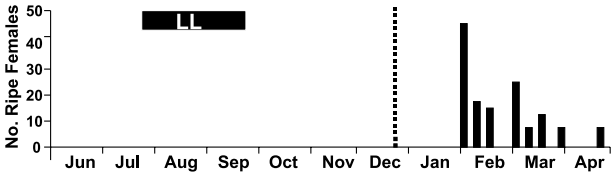

Figure 5. A two month period of continuous light (LL) superimposed on subdued ambient daylength (indoors) can delay spawning of rainbow trout. Natural spawning time is indicated by a dotted line

The highly promising results obtained by superimposing continuous light on the subdued natural lighting typical of indoor facilities lead to similar experiments in outdoor tanks and ponds. However, initial experiments in which continuous artificial lighting was superimposed on natural daylight in outdoor facilities were disappointing. On one farm, spawning was advanced by 2 months when continuous artificial light (300-400 lux at the water surface) was superimposed on ambient daylength for 2 months indoors, but exposing fish to a similar artificial light intensity outdoors had no effect on spawning time. The most obvious difference between the experiments conducted indoors and outdoors was the intensity of the natural light on which the artificial light was superimposed: light entering through windows and plastic corrugated roofing produced a maximum light intensity of around 800 lux at the water surface indoors, whereas the maximum intensity outdoors was 10,000 – 30,000 lux. This suggested that the intensity of the artificial light, relative to that of the natural light on which it is superimposed, is an important determinant of the success of continuous light regimes (i.e., a change from 20,000 lux during the day to artificial lighting of less than 1000 lux at the water surface at night is not perceived as continuous light, but as a daily light-dark

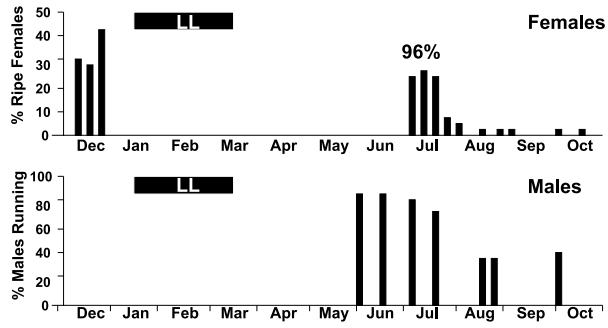

Figure 4. A two month period of continuous light (LL) superimposed on subdued ambient daylength (indoors) can advance spawning of rainbow trout. The percentage of females spawning within a 6 week period in July and August is indicated

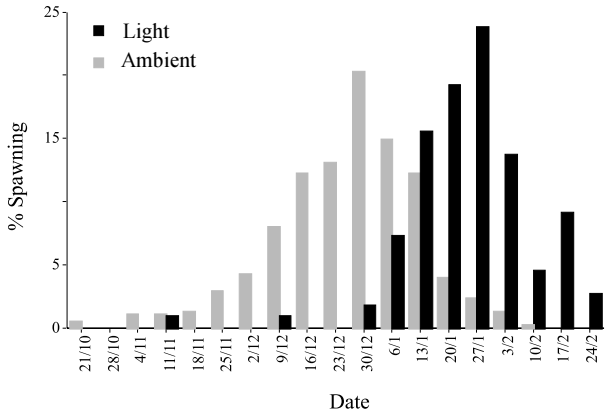

Figure 6. Continuous high intensity submerged artificial lighting (mid-July to mid-September) can delay spawning in rainbow trout maintained in outdoor tanks

cycle), as in salmon and cod[6]. A preliminary experiment, in which rainbow trout maintained in an outdoor tank were exposed from mid-July to mid-September to continuous high intensity light ('extended summer') provided by 3 x 250W submerged (to reduce light loss through reflection) floating lamps supports this conclusion: spawning was delayed by one month (Figure 6).

Artificial manipulation of photoperiod as a tool for enhancing growth

Long photoperiods have been reported to stimulate growth in a number of fish species[7]. However, there is surprisingly little information available on the influence of photoperiod on the growth of rainbow trout[7]. In a preliminary experiment under laboratory conditions, rainbow trout eggs were maintained in covered troughs under either a short photoperiod (6 hours light: 18 hours dark), a long photoperiod (18 hours dark: 6 hours light) or a simulated natural photoperiod from the day of fertilization (25th March). At first feeding on the 3rd June the fish were transferred to the same photoperiods in covered tanks (3 replicates per treatment). The fish in all tanks were fed an identical ration during the time that the lights were on in the short day tanks. Six weeks after first feeding fish maintained under a long photoperiod, or simulated natural photoperiod, were about 20% heavier than fish exposed to a short daylength. By the end of the experiment in October, fish maintained under a long photoperiod were 34% heavier than those under short days, and, importantly, also showed a 10% increase in weight over the fish maintained under simulated natural photoperiod (Figure 7), coincident with the marked decrease in the natural photoperiod which occurs in September and October. Thus, long days enhanced growth in rainbow trout, **without additional feeding**.

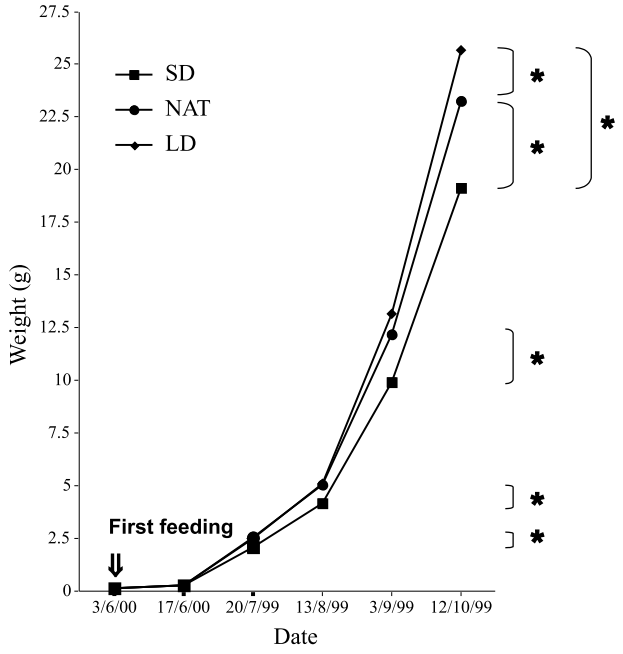

Figure 7. Influence of photoperiod on growth of rainbow trout in covered tanks (SD: short day; LD: long day; NAT: simulated natural photoperiod). For each photoperiod, data from replicate tanks has been combined. *Significantly different (P<0.05)

Photoperiod manipulation would be a particularly useful tool for enhancing growth if it were effective during the cooler months of winter and early spring. Several trials have now been conducted on fish farms during winter and spring using high intensity lamps in outdoor tanks, ponds and cages. In the first trial, rainbow trout fry (initially 35,000/tank) were maintained from November in tanks (supplied with river water) under either ambient photoperiod (outdoors), continuous artificial lighting provided by 2 submerged 400W metal-halide lamps (outdoors), or continuous artificial lighting provided by fluorescent tubes (indoors). Feeding was extended into the night in artificially lit tanks via clockwork feeders. Batch weights revealed that growth was significantly ($P<0.05$) enhanced in the fish exposed to outdoor lights 10 weeks after the start of the experiment. By the end of March fish maintained under continuous light were 44% (indoor lights) and 53% (outdoor lights) heavier than fish maintained under ambient photoperiod (Figure 8).

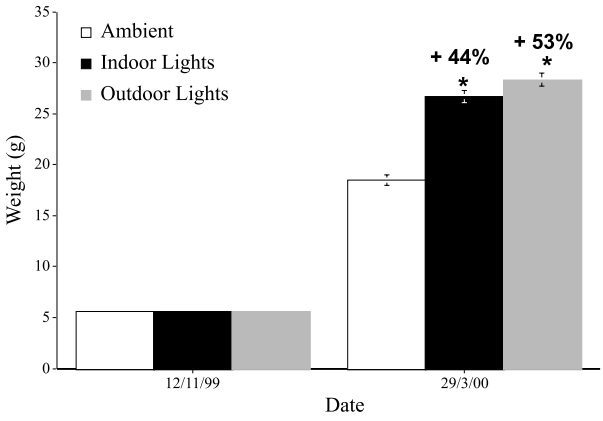

Figure 8. Effect of continuous artificial lighting and extended feeding on growth of rainbow trout fry in tanks. Data based on individual measurements of 100 (12/11/99) or 300 (29/3/00) fish. Percentages represent the % increase in mean weight relative to the fish maintained under ambient photoperiod. *Significantly different from Ambient (P<0.001)

The growth enhancing effect of continuous artificial lighting was also observed in demand-fed juvenile rainbow trout maintained in outdoor ponds (20,000 fish/pond; supplied by river water). Fish exposed to continuous light (4 x 400W submerged metal-halide

lamps in a 10 by 50 metre pond) from late January to early May were 28% heavier at the end of the trial than fish maintained under ambient photoperiod (Figure 9).

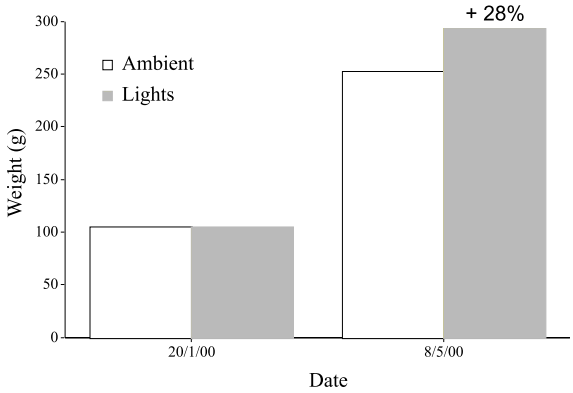

Figure 9. Effect of continuous artificial lighting on growth of demand-fed rainbow trout juveniles. Data based on total weights/ fish numbers at grading/transfer. The percentage increase in mean weight relative to the fish maintained under

Submerged lighting is particularly suitable for cage culture because light is not lost via surface reflection; this reduces the 'light pollution' associated with above cage lighting and means that fewer lights can be used per cage, resulting in lower costs. Consequently, trials are on-going to assess the effectiveness of submerged lighting for the manipulation of reproduction and growth in Atlantic salmon, cod and sea bass[6,8]. To determine whether photoperiod manipulation can enhance the growth of rainbow trout in cages in a freshwater loch, juvenile fish (60,000/cage, ca. 80g.) were maintained under either ambient photoperiod (control) or continuous light for 9 weeks between mid-February and mid-April. Continuous light was achieved by switching a submersible 400W lamp (1 metre below the water surface) on, shortly before dusk, and off, shortly before dawn. Cages were at different ends of the site to prevent artificial light entering the control cage.

A reduced feeding response and decreased specific growth rate (SGR) was observed at the start of the experiment in fish maintained under artificial lighting. The SGR remained lower in fish maintained under continuous light, relative to those under ambient daylength, for the first 8 weeks of the trial. After 9 weeks, however, the SGR of the fish held under continuous lighting had overtaken that of the control fish, and the weights of the fish in the two cages were similar. A similar initial growth dip has been observed over the first 8 weeks in Atlantic salmon trials in which fish were exposed to continuous light. The SGR of salmon under artificial lighting also overtook that of the controls after 9 weeks (as for rainbow trout), resulting in larger fish from week 12 onwards. The pattern of growth for rainbow trout maintained under continuous light therefore appears similar to that previously observed in salmon. However, longer trials will be necessary to determine whether photoperiod manipulation is an effective technique for enhancing growth of rainbow trout in cages.

Conclusions

All-year round spawning of rainbow trout can now be achieved by manipulating photoperiod in a variety of ways: Compressed/expanded and constant long/short photoperiods, adjusted by time clocks in covered tanks; Low intensity continuous artificial lighting in indoor facilities (subdued natural light); and High intensity continuous artificial lighting in outdoor facilities (full strength natural sunlight). The preliminary trials conducted to date suggest that manipulation of photoperiod is also a potentially very useful tool for enhancing growth in rainbow trout. However, further replicated trials are needed to differentiate the effects of photoperiod *per se* from those of extended feeding, to determine whether light intensity influences growth (with or without extended feeding), to confirm the effectiveness of photoperiod manipulation in cages, and to investigate whether photoperiod manipulation influences flesh pigmentation, which can vary with season in salmonids[9].

Interested?

Experimental trials on the effects of photoperiod on reproduction and growth of rainbow trout and salmon are continuing at the Institute of Aquaculture. For further details please contact Niall Bromage (E-mail: nrb1@stir.ac.uk).

Acknowledgements

Many people have contributed to the work described in this article. We are particularly grateful to Geoff Farrow (Aquabeam Ltd.), Mark Thrush (CEFAS), Nick Yonge, Graham Milroy and Mark Grant (Galahaugh Fish Farm), Mark Davies and Peter Gilbert (Torhouse Trout) and John Gardener and Niall Auchinachie (Institute of Aquaculture). The work on growth was supported by a Natural Environment Research Council ROPA grant (GR3/R9827).

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TROUT WARS

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Forget for the moment, the anti-hunting lobby's threat to angling. There is a much more immediate menace and it comes from a source one might expect to be fully supportive of all aspects of recreational fishing. The Environment Agency has been persuaded that the brown trout and sea trout stocks in England and Wales need protection and it wants to develop a National Strategy for this purpose. Within this strategy the Agency is proposing an extension of their regulatory powers so that the use of farmed trout to supplement stocks in river fisheries may be curtailed on the grounds that they are genetically inferior and constitute a threat to 'wild' trout.

A test case has just been argued in Dorset where the Agency backed down, in the face of sustained protest from the Piddle, Frome and West Dorset Fishery Association, over restrictions on stocking a part of the River Frome. This is a battle won for common sense, but the Agency still maintains it will go ahead with consultation on the Stategy, even to reverse the decision it has just taken on the Frome.

Trout farming in the British Isles began as a support for trout fishing almost 150 years ago and the practice has continued ever since. In his classic, *The History of Howietown*, published in 1887, Maitland describes in eloquent detail many of the husbandry techniques that were developed there. He described a fish transport tank:

> *"When these tanks have to be carried where there is no road, or across mountain paths, two poles are inserted in iron lugs fitted between the carrrying handles, and the tank forms a sort of sedan-chair. In this way many of the highest lakes in Scotland have been successfully stocked."*

On a fishing holiday at Altnaharra many years ago I elected, one day, to fish a loch high in the mountains. It was reached after an hour of steady climbing and once there, the effort was more than justified by the capture of several brown trout up to 2 lb in weight, beautifully formed and coloured. On return to the Hotel I commented on these wonderful wild fish. Not so, I was informed, the loch is stocked!

Lowland lakes and rivers in the UK must have been stocked since even before the advent of trout farming. It is extremely unlikely that any significant population of trout in our islands is free of the influence of supplemental stocking. Is there any evidence that any of this has been detrimental? On the contrary, one can expect much of it to have been highly beneficial.

What if the practice of supplemental stocking was abandoned? The outcome would be disastrous. If the current level of fishing continued the fish stocks would collapse as they have done for commercial fisheries around the world where exploitation is not matched by support. To sustain trout stocks at present levels would require a drastic reduction in fishing effort. In our society, that would make river fishing an exclusive, rich man's sport and have considerable economic repercussions.

We live in a crowded community, no aspect of our environment can stand alone. Fishing remains one of the grand illusions of modern life; back to Man, the hunter gatherer. Catch and release policies have been suggested, but these raise practical and moral problems of their own and cannot be justified as a general solution (even if there was a general problem to solve). The use of triploid, sterile fish, as proposed by some simplistic problem solvers, is an affront to the grand illusion; and it is not necessary. Putting sterile fish into a dynamic reproductive situation is the most serious of genetic insults. Brown trout and sea trout stocks are in good shape outside the areas devastated by the Scottish salmon industry. But there is always something positive

to do. Habitat degradation of our waterways has been only too obvious in recent history. From outright destruction through industrial and agricultural pollution, to chronic damage from abstraction, waste disposal and land drainage, to mention but a few of the many human impacts on the aquatic environment, there is much re-instatement to be done. It may not be glamorous, nor cheap, and not even easy, but no one doubts it would be beneficial.

The brown trout/sea trout species complex (*Salmo trutta*) is native to the cooler parts of Europe but has been introduced to many countries world wide (incidentally, from farm stock). It is the most widely distributed species of fish in the British Isles and occupies a varied range of habitats including spate rivers, chalk streams, estuaries, coastal waters and inland waters, large and small. It is a 'survivor' in ways that close relatives like the Coregonids (whitefish) are not. Where it has been eliminated, for example by pollution during the industrial revolution, it has staged comebacks once the source of pollution has been removed. It is a coloniser, a wandering exploiter of habitats. It is not fussy about what it eats – just about anything it can swallow from minute Cladocera, through sizeable trout pellets to substantial fish prey. It is by no stretch of the imagination an endangered species.

The genetic argument that the Agency uses to support its case for conservation derives from the long- standing approach by fisheries scientists to differentiate so-called fish stocks for management purposes. This has its origins in the increase in international concern in the 1960s over commercial fisheries, mostly marine, and hasn't been particularly successful in management terms. The scientists, ever mindful of opportunities to exploit their expertise, have now hitched their aspirations to the world of conservation and the glamour of all-embracing concepts like biodiversity and the precautionary principle. In so doing they often dispense with common sense.

The model the Agency accepts from its academic advisors comprises three beliefs:

(a) different populations or groups can be defined by genetic analysis;

(b) the genetic structure of each 'population' is finely tuned to its environment;

(c) the introduction of fish from another 'population' will upset that adaptation.

Groups of fish can be distinguished by genetic analysis, but this is a long way short of defining them. We can define a species precisely but geographic races within a species differ from one another in the frequencies of genes, not their presence or absence. They are not static but alter according to habitat change or to the influx of other groups of fish.

Of course populations adapt to their environments but it is not a one-way street. Where seasonal and temporal factors change, as in most dynamic habitats, the adaptation is in flux and is not fixed for any set of circumstances. It might be possible to think of close, mandatory adaptation in something like the relationship between an insect and a rare orchid where each is totally dependent on a specific aspect of the other's lifestyle, but the brown trout is not a specialist. On the contrary it is a robust colonising generalist that thrives in all sorts of environments, many of which it came to only as a result of man's intervention. In addition, our rivers and lakes are hardly representative of the conditions which prevailed 10,000 years ago when the retreat of the ice sheets allowed the ever exploring trout to colonise the starkly pure rivers of our emerging landscape. Goudie and Brundsden wrote, in *The Environment of the British Isles – An Atlas* (1994):

> *"Human beings are unable to leave water alone and there is no such thing as a natural river in Great Britain."*

Widespread restocking has mixed up all our so-called trout 'races'. The environments the trout occupy are quite different from those they might have experienced a few hundred years ago. For these, and other reasons, the notion of discrete populations so finely tuned to their environments that introduced individuals represent a genetic threat is to turn genetics on its head.

Gene flow between groups of animals or plants is a boon to their genetic health. It is the isolated population that is at risk and there are plenty of examples of this – paddle fish and cheetahs, for example – and trout populations cut off by impassable falls represent many more.

Finally, the genes of farmed trout are not 'inferior'. The domestication of trout is relatively recent and the fish have not been subjected to the pedigree type of breeding which characterises most farm animals. Farmed trout are barely a step away from their wild progenitors. In a recent book (*Fishing for Falklands Sea Trout*) puplished by the Falklands Islands Tourist Trust, Peter Lapsley describes the creation of strong sea trout runs in the Falklands Islands following introduction of brown trout from farm stock; and it took less than 50 years. Hardly the outcome one would expect of an enfeebled race!

Anyone with an interest in the welfare of our rivers and fisheries should be aware of the Environment Agency's genetic plans. Any attempt to repeat the Frome imposition should be vigorously challenged and if the promised consultation does arrive we should all make effective use of it. After all, we all pay for fishing licences to keep them in work and there is plenty for them to do in other, more fish-friendly, spheres.

NEW PIGMENTATION RECOMMENDATIONS FOR FARMED RAINBOW TROUT

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This article has been reproduced from the Spring 2001 edition of Trouw Outlook, the magazine from Trouw Aquaculture.

Flesh colour has long been an important consideration in the marketing of farmed trout. It has been demonstrated that flesh colour is one of the foremost quality characteristics used by the consumer in their perception of quality (Koteng, 1992). There is an increasing trend in the market towards value-added products, in particular fillets, and the majority of trout processors and retailers are now demanding an increased minimum standard of flesh colour.

For the retailer the consistency of flesh colour is a prime consideration. Flesh colour in farmed trout is affected by many factors; including genetics, age, sexual status, season, growth rate and nutrition. Flesh colour is highly variable within trout populations and if flesh colour is specified at too high a level it is inevitable that there will be a high proportion of rejected fish.

Farmed trout and salmon absorb pigment from their feed and deposit it mostly in their white muscle and skin. During maturation this pigment is transported to the eggs of the female fish and to the skin of the male trout. The male skin pigmentation is important in the behavioural aspect of mating. In females the pigment is thought to be important in protecting the eggs against adverse environmental factors and in camouflage.

There are a number of ways to increase flesh colour in immature trout:

1. Increase the amount of pigment in the diet
2. Grade carefully, to ensure all fish are fed pigment from a minimum weight
3. Start pigment from a minimum weight
4. Harvest the fish at a larger size.

The pigments astaxanthin (Asta) and canthaxanthin (Cantha) are available to pigment farmed trout. Asta pigment has been shown to be more effective at pigmenting trout but is more expensive.

The upper limit on the use of Asta in UK fish feeds is 100 mg per kg of feed and for Cantha, 80 mg per kg of feed. Mixtures of the pigments may be used up to 100 mg per kg of feed. Our research, as well as that of independent research institutions, shows that the most cost-effective pigmentation regimes for rainbow trout should use between 30-60 mg of pigment per kg of feed.

Trouw Aquaculture has recently carried out a thorough review of the relative merits of Cantha and Asta. From this review and taking account of market considerations we are now strongly recommending our rainbow trout farming customers to use Asta, the source of the entrancing pink colouration of the edible flesh in wild trout. This article is intended to help the farmer by suggesting a number of strategies for the cost-effective use of Asta in producing pink flesh in farmed rainbow trout.

Pigmentation strategies

a) Portion sized trout

The first point to emphasise is that pigment represents 10-15% of feed costs and it is therefore very important to keep pigmentation costs to the minimum necessary for market requirements.

Our experience shows that attention to a few basic guidelines can help to improve flesh colour consistency.

These can be summarised as follows:

1. Start pigmenting when the fish are small (60-80 g).
2. Grade fish early and feed pigment to a tight grade. For example, a loose grade averaging 70 g may contain fish between 35-140 g. In this instance, a lead fish harvested at 400g would have grown 260 g on pigmented feed whilst its initially smaller grade siblings might have grown 365 g when harvested at the same weight.
3. Be aware of the end market specifications. The colour specifications may vary by product and by customer.
4. Regard the cost of pigment as part of an insurance policy helping to mitigate the potential level of rejects based on poor flesh colour at the processing factory.

Pigmentation regime guidelines

Trouw now offers the following pigment regimes and Table 1 below suggest the suitability of each.

Table 1. Suggested pigmentation regimes for trout harvested at 200-600g

60-150 g	150-600 g	Recommendation for:
	40	Wholesale market for whole fish
25	40	Whole fish in processor
50	40	Processor for standard fillet production
50	50	Processor high colour fillets

The figures in the unshaded boxes are for dietary Asta in mg pigment/kg feed (ppm added at manufacture).

b) Large trout

It is recommended that trout intended to be sold as large fish to the smoking market should be fed pigment from at least 150 g until routine sample monitoring establishes that the flesh colour specified for harvest has been reached. From this point dietary pigment can be reduced to a maintenance plus level (40 ppm). The large trout producer must be very careful to put in place a strategy to avoid maturation. This can involve the use of triploid stocks. Mature fish will become pale fleshed and totally unsuitable for further processing.

Table 2. Suggested pigmentation regime for trout harvested at 1000-2000g

60-150 g	150-800 g	>800 g	Recommendation
50 (optional)	40	25*	**Standard smoking quality
50	50	40	Superior smoking quality

The figures in the unshaded boxes are for dietary Asta in mg pigment/kg feed (ppm).

* *Flesh colour monitoring highly advisable before reducing dietary pigment.*

** *Please note that the use of the description 'standard' implies a non-exacting specification and the farmer may prefer to err on the side of caution and use the higher pigment option.*

Summary

Although the cost of pigment adds substantially to the cost of producing trout it makes a major contribution to the attractiveness and hence value of trout, especially when its flesh is on show, such as in ready-made meals and in the form of fillets. Atlantic salmon is a fierce competitor in the fish protein market but trout has several advantages over this now ubiquitous fish; farmed rainbow trout are of a better colour size for size and the muscle is more densely textured than the salmon.

Both cold and hot smoked trout are wonderful products and have great potential in the marketplace.

In the absence of large quantities of un-pigmented trout on the market it is difficult to discern whether the farmer actually receives a premium for the investment in pigment involved. In today's highly competitive marketplace, however, it is imperative that the trout offered to the consumer is economical, nutritious, tasty, safe to eat and attractive to the eye.

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PUTTING THE SQUEEZE ON WHITESPOT

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Introduction

The characteristic white spots of the ciliated protozoan *Ichthyophthirius multifiliis* in the epidermis of host fish are well known (Figure 1) and the parasite, commonly known as 'Ich' or 'Whitespot Disease', causes high mortalities in both commercially reared food and ornamental fish.

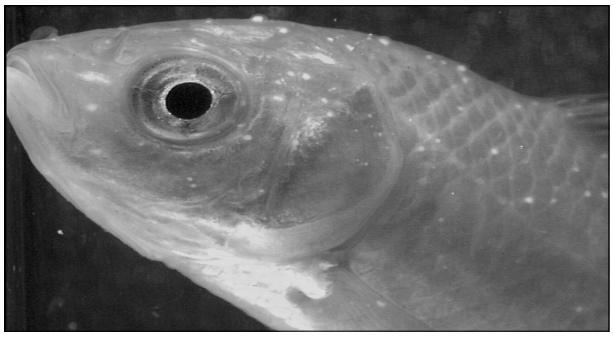


Figure 1. Fish with a heavy infestation of I. multifiliis

The pathogenicity of Ich is chiefly linked to immunopathological events, the depletion of nutrient reserves which leads to physiological dysfunction. Secondary bacterial infections have been associated with lesions. Unfortunately, there are no records of fish with natural resistance although inter and intraspecific variation in innate resistance within various tropical fish have been identified. Ich is a common parasite of teleost fish, has a broad temperature tolerance, and has been recorded from tropical regions to the Arctic circle. Man has been aware of ich for many years and was known as a disease of carp in China as early as the Sung Dynasty (960 - mid 1200s AD) and in the middle ages in Europe when it was probably introduced into the UK with cultured carp. Current control strategies are highly dependent on the use of chemicals and a vast number have been screened and assessed. Other approaches to controlling the disease include finding a molecular basis for treatment such as the development of a vaccine.

The life-cycle of Ich is well known. The parasitic phase of the life-cycle is the trophont or the white spots that are commonly seen located in the epidermis adjacent to the basal lamina in the skin, gills and mouth of fish. Aggregations of trophonts in the epidermis may arise as a result of multiple entry at single sites through tunnelling or reproduction. The duration of the trophont phase is temperature dependent but to give you an idea, it is about 10-12 days at 15°C in trout and about 7 days at 20°C. The parasite can overwinter in the fish, for about 3 to 4 months at 3°C. As a mature trophont, shown in Figure 2 with the characteristic horse-shaped nucleus and smaller, darker micronucleus, it actively exits the

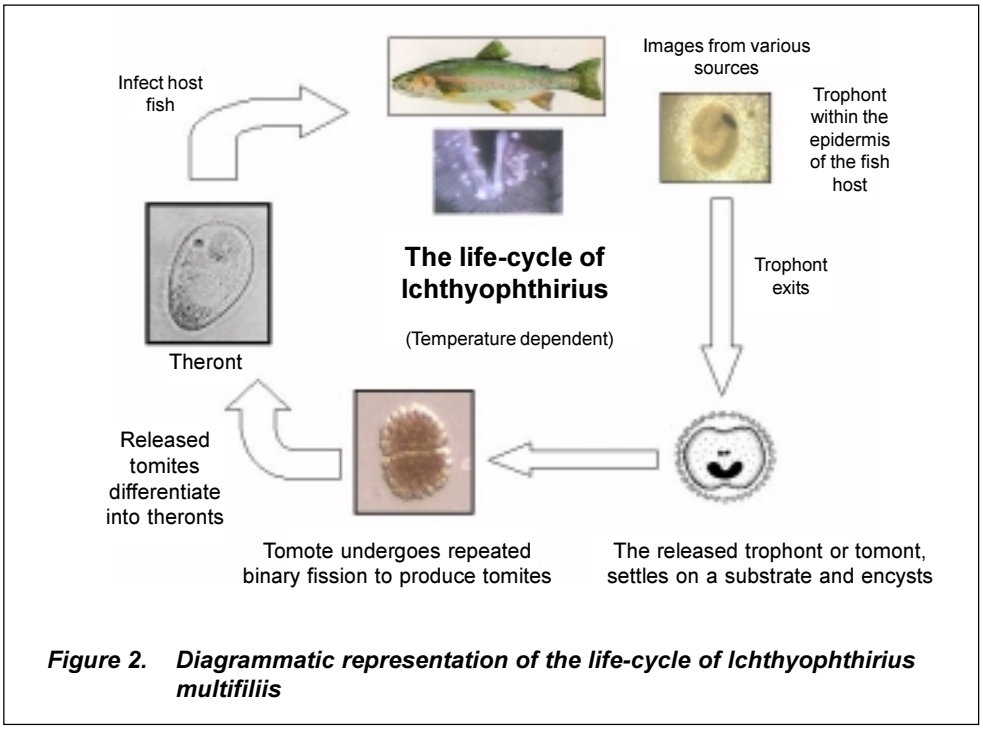


Figure 2. Diagrammatic representation of the life-cycle of Ichthyophthirius multifiliis

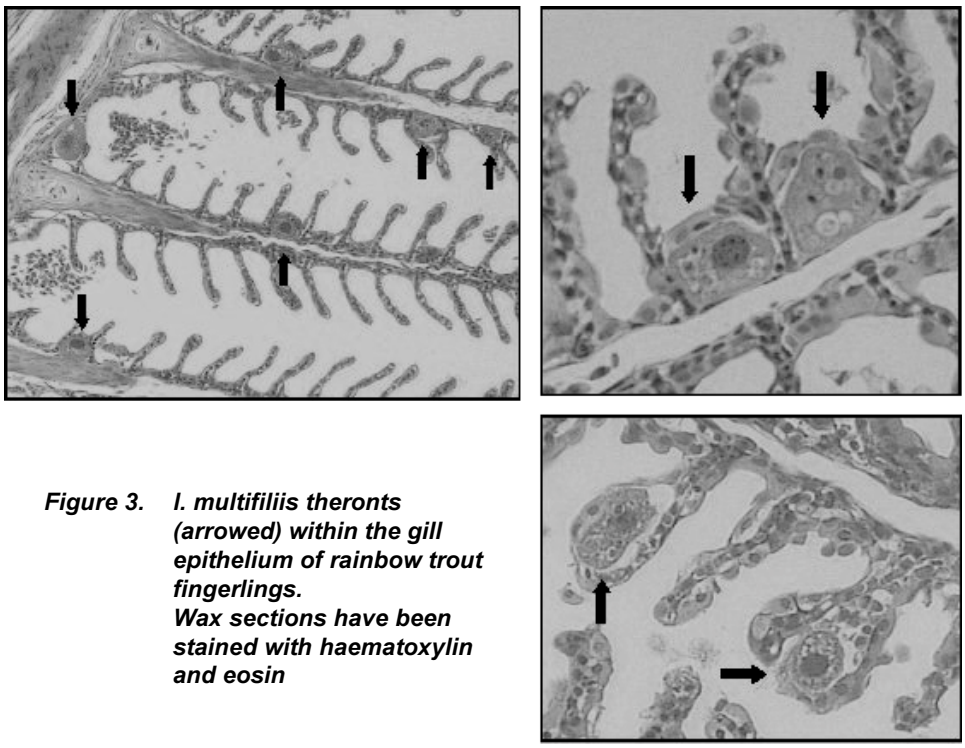


Figure 3. ***I. multifiliis theronts (arrowed) within the gill epithelium of rainbow trout fingerlings. Wax sections have been stained with haematoxylin and eosin***

epidermis leaving an exit wound. The released trophont is highly mobile, due to the cilia that cover the body surface. The trophont settles on the substrate, tank or stream bottom and encysts to become the tomont or cyst stage. As a tomont or cyst, it now undergoes repeated binary fission to produce 50 to 3000 tomites. The time from encystment to developed tomite taking about 36 hours at 15°C. These tomites now differentiate into theronts which are the stage infective to fish. The life expectancy of a theront at 15°C being about 36 to 48 hours.

Aims of the project

The control of whitespot is notoriously difficult and present methods are relatively ineffective, thus the aims of the present study were:

- To assess the activity of a number of antiprotozoal drugs both *in vitro* and *in vivo.*
- Any compounds killing the different stages of whitespot *in vitro* would then be the first to be explored *in vivo*, in fish infected with Ich.
- From the lab trials on infected fish, compounds still demonstrating action would then be tested under field conditions.

In vitro results

In vitro experiments on the three key life stages of *I. multifiliis*, mature trophonts, cysts and the infective theronts, were conducted to assess the efficacy of the water soluble chemicals proposed for testing prior to proceeding to laboratory *in vivo* trials. Each chemical was administered as a bath treatment, against each life stage under a range of concentrations and exposure periods. Of the antiprotozoal drugs selected for testing, four were water soluble, amprolium hydrochloride, monensin, bronopol and chloramine T. A total of 198 *in vitro* tests were conducted and the most efficacious doses and exposures were determined as follows:

a) Trophont stage

Figure 4 presents the usual sequence of events of the external phase of the *I. multifiliis* life-cycle in the absence of any control measure. The timing to each of the key development stages is given.

Having established the timing of each of the key developmental stages of the external stages of the parasite (mature trophont through the cyst stage to the infective theront stage) the action of each of the four water soluble bath treatments proposed for testing could be investigated.

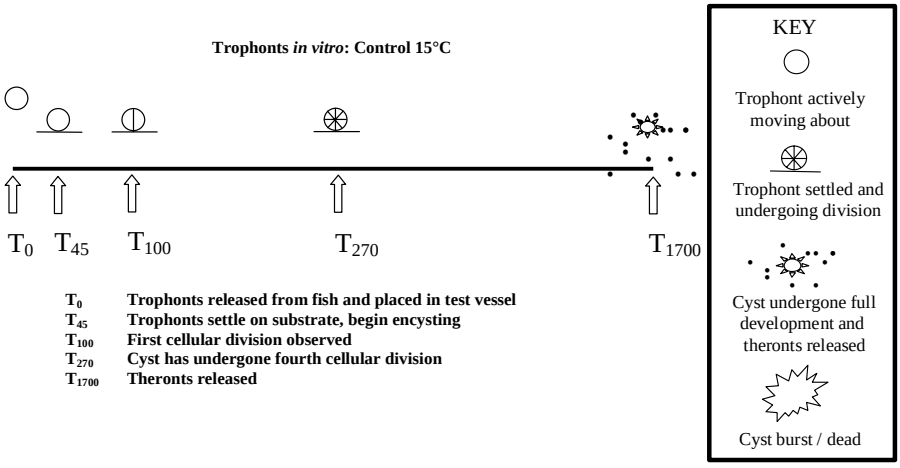
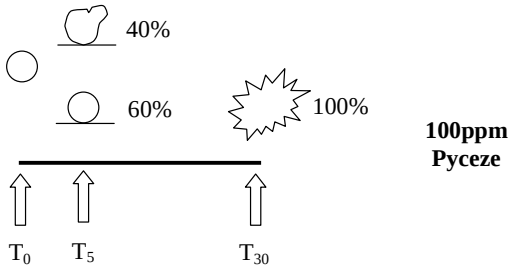
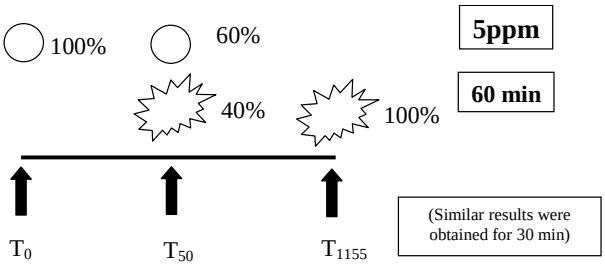


Figure 4. Development time (in minutes) of released trophont (tomont) to released theronts

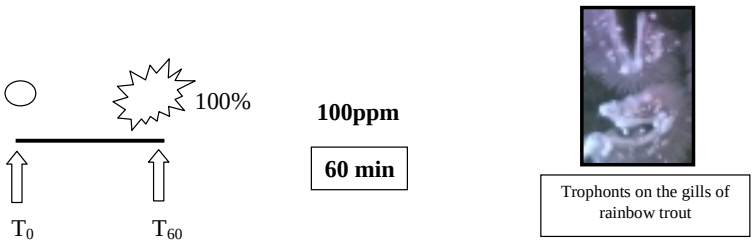
i) Bronopol (Pyceze)



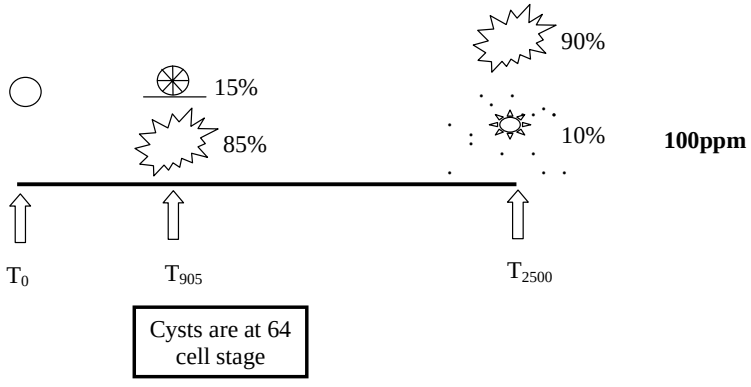
ii) Chloramine T



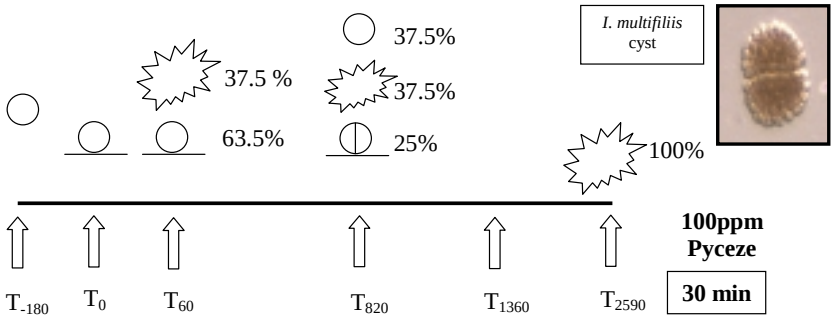
iii) Monensin



iv) Amprolium hydrochloride



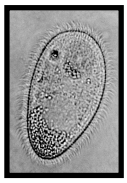
b) Cysts



c) Theronts

A range of chemical doses and exposure periods were tested against the infective theront stage of the parasite. The activity of each chemical was assessed immediately at the end of the period of exposure. The results for the four chemicals were:

Amprolium hydrochloride 100ppm (60 mins)	22.3% theronts dead*
Bronopol (Pyceze) 100ppm (30 mins)	51.7% theronts dead*
Chloramine T 50ppm (15 mins)	100% theronts dead
Monensin 100ppm (60 mins)	48.2% theronts dead*



* *As theronts cannot be removed from the chemical baths it is envisaged that the efficacy of chemical action and theront mortality would be higher if it were possible to transfer the theronts to a vessel of clean water and monitor the mortality rates with time.*

The demonstrated efficacy of all four water soluble compounds against certain or all of the life stages of *I. multifiliis* warranted their further assessment by *in vivo* trials.

In vivo results

The activity of bronopol and chloramine T was further tested under a regime of bath treatments at various concentrations and exposure times against *I. multifiliis* infections in rainbow trout. Amprolium hydrochloride, clopidol, decoquinate, monensin, nicarbazin, salinomycin sodium and a range of commercially available immunostimulants were tested as in-feed treatments for their protective capability to fish subsequently exposed to infective stages of the parasite or in their anti-protozoal action against the parasitic trophont stage in fish already infected with *I. multifiliis*. A total of 175 *in vivo* tests were conducted and the most efficacious doses from these methods of compound administration were determined. Figure 5 presents a schematic of the methodology followed.

Bath treatments

Single bath treatments with either bronopol or chloramine T were unsuccessful in significantly reducing the number of trophonts on treated fish. Multiple bath treatments however, with both compounds, showed efficacy in treatments of fish infected with the parasite significantly reducing trophont burdens in 50% of the test tanks. Better results were achieved by targeting the treatments to the external phase of the parasite life-cycle. These trials significantly reduced infections of naïve fish co-habited with the infected fish. Ten treatments of 100ppm bronopol (30 mins) gave a 17% reduction in trophont numbers whilst 10 treatments of 100ppm chloramine T (30 mins) gave a 93% reduction in trophont numbers.

In-feed treatments

Of the in-feed medication tested, doses of 104ppm and 75ppm amprolium hydrochloride and 65ppm and 92ppm clopidol, when given for 10 days prior to exposure with the infective stages (theronts) of *I. multifliis* significantly reduced trophont numbers in those fish receiving medicated feed. The trials with amprolium hydrochloride brought about a 62% and 63% trophont reduction in treated fish, while those with clopidol reduced trophont numbers on treated fish 35% and 23.2% respectively.

While these compounds have their place in a management control strategy, reducing the number of trophonts that could potentially infect fish at times of

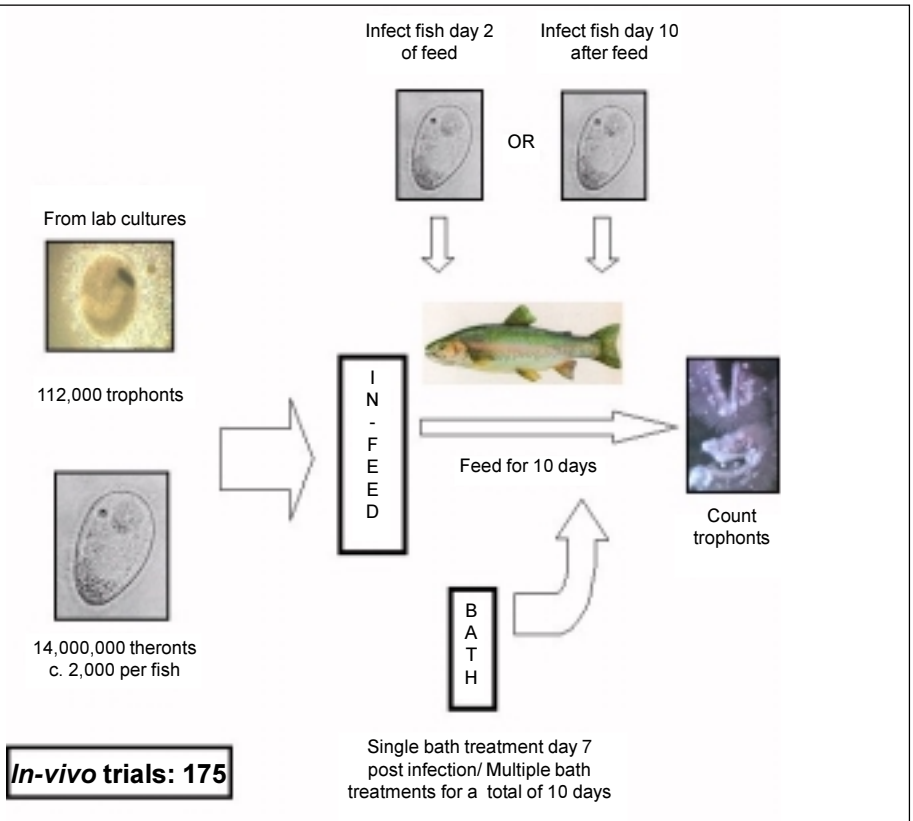


Figure 5. Schematic of the in vivo methodology followed for assessing the efficacy of the proposed in-feed and bath chemotherapeutants

high risk, it is more often the case that a compounds value is arguably increased if it can be effectively demonstrated that it can eradicate the parasite in fish that are already infected. Thus to test this, fish already infected with a single challenge of *I. multifiliis* were fed target doses of 100ppm amprolium hydrochloride and 100ppm salinomycin sodium. At the end of the 10 day period of feeding medicated feed, the number of trophonts per fish were counted and the precise doses calculated from the data collected at *post mortem*. The actual ingested dose 63ppm amprolium hydrochloride and 48ppm salinomycin sodium significantly reduced the number of trophonts surviving on treated fish by 75% and 94% respectively.

Field trials

While the laboratory trials were being conducted, there was a single opportunity (the summer of 1999) to assess the efficacy of the most promising compounds at that time on a commercial fish farm. Two compounds, chloramine T (bath) and amprolium hydrochloride (in-feed) emerged as possible candidates for field assessment. Thanks to the support of the BTA a farm was made available for conducting these trials. Six concrete raceways (c. 15ft long x 3ft wide x 3ft deep) each containing a minimum of 200 5g *O. mykiss* fry (c. 5g) were used for the two field trials.

For the first trial the efficacy of the bath treatments was tested. Two raceways received a dose of 100ppm chloramine T (30 mins) given 4 times over a 10 day period. Two raceways receiving a dose of 100ppm formalin (30 mins) was also given 4 times over a 10 day period and was used as a positive control in addition to a further two raceways receiving no bath treatment which acted as the control raceways.

The second trial assessing the action of amprolium hydrochloride added to the feed used two raceways (100ppm amprolium hydrochloride given daily over a 10 day period). Two raceways received a dose of 28ppm dimetridazole (positive control) and the last two raceways received ordinary pelleted feed (control). At the end of the 10 day period, a sample of 50 fish were taken from each raceway and the total number of trophonts on the gills, fins and body surface counted. A further 50 fish per raceway were taken 4 days later to assess whether there were delayed effects.

No significant difference in trophont numbers was found between any of the test and control groups. The levels of infection in the naturally infected stocks were too low to ascertain whether an effect had been elicted. The number of trophonts on the fish continued to remain low throughout what was a cool and rainy summer.

Summary

The results from the *in vivo* laboratory trials are very encouraging. Of the bath treatments, chloramine T and bronopol produced significant results in decreasing the number of trophonts successfully infecting naïve fish

when they were used to target the external stages of the parasite as it proliferates between cycles. Three in-feed compounds look promising. A course of medicated feed containing amprolium hydrochloride or clopidol prior to periods of theront exposure may reduce the number parasitising fish and, amprolium hydrochloride and salinomycin sodium may have their place as treatments against *I. multifiliis* once infected. It is hoped to assess the use of these chemotherapeutants in further field trials with a view towards developing a management strategy for the control of whitespot disease in trout.

FISH HEALTH CONTROLS:THE ACTIVITIES OF THE FISH HEALTH INSPECTORATE IN ENGLAND AND WALES 2000

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 1993 has been documented annually in Trout News since 1996.

This report aims to provide an update of the Inspectorate's work during 2000, showing how it performed with respect to the targets set in each area of its work and outlining the current status of notifiable diseases of fish in England and Wales.

This report makes no mention of the Inspectorate's shellfish programme, which is reported annually in Shellfish News.

Inspection programmes

Details of the number of inspections carried out in each area of the Inspectorate's work are shown in Table 1.

The salmonid farm inspection programme consisted of two visits per annum to sites with broodstock and an annual visit to non-broodstock sites. Included as broodstock sites were any laying down eggs. This ensured that all farms importing salmonid eggs were visited twice. Samples were as usual targeted from 50% of the farms visited, and from source of imported eggs. This inspection programme was completed as scheduled. Only two farms were not inspected, both remained fallow throughout the year.

Inspectors took samples from farms on suspicion of the presence of a notifiable disease during only 2 inspections, and following direct reports of disease problems from a further 9 farms. Additional samples were taken from 7 mortalities in wild salmonid fish populations. This represented a significant decrease in the number of disease investigations relative to 1999. None of these investigations resulted in the diagnosis of a notifiable disease.

Table 1. Number of tasks, by category, undertaken by the Fish Health Inspectorate in 2000

	Site type		
	Salmonid	Coarse	Total
Farm inspections (no samples)	287	160	447
Routine sampling and inspection	134	0	134
Inspection and sampling on suspicion	2	5	7
Notifiable disease re-tests and contact tests	12	12	24
Reported disease outbreaks & mortality investigations	20	94	114
Import checks: Sampling	4	46	50
Inspection/physical checks	3	14	17
Export certification	3	113	116
Farm registration visits	5	17	22
Site disinfection visits	1	0	1
Wild fish monitoring	46	1	47
Other visits/inspections	13	0	13
		Total	992

Several of these disease reports were in respect of large mortalities among brown trout in the late Autumn, caused by infections with Saprolegnia. Most of these were from farms on southern river systems, and it would appear that environmental conditions in this region resulted in an unusually high fungal spore challenge at this time. The restrictions on the use of compounds such as malachite green, which historically has been used as an antifungal treatment, are likely to have contributed to this situation.

The programme of checks on salmonid imports was again carried out in 2000. This involved the sampling of all batches of fish imported from Ireland, and random sampling of the juvenile fish derived from each source of egg imports from each exporting country, i.e. Denmark, Isle of Man, N Ireland and South Africa. These samples were taken when the imported stock were at approximately the six weeks' feeding stage, when any serious disease problems were likely to be manifest.

The Inspectorate also organised the collection of 44 samples of wild salmonids from rivers in England and Wales in 2000. These were part of a research survey, which aimed to establish whether wild salmonids had been exposed to, or were carrying, ISA virus. The results of this study are due to be released in a joint DEFRA/ SEERAD publication.

The inspection programme for coarse fish sites during 2000 involved a single visit to each farm site, targeted at harvest periods to aid stock inspection. A formal programme of import checks was established on consignments of SVC susceptible species coming from non-EU countries. This saw a total of forty-six samples processed from different sources covering twenty countries.

Both the salmonid and coarse fish inspection programmes were completed satisfactorily, with changes only made following changes in the number of sites holding broodstock and seasonal changes in broodstock sample availability.

The status of notifiable diseases in England and wales

VHS and **IHN**
All registered farm sites continue to test negative for these List II viral diseases, as did all samples of fish from UK sources. None of the samples taken on report of these disease problems was as a result of suspicion of either of these diseases.

BKD
There were no new cases of BKD detected in 2000, and 8 sites remain designated for the disease.

Re-test samples on 6 designated trout farms led to the re-isolation of Renibacterium *salmoninarum,* the causative agent, from 2 farms. One of these farms still held infected stock from the time the disease was first isolated in 1999, while the second site has tested positive in each of the previous 5 years.

Two of the designated farms have completed two of their three years of negative testing, and we remain hopeful that controls may be lifted from these farms in 2001. A third site is due to be re-developed, and a total clearance and disinfection of this site is anticipated in 2001.

Of the remaining designated 2 sites, one has been entirely dismantled, and another remains fallow and has been partially disinfected. It is hoped that the designations on these sites can be lifted, following tests on local feral fish populations and completion of disinfection respectively.

IPN
All salmon farms in England and Wales continue to be screened annually for IPN virus, and in 2000 all sites tested negative . There are no farms subject to movement restrictions for this disease.

Gyrodactylosis
All salmonid samples from farms or wild environments were screened for *G. salaris* and none was found positive. As in previous years a variety of other *Gyrodactylus* species were found, but never at problematic levels.

SVC
Re-testing for SVC took place on twelve sites in 2000, resulting in the successful completion of negative re-test programmes on 8 fishery sites.

No new cases of SVC were found in 2000, though a total of 94 instances of coarse fish mortalities in fishery or fish farm waters were investigated. In addition a total of 46 samples of SVC susceptible species were taken from imported ornamental fish consignments, and all tested negative for SVC virus.

Emergent diseases

Lactococcus garvieae investigations

In September 2000, the first occurrence of fish mortalities associated with the presence of the organism *Lactococcus garvieae*, was reported in a trout farm and fishery. This organism is known to cause Lactococcosis in farmed fish elsewhere in Europe. The bacterium was isolated following the onset of a dramatic mortality. The outbreak occurred following a grading exercise undertaken at high water temperatures. Poor environmental conditions and handling of the fish at the

site were thought to be major contributory factors to the high mortality rate. During the subsequent investigation, the infection was not detected on the 8 farms from which the fish had been sourced during the year. In addition, there have been no reports of mortalities in the fish subsequently restocked into the 18 major fishery sites that had been supplied from the affected site. Events have been, and will continue to be, monitored during the current period.

From the information gained and our testing, it has not been possible to identify the precise source of the infection. There has been a history of serious mortality problems in intensive trout culture in Italy, Spain and more recently France attributed to infection with *Lactococcus garvieae*. The recent French cases have clearly demonstrated links between outbreaks at new locations and movements of infected fish. In the outbreak in Southern England no such evidence has been uncovered and checks on UK farms which supplied fish to the site of the outbreak have all proved negative for *Lactococcus garvieae*. The Inspectorate has closely monitored the situation at the outbreak site this winter by taking samples and will be closely monitoring the site during the spring and summer of 2001 as the water temperature rises. The 18 fishery sites are also being contacted in order to remind them of the need to be vigilant and to contact us immediately if they suspect abnormal mortalities.

Import/export trade

As ever, there was a significant demand for licences to import fish from countries outside the EU. A total of 1021 licences were issued an increase of 45% over 1999 and 72% over 1998. Most of this increase was in licences to import tropical species or koi and goldfish. Table 2 gives details of the number and type of licences issued and also movement documents issued for fish exports, by fish type.

The major import trade remains that in tropical fish, goldfish and koi carp from outside the EU. Imports from other countries within the EU were predominantly of salmonid eggs and of turbot for direct consumption, as in 1998 and 1999.

The small export trade was again predominantly in ornamental fish to other countries of the EU, with few salmonid egg exports.

The illegal import of coarse fish for introduction to fishery waters remains a significant problem. During 2000 the Inspectorate intercepted a large illegal consignment of mixed cyprinids, which were being transported alongside a shipment of eels for the table trade. Action was taken in co-operation with the official services in another EU Member State to ensure that this trade was stopped and appropriate controls placed on future eel movements.

The Inspectorate remains keen to receive any information about potentially illegal imports of fish and its HOTLINE number 01305 206681 is available twenty-four hours per day. The Inspectorate also operates an on-call system providing twenty-four hour cover by fish health inspectors. The duty inspector can be reached via the DEFRA duty office on 0207 2708960.

Table 2. Imports and exports of fish monitored by the inspectorate in 2000

A.	**Import licences by category for trade from non-EU countries**		
	Tropical species (annual licence)		335
	Koi & goldfish (annual licence)		315
	Specified purpose (Indiviual consignment)		215
	Human consumption		156
		Total	1021
B.	**Movement documents for EU trade**		
	Import documents received/checked:		
	Salmonid eggs		144
	Turbot (for direct consumption)		148
	Coarse fish		71
	Shellfish		34
	Others		177
		Total	574
C.	**Export documents issued**		
	Salmonids		6
	Ornamental fish		280
	Shellfish		92
		Total	378

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 (FHI) 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 DEFRA 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 and can be found on our web site www.efishbusiness.com . Additional copies of our new Charter can be obtained from the FHI or on the CEFAS web site www.cefas.co.uk .

The FHI has agreed to answer all calls to the administrative team (01305 206673/4) promptly. Since the publication of our new charter document we have accepted the DEFRA standard within 10 rings (20 second period). This is monitored regularly by logging all calls received on a cFhosen day. We fully met this standard.

Over the spring the FHI launched a web site dedicated to the movement and keeping of fish - www.efishbusiness.com. This site includes electronic copies of application and registration forms as well as details of the legislation, rules and regulations. An increasing number of callers have been directed to this site to fulfil their requirements e.g. to obtain forms, students researching projects.

The following report shows the performance achieved against our target of 100%, for the period 1st April 2000 to 31st March 2001.

	Achieved in 2000-01
Correspondence	
The Inspectorate's target is to reply to all letters, e-mails, faxes and complaints, within 10 working days of receipt.	**93.8%**
Import licence applications	
The Inspectorate has undertaken to issue import licences within 10 working days of receipt.	**99.7%**
Deposit licence applications	
The FHI issue crayfish, lobster and mollusc deposit licences, these are <u>not</u> 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 registrations

Registration visits

The Inspectorate has undertaken to visit all potential farmers Within 20 working days of receipt of their application.	**70.6%**

Registration administration

The Inspectorate aim to complete the administrative action within a further 10 days from the date of the visit.	**93.1%**

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, marteiliosis, haplosporidiosis, iridovirosis, mikrocytosis and perkinsosis.	**100%**
Respond to other notifiable diseases within 2 working days.	**100%**

Reporting of test results and visit summaries

The FHI 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. We have agreed to provide a follow up letter within 10 working days to advise the farmers in writing of any points raised during the visit.	**78.2%**

Overall results

The overall compliance rate with our set targets.	**89.9%**

The total correspondence received and recorded by the Inspectorate was 2022. Our performance fully met or approached our targets in most areas. We will continue to strive to achieve all our standards in 2001/ 2002.

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 Union 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.

DEFRA/NERC/BTA FUNDED RESEARCH

LINK AQUACULTURE – TROUT RELATED R&D

Compiled by Dr Mark James of LINK Aquaculture

Although the LINK Aquaculture programme is now closed to applications, the progress of all of the on-going projects continues to be monitored annually.

Part of the LINK philosophy is to encourage "technology transfer". Like all buzz phrases this simple phrase was probably coined without any real understanding of the enormity of the task involved. In simple terms technology transfer implies that the outcome of a scientific research project is embraced by an enthusiastic industry capable of developing the results into marketable products.

The gulf between the point at which scientific research ends, however, and industry uptake begins, is often wide. As a result the exploitation of important science is delayed or does not take place and the commercial benefits of leadership in a particular field are lost. Future claims on the public purse to support applied research and development (R&D) may also be undermined.

What the LINK process has shown us is that it is vitally important to secure the input of industry at an early stage in project development. By so doing, scientific effort can be focused, producing results that are more likely to be accessible and useful to industry. It has also become clear that many projects require a robust development strategy as part of their initial rationale. This process should include a feasibility study to tease out the real commercial potential and identify possible barriers to development at an early stage.

Regrettably, many applied projects continue to pass scientific scrutiny, but fail to address key questions related to practical routes to exploitation. Unfortunately, such fundamental problems result from an R&D environment that discourages a business oriented approach. The scientist is required to continually engage in novel work to secure funding, whilst industry remains focused on production and margins.

The nature of research and development funding dictates that research projects tend to be structured around a three-year time frame. Few funding agencies are prepared to commit to longer-term projects, resulting in project focused R&D rather than problem solving R&D. By carefully monitoring the progress of LINK projects it is possible to facilitate the process of technology transfer, but a great deal more needs to be done to streamline the delivery of industrial relevant R&D from the outset. Of the 36 LINK Aquaculture projects funded, 15 have now been completed. The first marketable products resulting from these projects are now beginning to emerge, together with important contingent information on processes and ideas that will help the aquaculture industry to become more competitive.

For the trout industry, LINK has supported the successful development of an alternative to Malachite Green through Pyceze, a practical method for the automated humane slaughter of trout, as well as potential treatments for Proliferative Kidney Disease (PKD) and Whitespot. The progress documented in the following reports on LINK – trout projects is testament to what can be achieved through collaborative R&D in a relatively short period. Despite the lack of an obvious successor to the LINK programme, it is important that the momentum towards prioritised and well-focused industry led R&D is not lost.

Dr Mark James
Programme Co-ordinator

Project progress summaries:

Identification and Assessment of Chemical Control Methods for PKD – TRT04

Project Leader: ***Dr Sandra Adams***
Institute of Aquaculture
University of Stirling
Sponsor: DEFRA
Research Partner: ***University of Stirling***
Industrial Partners: ***Vetrepharm***
Aquaculture Vaccines Ltd
British Trout Association

Proliferative kidney disease (PKD) continues to affect many trout farm sites in the UK annually. This project extension (completed in March 2001) focused on the encouraging results obtained in the preceding three year Link project-TRT04 where two compounds were

identified as potential chemical treatments for PKD. One of the compounds was shown to directly affect the survival of *Tetracapsula bryosalmonae* (formerly known as PKX) *in vivo,* while the other compound appeared to delay the infection or reduce fish mortalities (due to PKD and co-infections). The specific objectives for the final year were to optimise the dosage and timing of administration for the compound directly affecting the parasite, performing large scale field trials with the other compound, and to examine the possibility of administering the two compounds together to examine any synergistic effect.

Preliminary work had established that both compounds are palatable but one (acting directly on the parasite) was found to be toxic for rainbow trout at the doses used. Further experiments confirmed that this compound is efficacious in removing *T. bryosalmonae* from rainbow trout, however, relatively high doses of the chemical adversely affect the haematopoetic tissue of trout resulting in the fish becoming immuno-compromised. A six days treatment with the compound at a level of 100mg/kg of feed administered at 1% body weight per day appears to be capable of removing all of the parasites from a moderately infected kidney while preventing high mortalities. From the infection data it is probable that substantially lower doses of the compound could be used to prevent PKD thus alleviating many of the adverse effects of the chemical. During and at the end of the trials kidneys were routinely taken from all experimental groups for immunohisochemical analysis using a cocktail of *T. bryosalmonae* specific antibodies. Using these antibodies it was possible to count the parasite numbers within kidney tissues and relate this to pathological changes in the kidney. The results indicated that the effect of the compound was cumulative in removing the parasite from the kidney. Only those fish that were fed the compound at a high dose for 6 days had all of the parasites removed from their kidneys. Lower doses significantly reduced the parasite number, in a dose dependant response. The timing of the treatment was also important in the successful administration of the compound. Those fish that were fed when they possessed pre-clinical PKD (grade 1 kidneys) all recovered from the disease. However, feeding fish during the clinical stages of the disease had little effect in reducing the parasite numbers. This may have been an effect of reduced feeding caused by the disease suggesting that timing of administration is very important and should be performed in the early stages of infection. It was also noted that those fish that were successfully treated with the compound became reinfected with the parasite later in the summer. This may be significant in allowing the fish to obtain natural resistance to the parasite while avoiding the disease though the height of the summer. Examining trout, retained on the farm from the previous year, suggested that natural resistance to PKD after feeding with the compound is achieved through this mechanism.

Large-scale trials were conducted with the other naturally derived compound. These trials containing over 22,000 fish that were fed the medicated diet over the summer period. These trials demonstrated that this compound had a measurable effect in reducing the mortality on enzootic farms. However, this effect was slight and appeared to be involved in enabling the fish to respond better to other stressors rather than PKD itself.

The results of the previous work examining these compounds suggested that any synergy between the compounds would rely on ongoing treatment with one compound and a 6 day treatment with the other compound (directly affecting the parasite). No synergism between compounds was observed.

A small amount of additional funding is presently being sought to undertake important additional field trials with the compound directly affecting the parasite, to confirm the optimum dose and timing for treatment of PKD.

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Development of Vaccination Methods for the Control of BKD – SAL10

Project Leader: ***Dr Sandra Adams***
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University of Stirling
Sponsor: DEFRA
Research Partners: ***University of Stirling***
University of Plymouth
Industrial Partners: ***Aquaculture Vaccines Ltd***
Scottish Quality Salmon
British Trout Association

Bacterial kidney disease (BKD is a chronic bacterial disease affecting both wild and cultured salmonid fish. There is no effective treatment for BKD although vaccination would be an ideal approach. Vaccine preparations are often simply composed of formalin-killed bacteria, and the different bacterial components (antigens) elicit a protective immune response in fish. However, this approach has been unsuccessful *in* the development of a BKD vaccine. In this project, individual *Renibacterium salmoninarum* antigens have been identified and synthesised in bulk in the laboratory using biotechnology. Scientists at the University of Plymouth produce these recombinant vaccines and they are tested for efficacy at the Institute of Aquaculture, University of Stirling. The British Trout Association, Scottish Quality Salmon and Aquaculture Vaccines Limited are industrial partners on the project.

A total of seven different *R. salmoninarum* recombinant antigens have now been produced and four of these have already been tested for toxicity, efficacy and immune response, while the remaining three are currently being

assessed. Aquarium trials indicated that one particular recombinant vaccine stimulated a significant protective immune response in Rainbow trout, and the immune response of Atlantic salmon to this antigen is now being assessed. These trials have also confirmed the immuno-suppressive nature of the P57 protein. The project has been given a six-month extension until the end of August to allow completion of the aquarium trials and for field trials to be set up.

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Automated humane slaughter of trout – TRT07

Project Leader: ***Mr Jeff Lines***
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Sponsor: DEFRA
Research Partners: ***Silsoe Research Institue***
Bristol University
Industrial Partners: ***British Trout Association***
Humane Slaughter Association
Aquatess Ltd
Waitrose Ltd
Tesco Stores Ltd
Safeway Stores plc
Marks & Spencer plc
Sainsburys Supermarkets Ltd

Industry concern to improve the welfare of trout at slaughter resulted in a Link Aquaculture project supported by DEFRA, The British Trout Association, Tesco, Sainsburys, Marks & Spencer, Waitrose, Safeway, the Humane Slaughter Association and GW Aquaculture. The objective was to develop and test a system capable of automatically and humanely slaughtering trout at high speed while maintaining current standards of carcass quality and operator safety. The project is being carried out by Silsoe Research Institute and the University of Bristol.

Following the previous background research reported in Trout News, a full-scale model has been built and trialled (Figure 1). Initial testing showed that the concept worked well. Fish are pumped out of a tank or raceway, using standard fish pumps. They enter a rotating barrel, made up of many individual chambers, each fully flooded with water (Figure 2). In the chambers the fish are immediately stunned using high frequency electricity. The barrel takes one minute to rotate round to the exit, during which time the fish are killed by the electric current. On exit from the chamber the fish pass over a dewatering system and fall into a bin of ice slurry ready for transport to the processing unit.

Figure 1. The humane trout slaughter unit under test

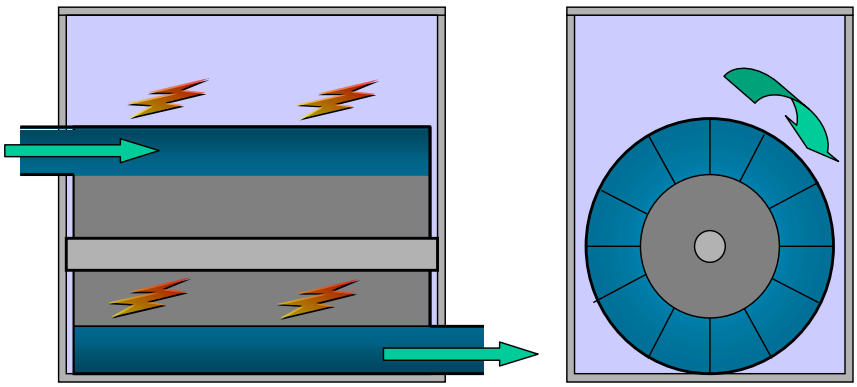

Figure 2. Cross-sections of the fish slaughter machine, showing the input and outputs into the individual chambers of the rotating barrel. Each chamber has an electric current passed across it and the whole barrel is flooded with water

The initial trials showed that additional work was necessary to improvement to the flow of fish through the machine. In the most recent tests this unit was able to stun and kill fish at a commercially viable rate, processing about 400 fish within seven minutes. All the fish investigated showed good carcass quality and were without the haemorrhages or broken bones often associated with electrical stunning.

The next stage of the project will be to use the machine for a full commercial slaughter. This will finally test its capability to run continuously with a high throughput of fish. The fish are to be smoked and filleted after slaughter, which will give the most rigorous testing of the quality. We are planning to show this machine at Sparsholt during the BTA conference and arrangements for demonstrations, following the conference, are being made.

For more information on the machine please contact the project manager, Jeff Lines at Silsoe Research Institute (email: jeff.lines@bbsrc.ac.uk).

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Investigations into non specific and acquired immune response to Rainbow Trout Fry Syndrome with a view to disease control – TRT10

Project Leader: ***Professor Randolph Richards***
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Sponsor: DEFRA
Research Partners: ***Heriot-Watt University***
University of Stirling
Industrial Partners: ***Drummond Fish Farm***
Caledonian Trout Co
Kames Fish Farming Ltd
Glenkens Fish Farming Ltd
J&W Stuart Ltd
SEPA

Rainbow trout fry syndrome (RTFS), caused by *Flavobacterium psychrophilum,* continues to be one of the most significant diseases affecting the rainbow trout fry and fingerling industry in the UK. Antibiotic treatment of infected fish is currently the only method of control as no commercial vaccine is available to prevent RTFS. This project, now in its final year, has made progress towards the development of an effective RTFS vaccine.

A variety of potential vaccines have been tested in fish to assess their immune response and to identify the optimal method of vaccine preparation. Preliminary data indicated that fingerlings mounted a rapid antibody response to *F. psychrophilum* antigens and significant protection was achieved with some of the vaccine formulations following challenge. Previous passive immunisation studies, whereby naïve fish were injected with serum collected from fish that had been exposed to RTFS and then infected with *F. psychrophilum*, also showed that protection could be conferred and provided evidence of the involvement of antibodies in protection against RTFS. Western blot analysis using bacteria cultured *in vitro* and *in vivo* is presently in progress to confirm the identity of the protective antigens.

Alternative media for the culture of *F.psychrophilum* that avoid the use of beef products have successfully been developed and aquarium trials are presently in progress to determine the efficacy of vaccine formulations prepared by these methods in fry of different weights.

All the research is now being performed at the Institute of Aquaculture, Stirling University in collaboration with Alpharma Animal Health and the British Trout Association following the appointment of Dr Rachel Rangdale to a full-time post in the microbiology and virology research and advice team in Environment and Food Safety at CEFAS Weymouth.

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Selective improvement in rainbow trout:mass selection and markers - TRT12

Project Leader: ***Professor Brendan McAndrew***
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Sponsor: NERC
Research Partner: ***University of Stirling***
Industrial Partner: ***British Trout Association***

This project officially started on the 1st June 2001 with the appointment of Dr Neil Cameron a quantitative geneticist from the Roslin Institute with extensive experience in the development of breeding programmes in the pig industry and Dr John Taggart of the Institute of Aquaculture a highly respected salmonid molecular geneticist. They both attended the first project meeting along with Prof Niall Bromage the technical Director of the British Trout Association, the two Principal Investigators Prof Brendan McAndrew and Dr John Woolliams and Mr Jóse Pedro Ureta an MSc research student who will be helping on the project.

The projects stated objectives are to identify breeding goals and produce a selection index for the UK rainbow trout industry. This will be achieved by the use of an industry wide questionnaire that will assess the relative importance of various performance characteristics of the species to the different sectors of the industry. This will be backed by detailed breeding experiments to assess the levels of genetic variation and the genetic correlations between performance traits in UK rainbow trout strains. This work will be carried out under commercial conditions and will utilise the latest PIT tagging and DNA fingerprinting techniques to identify the genetic relationship between individual fish.

John Taggart and Jóse Ureta have begun to optimise a genotyping system for rainbow trout from published studies. This work will identify the most informative microsatellite markers for parentage assignment within UK strains of rainbow trout. This type of highly variable marker system can be used to identify the parentage of any individual offspring from known parents by the analysis of a tiny sample of fin tissue. This means that large numbers of eggs from different families can be combined into a single population that ensures all individuals are grown under the same commercial conditions without the need for any other physical tagging or marking. The parentage of individuals of interest can then be assessed at or close to harvest so that unrelated fish of high genetic value can be bred as the next generation of broodstock. This process will maximise genetic gains while minimising any problems of inbreeding in the selected lines.

John Woolliams and Neil Cameron have begun to develop a questionnaire for dissemination to BTA members to identify performance goals and the traits of interest within each of these. The questionnaire will enable the relative importance and value of the traits to the various sectors of the industry to be assessed. A draft questionnaire has been submitted to the BTA council and they have agreed to the format and have identified a number of important traits. Meetings will be held with small number of BTA members representative of the different sectors of the industry to fine tune language and main traits of interest. The first of these meetings has already been held with Scot-trout, a large processing co-operative, to identify possible traits associated with quality and processing characteristics. Future meetings are planned with both large vertically integrated companies as well as smaller niche suppliers to fine tune the questionnaire before it is used in an industry wide survey. It is hope that the results of the survey will be available before the start of this year's spawning season so that the main traits of interest can be included in the proposed breeding experiments.

More details on the progress of this project and selective breeding strategies will be presented at the BTA conference in Sparsholt in September.

For further information on this project you can contact Prof Brendan McAndrew at bjm1@stir.ac.uk
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Off-flavour problems in farmed trout: Identification of causative organisms and development of management strategies – TRT13

Project Leader: ***Dr Linda Lawton, The Robert Gordon University, Aberdeen***
Sponsor: ***DEFRA***
Research Partners: ***The Robert Gordon University, University of Stirling***
Industrial Partner: ***British Trout Association***

The main cause of off-flavour problems in farmed fish is related to the musty/earthy taints produced by cyanobacteria (blue-green algae). Cyanobacteria are microscopic organisms that favour high sunlight, nutrients (especially nitrate and phosphate) and warmer water temperatures. They tend to cause taint problems during summer and early autumn, as this is when conditions are most favourable for their growth. This year, possibly as a result of an early warm sunny spell, we have already detected taint in some farmed trout. The musty/earthy compounds have been both detected through taste panel findings and, using the analytical methods which we have established in Aberdeen we can both identify and quantify the taint compounds that are present. Routine monitoring will be continued throughout the year to identify the relationship between changing environmental conditions and the occurrence of taint.

Our field monitoring studies are being complemented by controlled laboratory experiments. Our studies using taint producing cultures have indicated that the taint compounds are produced within the cyanobacterial cells and only released after at least three weeks growth when the cells begin to age. Information like this should help us develop an early warning strategy where detection of the cyanobacteria prior to the release of the musty/earthy taint may provide sufficient time to implement remedial measures preventing tainting of trout. Another focus of our laboratory studies is the evaluation of methods that can destroy the taint compounds before they accumulate in trout. The thrust of this work involves a novel water treatment that uses titanium dioxide as a catalyst to breakdown organic compounds to harmless by-products. Preliminary studies suggest that this technology may be helpful and could be employed to destroy taint producing compounds.

For further information on this project you can contact Dr Linda Lawton at l.lawton@rgu.ac.uk
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WHAT IS STOCKING DENSITY?

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What is stocking density?

The Farm Animal Welfare Council (FAWC) is concerned about the current stocking density practices operated by the salmon and trout farming industry. In their report (1) to the UK government and Council of Europe, they suggested that densities of 30-40 kg/m^3 were possibly too high for trout. They recommended that legislation be introduced to limit density. In the Government's response to this report (2), it was agreed that some research should first of all be carried out. Two projects were commissioned (AW1203, FC0916), with the support of the British Trout Association (BTA). At the outset of these two projects, both funded by the Department for Environment, Food and Rural Affairs (DEFRA formerly MAFF), we reviewed the scientific literature on relationships between density and trout welfare. This review has highlighted the fact that a simple definition of stocking density as weight per cubic metre has little or no value in regard to fish.

What is the definition of 'stocking density'?

Stocking density is rarely defined in aquaculture texts. Strictly speaking, "stocking density" should refer to the concentration at which fish are initially 'stocked' into a system. However, the term is normally used to refer to density of the fish at any point in time. Density is obviously not static after stocking, and increases as the fish grow, being reduced by thinning/grading several times during a production cycle. To reflect its dynamic nature, the concentration of fish at any point in time may more appropriately be termed "stock density" or just "density". However, due to its prevalent use, the term "stocking density" is one that we should probably continue to use, but its meaning needs to be clearly understood by all parties.

What factors should be considered?

Legislation in force for terrestrial livestock stipulates a minimum spatial area to provide for behavioural needs (3). What FAWC are in effect suggesting is that the same should be done for fish. However, the concept of 'minimum space' for fish is more complex than for terrestrial species. The medium in which the fish live is 3-dimensional and vital not just for their behaviour but also for their survival (i.e. the provision of oxygen and the removal of wastes). The term "carrying capacity" is also often used (e.g. 4) in a similar fashion to stocking density. However, carrying capacity is generally used to refer to the maximum biomass of fish based upon physiological needs, and therefore ignores spatial needs.

Despite much previous research, the roles of behaviour and water quality deterioration in causing the effects sometimes associated with higher densities (decreased growth and nutritional status; increased FCR, fin erosion and mortality) are not clear. The behaviour of trout is

Table 1. Various measures that have been used to express the density of trout

Authors' Term	Unit (metric equivalent)	Relation to requirements		Inclusion of environmental factors					Example reference
		Spatial	Physiological	Inflow rate	Fish size	Ration	Temperature	Oxygen availability	
Stocking rate	No/m^2	✔	✖	✖	✖	✖	✖	✖	6
Stocking density	Kg/m^2	✔	✔	✖	✖	✖	✖	✖	7
Rearing density	No/m^3	✔✔	✖	✖	✖	✖	✖	✖	8
Stocking density/ Static loading density	Kg/m^3	✔	✔	✖	✖	✖	✖	✖	1, 4, 9
Loading density	Kg fish/kg water	✔	✔	✖	✖	✖	✖	✖	10
Density Index	Kg/m^3/cm	✔	✔	✖	✔	✖	✖	✖	10
Carrying capacity/ Metabolic loading density	Kg/l/min	✖	✔✔	✔	✖	✖	✖	✖	4, 9
Carrying capacity	kg food/d/m^3	✖	✔	✖	✔	✔	✔	✖	11
Carrying capacity	Food/ available O_2/l/min	✖	✔✔	✔	✔	✔	✔	✔	12
Flow Index/ Loading factor	Kg/l/min/cm	✖	✔✔	✔	✔	✔	✔	✖	10, 13

affected by many environmental factors including food ration and distribution, current speed, fish size, temperature, water depth and lighting conditions. Similarly, water quality is affected by water management procedures and the fish's metabolic rate. Factors such as temperature, pH, inflow rate, fish size, ration and aeration/oxygenation will therefore determine the impact of density on water quality. Any density limits should, therefore, relate to both physiological and spatial needs, and be inclusive of significant environmental conditions. In this regard, it is encouraging that the FAWC report acknowledges the importance of such factors. Body size and holding system size are also incorporated into existing legislation for pigs and hens (3).

How should stocking density be expressed?

There is apparent confusion over how best to express density. The situation is demonstrated by a rare definition of stocking density (5), which illustrates four different ways of expressing density:

> Numbers or biomass of fish expressed either per unit volume of tank or pond capacity or per unit volume in unit time of water inflow

The FAWC report made density recommendations in kg/m^3 (1), as do certain quality schemes currently operating in the UK. The BTA Code of Practice (4) makes recommendations in both kg/m^3 and kg/l/min, and qualifies these recommendations to fish size. However, these units are only a selection of the various ways that trout density has been expressed (Table 1). The different measures vary in their relation to spatial and physiological requirements, and whether additional environmental factors are included. The various measures therefore differ greatly in the detail required, ease of calculation, and applicability to different system types.

Previous approaches

In practice, the densities at which farmers have kept their stock have been based on experience and intuition, with codes of practice and handbooks being used as a guide. However, it is worth highlighting the work of a series of US scientists who attempted to determine carrying capacity limits quantitatively by combining theory with empirical data.

Haskell (11) initiated the process by assuming that

- carrying capacity was limited by oxygen consumption and accumulation of metabolic wastes
- both oxygen consumption and metabolic waste production are proportional to the amount of food fed.

He therefore suggested that carrying capacity would be limited by the amount of food that could be fed per day per unit volume, and this could be determined empirically by trial and error. He did, however, recognise that he had not incorporated additional factors such as water flow, which would be important. Willoughby (12) extended Haskell's approach by assuming that

- oxygen, rather than accumulated metabolic wastes, determines carrying capacity.
- a constant amount of oxygen is required to metabolise a given weight of trout pellets.

He therefore reasoned that carrying capacity, in terms of weight of food, could be predicted from the amount of oxygen available in the water and the flow rate. Both Haskell's and Willoughby's maximum carrying capacities could then be extrapolated to different fish sizes and temperatures by combining the permissible ration with information from feed tables. Implicit in these approaches, therefore, is that lower temperatures and larger sized fish allow a higher carrying capacity.

Piper (13) further extended this approach by suggesting that fish length could replace food weight, as there was a simple relationship between fish length and daily ration. Once a carrying capacity in terms of fish weight had been determined empirically, it could be combined with the water inflow rate and fish length to calculate a "loading factor". This loading factor could then be used to predict carrying capacity for other fish sizes and flow rates. Piper also provided a table to correct loading factors for temperature and altitude. Westers (14) then produced a series of graphs based upon assumptions and some empirical data relating carrying capacity in weight per unit volume to water exchange rate, for different fish sizes and temperatures (a selection of which are redrawn in Figure 1).

Piper (10, 13) recognised that although a maximum loading level may allow survival and growth and maximise economic return, it might be sub-optimal for disease control and fish quality, and hence welfare. Therefore, in addition to his "Flow Index" which accounts for physiological needs, he also proposed a simple "Density Index" to account for spatial needs. His suggested density index for trout was 0.5, i.e. the density in lbs./ft^3 should not exceed half the fish length in inches. This equates to a metric ratio of 3.2, between fish length in cm and density in kg/m^3 (Figure 2). However, although such a simple index does consider fish size, it does not account for other environmental factors.

This significant series of papers therefore not only illustrates the importance of additional factors in determining physiological and spatial limits, but also provides insight into how such factors might be incorporated into density guidelines. However, on a cautionary note, an important caveat added by all four authors was that the suggested limits were only applicable to their particular systems. Values would therefore have to be modified before being applied to any other system.

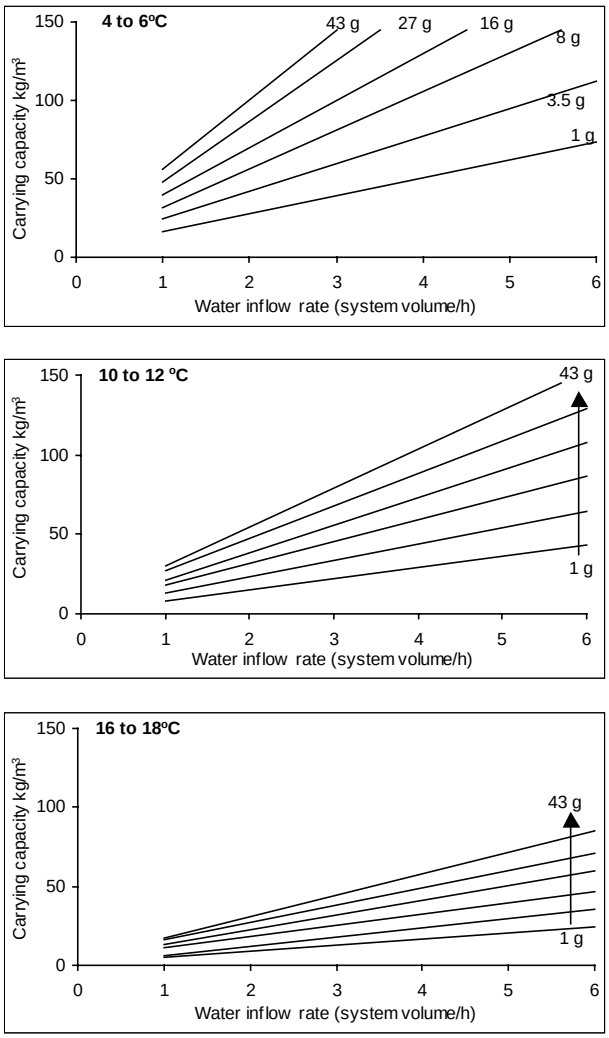

Figure 1. Relationships between carrying capacity, water inflow rate, fish size and temperature proposed by Westers (14) for coho salmon, converted to metric equivalents. Note the increase in carrying capacity with increasing water flow and fish size, and decreasing temperature

Conclusions

Three decades ago there was much interest in the US in determining maximum carrying capacities to prevent physiological overloading and consequent mass mortalities. Nowadays the driving force, certainly within the UK and Europe, is in determining and controlling densities to ensure acceptable fish welfare. If control of density itself is seen as the way forward, either through voluntary codes of practice, quality schemes or legislation, it is important to ensure that the most efficient and appropriate means of quantifying density and incorporating environmental factors is chosen. However, both specification and verification of densities dependant upon a series of other variables will be highly complex. An alternative approach to safeguard welfare may be the designation of appropriate water quality conditions and behavioural indicators.

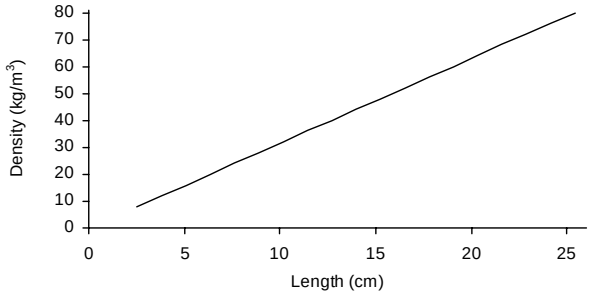

Figure 2. Relationship between stocking density limit and fish length, based upon a Density Index of 0.5 suggested for trout by Piper (10, 13). This equates to a metric ratio of 3.2, i.e. density in kg/m³ should not exceed 3.2 times the length in cm

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INFORMATION FILE

WHERE TO GET HELP OR ADVICE

Policy Matters

Department for Environment, Food and Rural Affairs,
Nobel House, 17 Smith Square, London SW1P 3JR
(Switchboard tel. 020 7238 3000)
(General fax. 020 7238 6591)

Fish farming policy:-
Fisheries Division IIA, Room 308, Nobel House,
(Tel. 020 7238 5947) (Fax. 020 7238 5938)

Grant Aid:-
Fisheries Division 1B, Room 441 Nobel House,
(Tel. 020 7238 5710) (Fax. 020 7238 5951)

Research and Development Programmes:-
Chief Scientist's Group, Cromwell House Dean
Stanley Street, London SW1 3JH
(Tel. 020 7904 6000) (Fax. 020 7904 6715)

You can also visit the MAFF website at
http://www.maff.gov.uk/

The National Assembly for Wales,
Agricultural Department, Division 2 (Fisheries),
New Crown Buildings, Cathays Park, Cardiff CF1 3NQ
(Tel. 02920 823567) (Fax. 02920 823562)

Scottish Executive of Rural Affairs Department,
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Department of Agriculture and Rural Affairs for
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Fisheries Division, Annexe 5, Castle Grounds,
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Scientific and technical advice

Health regulations and disease control -
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Pollutants and their effects -
CEFAS Burnham Laboratory, Remembrance Avenue,
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You can also visit the CEFAS website at
http://www.cefas.co.uk

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Government Buildings, Hook Rise South,
Tolworth, Surbiton, Surrey KT6 7NF
(Tel. 0181 330 4411) (Fax. 0181 330 8764)

Environmental issues -
Environmental Agency, Rio House, Aztec West,
Almondsbury, Bristol, BS32 4UD
(Tel. 01454 624400) (Fax. 01454 624033)

Veterinary medicines -
The Veterinary Medicines Directorate,
Woodham Lane, New Haw,
Addlestone, Surrey KT15 3LS
(Tel. 01932 336911) (Fax. 01932 336618)
http://www.open.gov.uk./vmd/vmdhome.htm

Food hygiene -
Food Standards Agency
PO Box 31037
Ergon House, 17 Smith Square, London SW1P 3JR
(Tel: 0207 238 3000)

Advice on commercial activities

The British Trout Association,
8/9 Lambton Place, London W11 2SH
(Tel. 020 7221 6065) (Fax. 020 7221 6049)

Wildlife conservation

Joint Nature Conservation Committee,
Monkstone House, City Road, Peterborough PE1 1JY
(Tel. 01733 562626) (Fax. 01733 555948)

English Nature,
Northminster House, Peterborough, PE1 1UA
(Tel. 01733 455000) (Fax. 01733 568834)

Countryside Council for Wales,
Ffordd Penrhos, Bangor, LL57 2LQ
(Tel. 01248 385500) (Fax. 01248 355782)

Scottish Natural Heritage
12 Hope Terrace, Edinburgh, Scotland, EH9 2AS
(Tel. 0131 447 4784) (Fax. 0131 446 2277)

Other Useful Numbers

LINK Aquaculture
Dr Mark James, Marine Resource Consultants Ltd,
c/o Freshwater Fisheries Laboratory
Faskally, Pitlochry, Perthshire PH16 5LB
(Tel. 01796 472060) (Fax. 01796 473523)
E-mail: majames@compuserve.com

BTA NEWS

Jane Davis, Executive Officer, British Trout Association

Quality Trout UK

In March 2000 the development of a single quality assurance scheme was identified as essential for consistent industry wide production of high quality product by participants at the DEFRA sponsored 'Future Strategies for the Industry' seminar. Much discussion ensued between the BTA, Scottish Quality Trout and key industry players resulting in the establishment of Quality Trout UK (QTUK), the broadening of the SQT assurance scheme to fulfill this much needed industry development.

The interim management group and technical advisory committee appointed to oversee the development of QTUK completed their review of the principles and standards of the new scheme early this June. Lord Southesk of Kinnard Mill Trout Farm was elected Chairman of the Management Board and the BTA Executive Officer Jane Davis was appointed QTUK Company Secretary. Lord Southesk said how delighted he was to accept the Chairmanship of the scheme which he believed would be of great benefit to its members and an important step forward for the UK trout industry.

The QTUK assurance scheme will be certified by EFSIS Certification Ltd. The QTUK Farm standard which is EN45011 accredited requires one annual inspection and also provides members with a hatchery standard for their suppliers. The scheme's Processor standard consists of an EFSIS accredited inspection for food safety which conforms to British Retail Consortium (BRC) minimum standards and a bolt on standard on issues of food quality.

Sign-up packs which included the QTUK standards and the cost of membership were issued to trout farmers and processors throughout the UK at the end of June encouraging potential members to join the new scheme.

As the success of the scheme relies on solid membership numbers it is hoped that QTUK will receive the full support of the UK trout industry. To receive a copy of the QTUK sign-up pack or request further information please contact the offices of the British Trout Association.

Sarum Foods

Consolidation of the processing industry and the development of better links between growers and processors were identified as central to competing in a modern food market and the industry's future viability by both the 'Promar Report' and the later 'PMS Report on the English and Welsh Trout Farming Industry' which was part funded under the Agricultural Development Grant Scheme and by English and Welsh producers.

In a positive response to The Promar Report and the later PMS Report, Trafalgar Fisheries, Andwell Mill Foods Ltd. and Alderley Trout Ltd. have consolidated their operations to form a new added value processing business Sarum Foods. Sarum Foods will operate from the existing sites at Andwell and Alderley. Ben Read and Adam Komrower executive directors of Sarum intend to build on their existing supply arrangements with growers to achieve planned supply of controlled quality fish throughout the year.

BTA Restructuring

As BTA members will be aware the Association has recently undergone an internal review of its aims and objectives including a reexamination of the effectiveness of the Association's structure in meeting its obligations to the membership.

A direct result of this process has been the restructuring of the BTA Council along sectoral lines. In effect this has meant that members are represented by sectors that best reflect their business interests rather than represented by geographical boundaries. There are four sectors and each sector has a representative on Council. These sectors are Egg, Fry and Fingerling, Small Producer and Niche Markets, Restocking and Large Producer. Scotland and Northern Ireland being they only remaining regional sectors.

It is hoped that this restructuring will develop clear channels of communication amongst the membership and bring specialist sector knowledge to Council. Sector representatives would then be in a position to establish working group to conduct business unique to their sector drawing on the knowledge of the membership sectors. The result of elections for sector representatives will be available at the end of June 2001.

Another outcome from the review process will be the implementation of a new levy structure that will come into effect in the forthcoming year. All BTA members will see a reduction in their levy contributions.

Promotional Activities

The BTA promotional campaign for 2001/2002 will place emphasis on added-value products, particularly trout fillets and smoked trout and has identified a target

audience of young people, the health conscious and children's dinners. A series of new recipes have been developed for these target groups to focus the media attention and present trout as healthy, versatile and contemporary. The Catering sector has also been identified as a target and will feature in this year's campaign.

Given the unlikely timing of the General Election and the nations preoccupation with foot & mouth (F&M), National Trout Week (NTW) was somewhat scaled down this year. However the momentum gained from last years successful campaign continued with celebrity chef Ross Burden (the Bond look-a-like) developing a tasty new fillet recipe 'Trout with Mustard sauce' for the BTA. The BTA's website was also launched during NTW, take a look at www.britishtrout.co.uk. Several BTA members held open days for the public over the bank holiday weekend. Information on members local open days and farmers' markets coupled with a competition to win a copy of Ross's latest cookbook was readily picked up by regional press.

BTA/BioMar Denmark Study Trip

In early April fifteen BTA members embarked on a 3 day study tour of the Danish trout farming industry. The tour organised by Gitte Christensen of BioMar, Denmark allowed for first hand examination of the latest trends in automated monitoring, farm design and environmental management. Members visited a wide range of industry sectors and attended a series of lectures at BioMar HQ. Such was the enthusiasm for the tour that BioMar have graciously offered to host another in April 2002.

Current Market

Reports are of a buoyant table market with strong demand and little surplus table trout available. Southern floods, cold Scottish winters, F&M and bad press for the salmon industry can all have been said to contribute to this current increase in consumer demand. The prevailing atmosphere amongst producers is of greater optimism with many taking advantage of the resurgence of interest in trout to explore opportunities in product development. Some see the development of QTUK coupled with a general upturn as indicative of a potential price increase.

The effects of F&M for the restocking industry have been harsh, with late season openings and a reduction in visitors to the countryside, many restockers in effected areas are foreseeing considerable losses. The situation for brown trout restockers is particularly depressed especially for those operating in restriction zones as a number of fisheries have not and are unlikely to open at all this season.

Legislation

An alternative method of monitoring fish farm discharges has been developed by the Association who will take the opportunity afforded by the forthcoming review of the methods of monitoring discharges to present the proposal to the Environment Agency (EA). The proposal, which has been subject to consultation amongst the membership, would see farms operating under agreed General Binding Rules which would represent best practice and a self-monitoring regime. The monitoring regime, based on risk assessment, would provide reassurance that the environment was being safeguarded. It is important that the costs of monitoring should be proportional to the risk and be affordable to those being monitored and an appropriate reduction in current EA monitoring charges would be expected.

Socio-Economic Study

The BTA have recently secured FIFG grant money towards a socio-economic study of the UK trout industry. The study aims to learn more about the socio-economic importance of trout farming and to quantify the role of the industry in the rural economy. Nautilus Consultants, based in Edinburgh, were awarded the project which will run from April-September 2001. This study will provide a more comprehensive overview of the size, distribution and links between the different sectors of the trout industry, from feed manufacture and farm supplies through cultivation to final retail.

The results of the study will be available to individual farms in a consolidated form, giving them access to statistical data on which to base production targets, market initiatives and development plans. The study will also provide simple production models and industry benchmarks against which farmers can test their performance.

The data collection part of the study will involve questionnaires being sent to UK trout farms. It includes questions about the type, size and production of the farm, about indicative turnover and the costs of operating a modern trout farm.

All data is confidential and handled entirely by Nautilus Consultants. If you would like more information about the study, please contact Kath Winnard at Nautilus Consultants on 0131 555 0660 or by e-mail at kath@nautilus-consultants.co.uk

BRITISH TROUT FARMING CONFERENCE, SPARSHOLT 2001

Wednesday 5th, Thursday 6th and Friday 7th September 2001

PROGRAMME

Wednesday 5th September

	Delegates gather
from 1900	Trouw Barbecue at Fit Jym's

Thursday 6th September

0900-1000	Registration
Morning Chair:	Robin Scott, Nidderdale Trout Farm
1005-1015	Welcome and Opening Address Tim Jackson, Principal, Sparsholt College Hampshire
1015-1040	The Food Industry under attack Barrie Gardner, Hydro Seafood a.s.
1040-1045	Discussion
1045-1110	Salmon market research project David Nickell, Roche Products Ltd.
1110-1115	Discussion
1115-1145	Coffee
1145-1210	State of the fish stocks Dr Richard Millner, CEFAS Lowestoft
1210-1215	Discussion
1215-1240	Vegetable oils in fish feeds John Sargent, University of Stirling
1240-1245	Discussion
1245-1400	Lunch
Afternoon Chair:	Nick Read, Alderley Trout Farm
1400-1425	Healthy fish - healthy business Helma Slierendrecht, Biomar
1425-1430	Discussion
1430-1455	Algal taints Linda Lawton, Robert Gordon University, Aberdeen
1455-1500	Discussion
1500-1530	Tea
1530-1555	Quality Trout UK Director, QT UK
1555-1600	Discussion
1600-1625	Poultry Value Added Products Mike Alcorn, O'Kanes Poultry
1625-1635	Discussion

1635-1650	Address by Robin Scott, BTA Chairman
1900	Aquaculture Vaccines Ltd. Reception
1930	Conference Dinner Supported by Biomar, Dana Feeds and Roche Products Ltd.

Friday 7th September

0900-0945	Registration and Coffee
Morning Chair:	Dick Lincoln, CEFAS
0945-1030	Immunostimulants Jan Raa, Biotec Asa
1030-1035	Discussion
1035-1105	Coffee
1105-1130	The modern coarse fishery: monster or Mecca? Simon Scott, Sparsholt College
1130-1135	Discussion
1135-1200	Automated Humane Slaughter of Trout Jeff Lines, Silsoe Research Institute
1200-1205	Discussion
1205-1230	Selective breeding Brenden McAndrew, University of Stirling
1230-1235	Discussion
1235-1330	Lunch
Afternoon Chair:	Chris Ryder/Colin Penny, DEFRA
1330-1355	EU Review of fish health regulations Barry Hill, CEFAS Weymouth
1355-1400	Discussion
1400-1425	Fish medication: red tape and consumer protection Peter Scott, Zoo and Aquatic Veterinary Group
1425-1430	Discussion
1430-1500	Tea
1500-1525	The efficacy and use of Pyceze - the malachite replacement Richard Hunter, Novartis Animal Vaccines
1525-1530	Dicussion
1530-1555	Biosecurity Edward Branson, Trouw Aquaculture
1555-1600	Discussion
1600	Close of Conference

A display of DEFRA and LINK Aquaculture poster papers will be located next to the Main Hall for the duration of the Conference

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

RESEARCH NEWS

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

1. Storage of unfertilised eggs

The eggs of salmonid fish are released into the body cavity at ovulation where they are bathed in coelomic or ovarian fluid before extrusion. The external storage of eggs in this fluid is possible for several days, the duration depending on the holding temperature. Storage in artificial media is not as effective although this has been less extensively investigated. The present study examined the storage of unfertilised rainbow trout eggs in coelomic fluid and in Cortland medium (devoid of bicarbonate and phosphate), which was buffered with 20 mM Hepes (4-(2-hydroxyethyl)-l-piperazineethane- sulfonic acid) or Tris-HCl (Tris hydroxymethyl amino-methane hydrochloride) and adjusted to a pH of 8.5. Eggs stored in these solutions for 24 and 48 hours, were fertilised using sperm derived from 4-6 males. The sperm was applied in a diluant (127 mM NaCl, 20 mM Tris-HCl, pH 9.5). The percentage of embryos reaching the eyed and hatching stages was recorded as an index of fertility. Unfertilised trout eggs stored for 48 hours at 12 – 13°C in Cortland medium buffered with Hepes or Tris exhibited the same fertility as eggs fertilised prior to storage. In fact, the percentage of embryos reaching the eyed stage was significantly greater in eggs stored in the modified Cortland solutions than in eggs stored for the same amount of time in coelomic fluid. It appears that fertility may be better in eggs stored in Cortland medium containing Hepes than in medium containing Tris. Since serine protease inhibitors have been shown to enhance fertility of goldfish eggs, the effect of a soybean trypsin inhibitor on egg fertility was investigated. Trout eggs stored for 24 hours in Cortland medium containing 2.0 mg soybean trypsin inhibitor/ml were almost completely infertile. Eggs stored in modified Cortland medium and fertilised in the direct presence of soybean trypsin inhibitor (0.01 mg/ml sperm dilutant) exhibited the same percentage of eyed and hatched embryos as eggs stored in Cortland medium alone. This suggests that the inhibitor did not directly block fertilisation but had an effect during storage. The results of this study demonstrated that unfertilised trout eggs can be maintained for at least two days without loss of fertility in modified Cortland solution buffered with Hepes or Tris. Storage in this modified Cortland solution is better than in the coelomic fluid produced by females at the time of ovulation. While serine proteases enhance egg fertility in goldfish, the presence of these inhibitors significantly reduces the fertility of trout eggs stored in modified Cortland solution.

Reference

GOETZ, F.W. (Department of Biological Sciences, University of Notre Dame, P.O. Box 369 Notre Dame, IN 46556-0369, USA. Tel.: +1-219-631-5545; fax: +1-219-631-7413; e-mail:goetz.1@nd.edu) AND COFFMAN, M.A. 2000. Storage of unfertilised eggs of rainbow trout (*Oncorhynchus mykiss*) in artificial media. Aquaculture, 184(3-4): 267-276.

2. Breakdown of fish-cage waste

Substantial quantities of organic matter are deposited in sediments beneath fish cages during salmonid production, derived either from waste food or directly as fish faeces. In most cases these accumulate with time since their removal by natural biochemical degradation and physical processes is generally insufficient. The input of highly labile organic matter can modify the sediment characteristics affecting benthic communities directly and promoting chemical processes with products such as methane and hydrogen sulphite all of which are toxic to fish. This study looked at the composition and rate of degradation of organic waste in sediments beneath and adjacent to fish cages in order to better determine the duration of fallowing required for sediments to recover and allow restocking to take place. Sediment samples from two near-adjacent sites, but with different sediment types and depths, were analysed for total organic matter, lipids (fatty acids and sterols), %C, %N and redox potential during a 12-month fallowing period. Additionally, representative samples of fish food and fish faeces were analysed. It was found that most of the accumulation of organic matter was confined to an area directly underneath the fish cages, but at 30 m from the centre of the cage, indicators of fish cage waste (faeces and fish food) were still elevated compared with reference sites. As both fish food and faeces have distinctive fatty acid profiles, the relative proportion of food and/or faeces deposited on the sediment could be determined. After 12 months fallowing, fish-farm-derived organic matter in surface sediment at the centre of the cage remained greater than at 30 m distance, even though redox potentials indicated that normal oxic conditions had returned. Thus although the sediment appeared to have returned partially to conditions existing prior to stocking with fish the risk exists that with subsequent restocking sediments may degenerate more rapidly.

Reference

MCGHIE, T.K. (CSIRO Division of Marine Research, GPO Box 1538, Hobart, Tasmania 7001, Australia), Crawford, C.M., MITCHELL, I.M. AND O'BRIEN, D. 2000. The degradation of fish-cage waste in sediments during fallowing. Aquaculture, 187: 351-366.

3. The use of by-product meals in trout aquaculture

The cultivation of salmonid and sea-water fish species relies heavily on fish meal as the major constituent of the feed supply. The rapid growth of aquaculture world wide has placed increasing demands on capture fisheries for fish meal supplies which are already nearing maximum sustainable limits. This study looked at the potential of using alternative sources of meal utilising animal and fish products. The apparent digestibilities (availabilities) of dry matter, protein, phosphorus and selected minerals was determined using rainbow trout for a variety of products. Blood meal (ring dried), feather meal and deboned fish meal had relatively high concentrations of protein, low concentrations of phosphorus and many minerals, and high degestibilities (availabilities) of these nutrients. Other animal by-products, however, had high concentrations of minerals, including phosphorus, which are associated with the bone fraction. Availabilities of manganese and zinc in the diet were reduced by the inclusion of high-ash animal by-products in the diet, whereas availabilities of potassium, sodium and copper were relatively unaffected. Dietary concentrations of bone minerals (calcium, phophorus) and ash were inversely correlated with availabilities (% of intake) of most minerals except copper in the diet. Also, dietary concentrations of bone minerals correlated inversely with the net absorption (mg per gram) of zinc, manganese and magnesium in the diet. When rainbow trout were fed diets containing incremental concentrations of fish bones, the apparent availabilites of phosphorus, calcium, magnesium and iron decreased as fish bone content in the diet increased. Reducing the bone fraction of high-ash (high-phosphorus) by-product meals is therefore an essential approach to using such ingredients in low-pollution fish feeds.

Reference

Sugiura, S.H., Babbitt, J.K., Dong, F.M. and Hardy, R.W. (Hagerman Fish Culture Experimental Station, University of Idaho, 3059F National Fish Hatchery Road, Hagerman, ID 83332, USA). 2000. Utilization of fish and animal by-product meals in low-pollution feeds for rainbow trout *Oncorhynchus mykiss* (Walbaum). Aquaculture Research, 31(7): 585-593.

4. Muscle activity at slaughter affects flesh quality

There is increasing evidence that activity at slaughter affects the flesh quality of fish. Greater activity immediately prior to death results in a more rapid drop in muscle pH as the white muscle metabolism is predominantly anaerobic, producing lactic acid. Greater activity also results in shorter times to the onset of rigor. The strength of the muscle is affected, the muscle breaking more easily under strain after increased activity. Anecdotal evidence also indicates that there are potential effects of muscle activity on gaping which occurs when the tissues between the muscle blocks break and the blocks become separated and muscle coloration, both important aspects of flesh quality in commercial terms. This paper reports on experiments aimed at investigating the extent that activity affects flesh quality by using two extremes of muscle activity. An anaesthetic, used commercially on fish farms in Australia, was used to produce a 'no activity' or 'rested' group and electro-stimulation of a carcass immediately after death was used as a model for high levels of muscle activity prior to death. The experiment showed that electro-stimulation of 1.5 kg rainbow trout immediately after slaughter not only resulted in short times to rigor, but that the flesh colour was also affected. The flesh became significantly lighter, less red, had a higher chroma measurement and a lowered score on the Roche colour card compared to flesh from fish that had shown very low levels of activity before slaughter. The fillets were also significantly more susceptible to gaping following the post- mortem stimulation indicating that electro-stimulation after death reduces the quality of trout flesh.

Reference

Robb, D.H.F. (Department of Clinical Veterinary Science, University of Bristol, Langford, Bristol, BS40 5DU, UK, Tel: +44-117-9289312; fax: +44-117-9289324; e-mail: david.robb@bristol.ac.uk), Kestin, S.C. and Warriss, P.D. 2000. Muscle activity at slaughter: 1. Changes in flesh colour and gaping in rainbow trout. Aquaculture, 182(3-4): 261-269.

5. Triploid induction in brook trout

Techniques for production of triploids are well described for commercially reared salmonids for example rainbow trout and Atlantic salmon. Among less commonly used species, including brook trout *Salvelinus fontinalis*, these protocols have not been optimised. As a prelude to investigating the regional potential for commercial culture of brook trout with all-female and all-female triploid stocks, experiments were conducted to test the effects of the primary variables of thermal shock used to induce retention of second polar bodies. The objective was to identify a protocol that maximises yield of both triploid and gynogenetic diploid progeny. The first experiment measured survival of gynogenetic embryos produced by heat shocks involving combinations of different temperatures (26, 27 28, and 29°C) and durations (7, 10, 13, 16, 19, or 22 min). In three subsequent experiments, production of triploids was assessed for thermal shocks involving variable times of initiation (7, 10, 13, 16, 19, or 22 minutes post activation) in addition to the above temperatures and durations. A significant trend for decrease in survival and increase in percent triploidy was observed with increase in temperature and duration of thermal shock. Effects for time of initiation in two of three experiments were not significant; in the third, survival tended to increase and percent triploidy to decrease with increase

in time of initiation. With a pre-shock incubation temperature of 11-12°C. the most generally effective protocol involved a thermal shock of 28°C for 10 min duration initiated at 10-16 min post-activation, for which relative survival was 68-71%, percentage triploid yield was 54-70%. In a fifth experiment, the fertilized eggs of 14 females were treated separately with a 28°C shock of 10 min applied at 10 min post activation. Although relative survival to initiation of feeding raged between 42% and 100%, percentage triploidy was consistently 98-100%.

Reference

GALBREATH, P.F. (Mountain Aquaculture Research Center, Western Carolina University, Cullowhee, North Carolina 28723, USA. e-mail:galbreat@wcu.edu) AND SAMPLES, B.L. 2000. Optimization of thermal shock protocols for induction of triploidy in brook trout. North American Journal of Aquaculture, 62(4): 249 – 259.

6. Reducing biofouling of fish-cage netting

Bio-fouling of fish-cage netting is a serious problem to the marine cultivation of fish world-wide. Fouling significantly impedes water flow and therefore the supply of oxygen to caged fish, increases structural fatigue on cages and may harbour disease causing micro-organisms. To overcome the necessity of frequent and costly cleaning of nets this paper evaluates the efficacy of a silicone coating (Veridian 2000, Internation Coatings) to reduce fouling on salmon-cage netting at a farm in Tasmania, Australia. The development, composition and adhesion of fouling was compared between white silicone-coated netting, white non-coated netting and black non-coated netting. Results showed that significantly less fouling occurred on the white silicone-netting (1.9 kg/m squared) compared to non-coated white (7.8 kg/m squared) netting after 163 days immersion. On silicone-coated netting the green alga *Ulva rigida* dominated the fouling mass, with smaller amounts of solitary ascidians. In contrast, solitary ascidians dominated the non-coated black and white netting and accounted for more that 75% of the fouling mass. Netting colour significantly affected the growth and composition of algal fouling, but had no effect on invertebrate fouling. Cleaning experiments demonstrated that fouling organisms were poorly adhered to the silicone coating and that relatively little effort was required for their removal. It was concluded that the flexibility and non-toxic properties of silicone coatings make them highly suitable for significantly reducing the total fouling mass and greatly increased the effectiveness of in situ (underwater) net cleaning. Although colour significantly affected the colonisation of netting by some algal species, fouling was always more difficult to remove from non-coated netting in comparision to silicone-coated netting.

Reference

HODSON, S.L. (Cooperative Research Centre for Aquaculture, Tasmanian Aquaculture and Fisheries Institute, PO Box 1214, Launceston, Tasmania 7250, Australia. Tel.: +61-3-6324-3816; fax: +61-3-6324-3804.), BURKE, C.M. AND BISSETT, A.P. 2000. Biofouling of fish-cage netting: the efficacy of a silicone coating and the effect of netting colour. Aquaculture, 184(3-4): 277-290.

7. Effect of growth rate on quality traits and feed utilisation

The rapid expansion of salmonid farming world wide has been achieved by improvements in all aspects of production including the establishment of breeding programmes, feed quality and disease control. This has resulted in a reduction in fish mortality and production times but also some negative aspects such as low slaughter yield and reduced flesh quality in terms of high fat content. This study looked at the effect of fast and slow growth rate of rainbow trout and brook trout on feed utilisation and conversion, slaughter yield and fat content in attempts to redress these problems. Rainbow trout of initial average weight 150 g and brook trout initially weighing 124 g on average, were reared at different growth rates, by feeding either a high (H, close to satiation) or low (L, half of H) ration of a commercial diet. Fish were reared for 6 to 15 weeks respectively in order to reach the same size class. Fast growth significantly increased whole body lipid and dry matter but reduced ash in both species. Brook trout were both more fat and had a higher protein content, lower moisture and lower ash content than the rainbow trout. Neither the feed conversion ratio (FCR = g feed intake/g weight increase) nor protein retention efficiency (PRE) was affected by growth rate. The brook trout, however, were more efficient in retaining protein than the rainbow trout. Enhanced growth increased fat content in fillets. Whole body protein and dry matter was higher in brook trout fillets than in fillets from rainbow trout. Carcass percentage was overall lower at high growth rates compared to slow growth while both carcass percentage and fillet yield was lower in brook trout than in rainbow trout.

Reference

RASMUSSEN, R.S. (Aalborg University, Department of Civil Engineering, Aquaculture Division, Sohngaardsholmsvej 57, DK-9000 Aalborg, Denmark. Tel.: +45-96-35-84-61; fax: +45-98-14-25-55; e-mail: gitric@get2net.dk) AND OSTENFELD, T.H. 2000. Effect of growth rate on quality traits and feed utilisation of rainbow trout (*Oncorhynchus mykiss*) and brook trout (*Salvelinus fontinalis*). Aquaculture, 184(3-4): 327-337.

8. Angler motives in put-and-take trout fisheries

Several studies have shown that anglers fishing in put-and-take trout fisheries requiring payment of daily fishing fees or purchase of special seasonal permits consider catch/harvest elements of the angling experience to be very important. Less is known about motives and

attitudes of anglers who participate in state-wide put-and-take trout fisheries that do not require special permits. This study used a mail questionnaire to compare motives and attitudes of Massachusetts freshwater anglers who: (1) fish most often for trout to those who fish most often for largemouth bass (*Micropterus sllmoides*) and/or smallmouth bass (*Micropterus dolomieui*); and (2) fish most often in a put-and-take trout fishery to those who fish most often for wild trout. Bass anglers were selected for comparison to trout anglers because largemouth/smallmouth bass fisheries attract a substantial proportion of freshwater angling activity in Massachusetts, and these fisheries are supported solely by natural production of bass resources. Thus the first comparison investigated whether motives/attitudes differed among angling subgroups according to taxa that are most often pursued, and the second investigated whether motives/attitudes differ between subgroups fishing for the same taxa according to the type of fishing opportunity provided to them (i.e. a put-and-take fishery with relatively high catch opportunity versus a wild fishery with relatively low catch opportunity). Motives and attitudes of angling subgroups differed little. Although participating in a fishery offering the opportunity for high rates of catch and harvest, put-and-take anglers did not indicate that catch/harvest-related factors were more important to the quality of an angling experience than did other angling subgroups. Generally, responses did not clearly separate trout anglers from bass anglers, nor put-and-take trout anglers from those who fish for wild trout.

Reference

Ross, M.R. (Department of Natural Resources Conservation, Holdsworth Natural Resources Center, Universty of Masachusetts, Amherst, MA 01003-4210, USA). 2001. Put-and-take fisheries: investigating catch and retention assumptions. Fisheries, 26(2): 13-18.

9. Monitoring trout behavioural responses

Aquaculture employs a variety of husbandry methods which need to be evaluated in terms of the health and welfare of the farmed fish. Behavioural tests can be used as indicators of short-term stress, as well as of the long-term recovery from stressors that occur in aquaculture facilities. Few studies have been carried out on this however, due to the difficulty of measuring and quantifying animal activity under these conditions. The advent of physiological telemetry in recent years now makes it possible to obtain and record quantitative information reflecting locomotory activity of free-swimming fish *in situ*. The technique involves implanting wireless devices capable of detecting and transmitting electrical signals generated within muscle fibres known as electromyographic (EMG) signals. The objective of this study was to validate the use of physiological telemetry as a behavioural indicator, by correlating telemetered EMG signals with video-recorded swimming activity. Video-recorded observations of the 'startle-response' of rainbow trout induced by instant-on lighting, were analysed and could be correlated with telemetric EMG signals, suggesting that telemetry data was an accurate measure of swimming behaviour. A preliminary experiment examining the behavioural responses of fish to transportation by truck was also completed. EMG recordings during this transportation indicated that vigorous and energetically expensive swimming patterns were occurring, which could lead to post-transport stress. Physiological telemetry may therefore allow for the objective quantification of both fish activity and behavioural responses to rearing methods used in aquaculture and may thus prove to be a valuable tool to evaluate captive husbandry protocols with the aim of improving the welfare of farmed fish.

Reference

Chandroo, K.P. (Department of Animal and Poultry Science, University of Geulph, Guelph, ON, Canada NIG 2W1), Moccia, R.D. and McKinley, R.S. 2000. Utilization of physiological telemetry to monitor behavioural responses of rainbow trout *Oncorhynchus mykiss*, to captive culture conditions. Bulletin Aquaculture Association of Canada, 99(4): 34-36.

10. Effect of carotene on the immune response

Under intensive aquaculture conditions fish are predisposed to stress and subsequent infection by pathogens. Prophylactics as well as therapeutic drugs are increasingly being used to overcome diseases but the use of antibiotics can lead to the development of drug-resistant strains of pathogens. Disease resistance in fish may become elevated following supplementation of micronutrients like vitamins and minerals. Immunoenhancement by dietary manipulation may therefore offer a viable alternative to the use of drugs in aquaculture. This study investigated the influence of different levels of dietary β-carotene on immune function in rainbow trout. Semi-purified diets containing 0, 40, 200, and 400 mg β-carotene per kg dry diet were fed for 12 weeks to fish with average weight of 45 g. In addition to the humoral and cellular immune parameters, growth and feed utilisation was also examined. There were no marked differences in growth and feed utilisation showing that b-carotene was not particularly efficient in enhancing growth of rainbow trout. Of the immune parameters measured, total immunoglobulin was significantly higher for the 200 mg β-carotene fed group. Serum complement activity (alternate pathway) at 200 and 400 mg β-carotene supplementation was significantly higher than that of the unsupplemented group. An increasing trend in lysozyme activity was observed, however, the differences among the groups was not significant. Phagocytic activity was similar among diet groups except at the highest level of supplementation where it was at the maximum. Oxygen radical production by

peripheral blood leukocytes appeared to be lower at higher levels of carotenoid supplementation. Overall, dietary β-carotene clearly enhanced immune response parameters in rainbow trout such as serum complement activity and total plasma immunoglobulin but did not show a definite influence for the other factors examined.

Reference

AMAR, E.C., KIRON, V. (Department of Aquatic Biosciences, Tokyo University of Fisheries, Minato, Tokyo 108-8477, Japan. E-mail: vizi@tokyo-u-fish.ac.jp), SATOH, S., OKAMOTO, N., AND WATANABE, T. 2000. Effects of dietary β-carotene on the immune response of rainbow trout (*Oncorrhynchus mykiss*). Fisheries Science, 66(6): 1068-1075.

11. Controlling parasites with hydrogen peroxide

Hatchery reared fish are commonly afflicted with external parasites which may cause stress and result in mortalities during severe outbreaks. A promising fish therapeutic agent that may effectively control certain external parasites is hydrogen peroxide which is classified as a low-regulatory priority agent (it degrades to water and oxygen in the environment) when used to treat fungal infections on fish eggs. Data on the use of hydrogen peroxide against parasites is limited however, and this paper evaluates its efficacy to control external parasitic infestations on juvenile (10-33 g) rainbow trout in three clinical field trials. Fish were exposed to hydrogen peroxide concentrations ranging from 0 to 560 mg/L for 30 min once every other day for a total of three treatments. Pre- and post treatment skin scrapes and gill wet mounts of test fish were microscopically examined to identify and enumerate external parasites. Infestation severity was classified as non-existent (0 organisms), low (1-10 organisms), moderate (11-20 organisms), or high (>21 organisms). In trial 1, pre-treatment skin examinations revealed a severe infestation of the protozoan *Ambiphrya* on all fish examined. Post-treatment skin examinations conducted within 24 h of the last treatment indicated that all hydrogen peroxide treatments eliminated *Ambiphrya*, whereas control fish remained severely infested with the protozoan. In trial 2, pre-treatment examinations of skin and gill samples indicated a high infestation of the trematode *Gyrodactylus* (skin) and the protozoan *Trichodina* (gills) on all fish. Post-treatment examinations conducted within 24 h of the last treatment indicated that *Gyrodactylus* was eliminated from the skin of all treated fish; however, the high infestation of *Trichodina* remained on the gills of the test fish. All control fish had high infestation levels of both parasites. A high infestation of *Ambiphrya* was found on the skin of test fish before treatment (trial 3). Post-treatment examinations conducted 14 days after the last treatment revealed that 56% of the fish were parasite free, whereas the remaining test fish had low infestation levels. Control fish remained severely infested with the parasite. Based on the efficacy data, all hydrogen peroxide treatment regimens were efficacious in the control of *Ambiphrya* and *Gyrodactylus*.

Reference

RACH, J.J. (U.S. Department of Interior, U.S. Geological Survey, Upper Midwest Environmental Sciences Center, 2630 Fanta Reed Road, La Crosse, Wisconsin 54603, USA, e-mail: jeffrey_rach@usgs.gov), GAIKOWSKI, M.P., AND RAMSAY, R.T. 2000. Efficacy of hydrogen peroxide to control parasitic infestations on hatchery-reared fish. Journal of Aquatic Animal Health, 12(4): 267-273.

12. Fungal control using hydrogen peroxide – affect during critical egg stage

The use of malachite green as an egg fungicide was withdrawn by the US Food and Drug Administration in 1991, and currently formalin fills this role. Although effective as a fungicide, concerns have arisen over user safety of formalin related to its odoriferous nature and suspected carcinogencity. Hydrogen peroxide is another effective agent in controlling fungus on rainbow trout eggs and is preferred because of its low environmental impact. A previous study has shown that reduced survival and increased deformities following hydrogen peroxide treatment may be linked to a sensitive stage in egg development in rainbow trout which occurs between 70-140 daily temperature units (DTU°C), coinciding with the period between blastopore formation and its closure. The objective of this study was to evaluate the effect of hydrogen peroxide treatment, in comparison with formalin, in controlling fungus in rainbow trout eggs when hydrogen peroxide treatment was constant, reduced to 5 minutes or was withheld entirely during the sensitive stage of development. Data collected included survival at eyeing and hatch and percentage deformities of sac fry. Two separate trials were conducted; in the first treatment regimens consisted of no chemical treatment (control) or daily treatments of either hydrogen peroxide at 500 mg/L for 35 min or formalin at 1,667 mg/L for 15 min. Hydrogen peroxide treatment duration was reduced to 5 min daily during 70-140 DTU°C. In this trial, 27% of control eggs were infected with fungus, compared with 0 % for the hydrogen peroxide and formalin treatments. Eyed egg percentages were significantly lower for control eggs compared with the hydrogen peroxide and formalin treatments. Comparing formalin and hydrogen peroxide treatments, percentage hatch at 91% and 90% and percentage deformities of sac fry at 1.0 % and 1.3 %, respectively, were not significantly different. In the second trial, rainbow trout eggs were reared from fertilization to hatch under four treatment regiments; (1) control or no chemical treatment, (2) 500 mg hydrogen peroxide/L for 35 min daily (hydrogen peroxide A), (3) 500 mg hydrogen peroxide/L for 35 min daily with treatment completely withheld during 70-140 DTU°C (hydrogen peroxide B), and (4) 1,667 mg formalin/L for 15 min daily. Within this trial 15% of control eggs were infected with fungus, compared with 1% for hydrogen peroxide B and 0% for both hydrogen peroxide A and formalin. Eyed egg percentages were significantly better

for hydrogen peroxide B than for hydrogen peroxide A. Hatch was significantly reduced in the control group compared with the formalin treatment. Incidence of deformities was not significantly altered by treatment type. For both trials reducing the treatment duration to 5 min or withholding treatment completely during the critical stage may be an effective way of controlling egg fungus when using hydrogen peroxide. The trials also suggested there was no significant difference in survival between hydrogen peroxide or formalin treatments for rainbow trout eggs.

Reference

ARNDT, R.E. (Utah Division of Wildlife Resources, Fisheries Experiment Station, 1465 West 200 North, Logan, Utah 84321, USA, e-mail: rarndt@state.ut.us), WAGNER, E.J., AND ROUTLEDGE, M.D. 2001. Reducing or withholding hydrogen peroxide treatment during a critical stage of rainbow trout development: effects on eyed eggs, hatch, deformities, and fungal control. North American Journal of Aquaculture, 63(2): 161-166.

13. Spinal column deformities and treatment for RTFS

Infection with *Flavobacterium psychrophilum* the causative organism for Rainbow Trout Fry Syndrome (RTFS) and oxytetracycline have both been associated with spinal deformities in salmonids. This paper describes experiments carried out to investigate whether fish infected with RTFS or medicated with oxytetracycline (OTC) at the fry stage would result in an increased occurrence of vertebral column deformities in rainbow trout. Fish were on-grown for 9 months and examined by radiology at the end of the experiments. There was a relationship between infection by *F. psychrophilum* and deformities of the spinal column, if fish with more than 10 affected vertebrae were classified as deformed. The deformities found among infected fish were often visible externally and were more severe than those seen among control fish (most deformities found among controls were only seen on X-ray photographs). Deformities were evenly spread along the vertebral column of infected fish. OTC treatments of up to 200 mg per kg of fish per day for 10 days and repeated three times did not result in increased spinal deformities relative to untreated control groups. It was concluded therefore, that medication of rainbow trout with oxytetracycline did not cause deformities of the spinal column under the prevailing treatment conditions.

Reference

MADSEN, L. (Danish Institute for Fisheries Research, Fish Diseases Laboratory, Stigbøjlen 4, DK-1870 Frederiksberg C, Denmark), ARNBJERG J. AND DALSGAARD, I. 2001. Radiological examination of the spinal column in farmed rainbow trout *Oncorhynchus mykiss* (Walbaum): experiments with *Flavobacterium psychrophilum* and oxytetracycline. Aquaculture Research, 32(3): 235-241.

14. Review of effluent treatment facilities and methods

The trend towards intensification in aquaculture has contributed to the deterioration in the quality of the water in fish farm effluents. Suspended solids, ammonia nitrogen and phosphate phosphorus are considered to be the main pollutants. In order to reduce pollution studies have focussed on improving the digestability of fish feed and varying feeding strategies while others have tried to determine the carrying capacity of a given area or focussed on the removal of pollutants using treatment facilities. This paper investigates the specificity and the efficiency of treatment devices for single flow-through and re-circulating systems used at present in aquaculture, and proposes some alternatives for removing dissolved nutrients, particularly phosphate phosphorous.

Reference

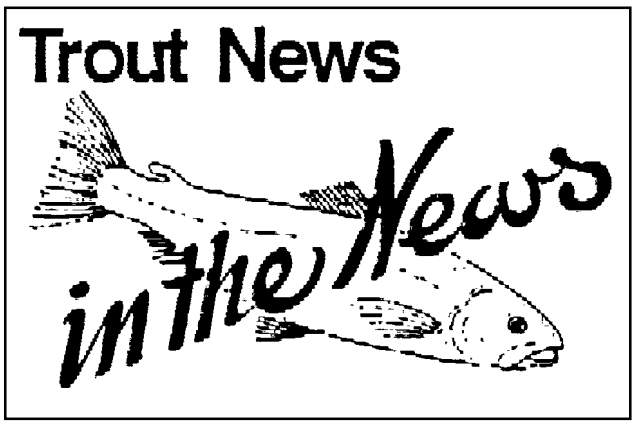
DUMAS, A. (Aquatic Biotechnology and Aquaculture, 542 St-Cyrille, Normandin, Quebéc, Canada, G8M 4H4) AND BERGHEIM, A. 2000. Effluent treatment facilities and methods in fish farming: a review. Bulletin of the Aquacultural Association of Canada, 100(1): 33-38.

15. *Carnobacterium* sp. proves an effective probiotic

The intensification of commercial aquaculture has lead to higher outbreaks of disease covering an increasing range of pathogens. In order to combat this recent attention has focussed on alternative treatments using probiotics. This involves the supplementation of food with live bacteria which must have the ability to survive passage through the intestinal tract. Their benefit is thought to arise either from the breakdown of toxic or otherwise non-nutritious components of the diet which the host can then digest or by preventing potential pathogens from colonising the gut by production of anti-microbial components or by out competing them for nutrients or mucosal space. The majority of probiotics comprise lactic acid bacteria which may form a major component of the microflora of the gut of healthy fish. This study evaluated the benefit of *Carnobacterium* sp. bacteria isolated from the intestine of Atlantic salmon. In vitro studies demonstrated antagonism against a range of pathogenic bacteria. Feeding salmonids with diets containing the probiotic revealed that the isolate remained viable in the gastrointestinal tract. After reverting to feeding with control diets, the isolate was re-isolated from the intestine up to 4 and 10 days in fingerlings and fry, respectively. After feeding with the probiotic for 14 days, challenge by cohabitation indicated effectiveness at reducing disease caused by *A. salmonicida*, *V. ordalii*, and *Y. ruckeri* but not *V. anguillarum.*

Reference

ROBERTSON, P.A.W., O'DOWD, C., BURRELLS, C., WILLIAMS, P. AND AUSTIN, B. (Tel: +44-131-451-3452; fax: +44-131-451-3009; e-mail: b.austin@hw.ac.uk). 2000. Use of *Carnobacterium* sp. as a probiotic for Atlantic salmon (*Salmo salar* L.) and rainbow trout (*Oncorhynchus mykiss*, Walbaum). Aquaculture, 185(3): 235-243.



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