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Management and control of proliferative kidney disease (PKD) in a freshwater Atlantic salmon (*Salmo salar* L.) farm in Ireland: a case history

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Abstract

During July 1992, an acute clinical outbreak of proliferative kidney disease (PKD) was experienced in two strains ('Irish' and 'Norwegian') of juvenile (age 0+) Atlantic salmon (Salmo salar L.) held at two adjacent freshwater sites on the River Lee in southern Ireland. Various management strategies (including reduced stocking densities, handling, feeding rates and increased oxygenation), and treatment regimes (involving malachite green and fumagillin DCH) were used to control the disease. A total of 1·3 million juveniles died during the PKD outbreak, representing 61·6% and 54·6% of the Norwegian stock at the two farms respectively. The Irish stock appeared to be more resistant to the disease and only 15·6% died. The weekly prevalence of PKD fluctuated throughout the summer but seemed to disappear by mid-August.

Although PKD was detected again during 1993, no clinical outbreak occurred. In conjunction with the management strategies adopted in 1992, seven consecutive weekly prophylactic bath treatments with malachite green (1·6 ppm for 40 minutes) administered prior to mid-July appeared to control the disease. During August 1993, a ten day course of fumagillin (6 mg/kg bodyweight per day) reduced the prevalence of the PKD parasite in a trial batch of juveniles from 24% to zero. The results of this study demonstrated the effectiveness of various management strategies and treatment regimes in controlling PKD.

Introduction

Proliferative kidney disease (PKD) is considered to be one of the most economically important diseases affecting both wild and commercially reared salmonids in freshwater (Hedrick and others 1993). The disease has been recorded in Canada, the U.S.A. and several European countries including Ireland (O'Brien and others 1977, O'Flynn and Mulcahy 1995).

PKD was once considered an untreatable disease. However, at least two chemotherapeutants (malachite green and fumagillin DCH) are now known to be effective in controlling infections (Alderman and Clifton-Hadley 1988, Hedrick and others 1988). Various management and husbandry strategies can also be applied in order to help reduce the risks and severity of the disease.

Under field conditions, repeated bath applications of malachite green gave good control over PKD (Alderman and Clifton-Hadley 1988). However, there are several problems with malachite green: it is toxic to fish, particularly at high temperatures (Alderman 1985); it accumulates in fish tissues (Gerundo and others 1991); and there is growing concern about the effect of malachite green discharges on the environment and on consumer safety (Hedrick and others 1993).

More recently, orally administered fumagillin was shown to be effective in protecting chinook salmon (*Oncorhynchus tshawytscha* Walbaum) and rainbow trout (*Oncorhynchus mykiss* Walbaum) against PKD (Hedrick and others 1988, Wishkovsky and others 1990, Le Gouvello and others 1993a&b). The antibiotic was also demonstrated to be effective against renal sphaerosporosis (*Sphaerospora renicola*) in common carp (*Cyprinus carpio* L.), and *Loma salmonae* in chinook salmon (Kent and Dawe 1994). Dosing, however, must be critically controlled to avoid toxic side-effects (Wishkovsky and others 1990, Lauren and others 1989). Studies on its effectiveness in controlling PKD in Atlantic salmon (*Salmo salar* L.) have not been published.

Materials and methods

During mid-July 1992, an acute outbreak of PKD was experienced in two strains of juvenile Atlantic salmon (age 0+) held at two freshwater farms on the River Lee, Co Cork, in the south of Ireland: Carrigadrohid and Inniscarra (Fig 1). Carrigadrohid is a conventional land-based gravity-fed hatchery and

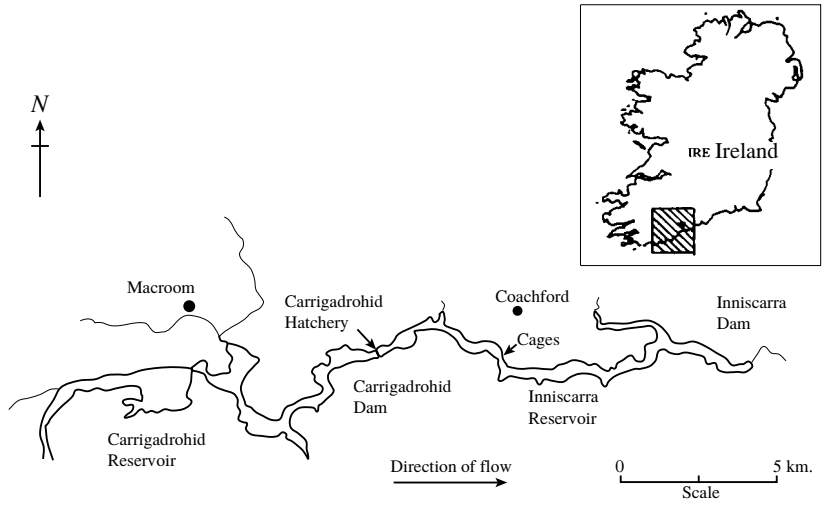

Figure 1: Carrigadrohid and Inniscarra Reservoirs on the River Lee system, showing the positions of the cages and the hatchery.

smolt-rearing farm. Inniscarra is a supplementary cage-based smolt-rearing farm located about 4 km downstream of Carrigadrohid. The largest grade fry are usually transferred from Carrigadrohid to Inniscarra during the summer months for on-rearing to the smolt stage. Both farms have been managed by the same company since 1970 and 1980 respectively. Water quality is typically alkaline (*p*H 7·19–7·46), soft (17·29–38·23 mg $CaCO_3$/litre), and eutrophic (0·53–12·82 µg/litre chlorophyll; 11–44 mg/m^3 total phosphate). Prior to 1992, PKD had not been recorded at either farm. Two stocks of salmon are reared in both farms: a native Irish grilse stock which has been used for restocking the River Lee since 1971 ('Irish stock'), and a commercially farmed two-sea-winter stock of Norwegian origin which has been used by the Irish salmon farming industry for almost two decades ('Norwegian stock').

The purpose of this report is to describe the progress of the disease throughout the summer of 1992 and 1993 and to discuss the efficacy of management strategies and control measures, including the use of malachite green and fumagillin.

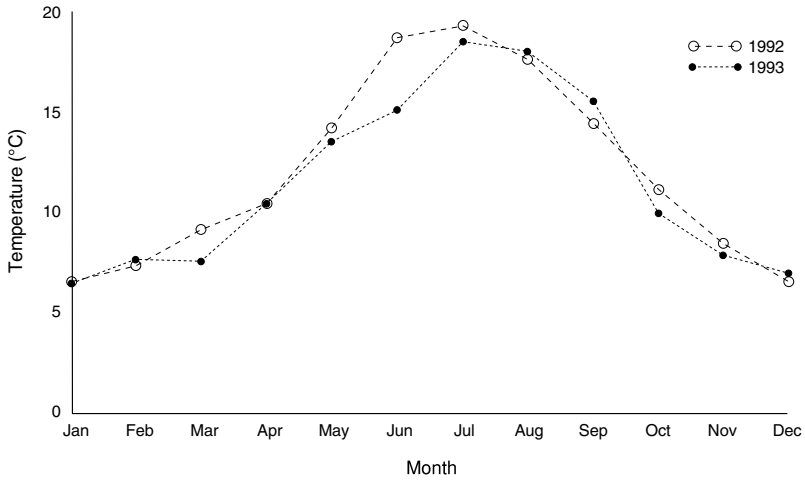

Figure 2: Mean monthly water temperatures (°C) at Carrigadrohid in 1992 and 1993.

Clinical history in 1992

PKD was recorded for the first time at Carrigadrohid and Inniscarra following a significant increase in mortalities in 0+ age Norwegian stock (average weight 5 gram) on 7 July 1992; 100% prevalence was confirmed in a sample of 30 moribund fry on 9 July 1992. Diagnosis of PKD was based on overt clinical signs (*eg* swollen abdomen and kidneys, pale gills and exophthalmos) and was confirmed by histological examination of several organs including kidney, liver, spleen and pancreatic tissue (Roberts 1989). Samples were examined histologically on a regular basis up to the beginning of September in order to monitor the progress of the outbreak and the efficacy of treatments. The occurrence of bacterial gill disease during the same period compounded the PKD problem.

Although water temperatures were high (19–20°C) (Fig 2), it was decided to dose the fish initially with a 2 ppm flush of malachite green. This was followed by two one-hour bath treatments at seven day intervals; various dose rates were used on individual tanks and cages (0·5–2 ppm). During the last

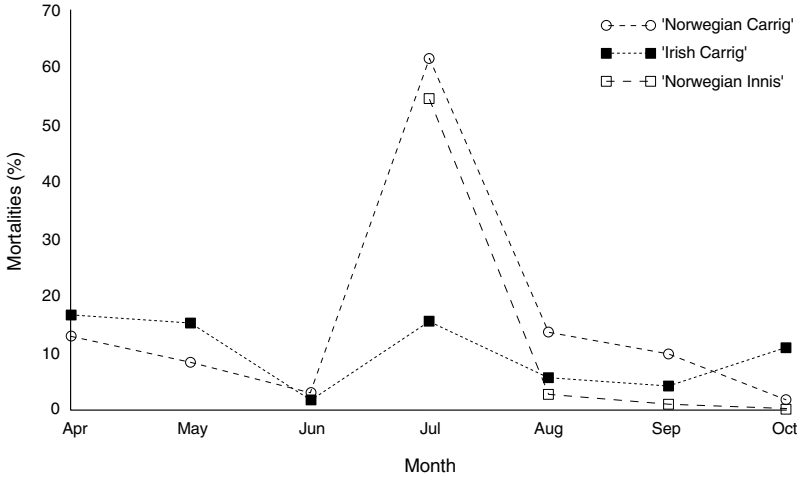

Figure 3: Monthly mortalities (%) of Norwegian and Irish salmon parr at Carrigadrohid and Inniscarra during 1992.

three weeks of the outbreak, a dose rate of 1·6 ppm for 40 minutes was used throughout both farms (Alderman and Clifton-Hadley 1988).

Dose rates were calculated according to individual tank and cage volumes. The depth of the cage was reduced to 1 metre and the net was surrounded by a tarpaulin bag prior to treatment. The required concentration of malachite green for tanks and cages was pre-diluted in 10 and 300 litres of water respectively. The pre-diluted dose was applied evenly over the surface of the tank and cage with watering cans and pumps. Supplemental oxygen was supplied to each tank and cage during the treatment period.

Although initial stocking densities were relatively high (10 kg/m^3), it was decided not to handle the fish in any way (particularly by grading) lest this should aggravate the problem. Feeding rates were reduced to 1% bodyweight per day and the feeding period was also reduced to two 4-hour periods per day (6–10am and 4–8pm). Supplemental oxygen was continuously added to the hatchery water supply using the on-site oxygen generation system.

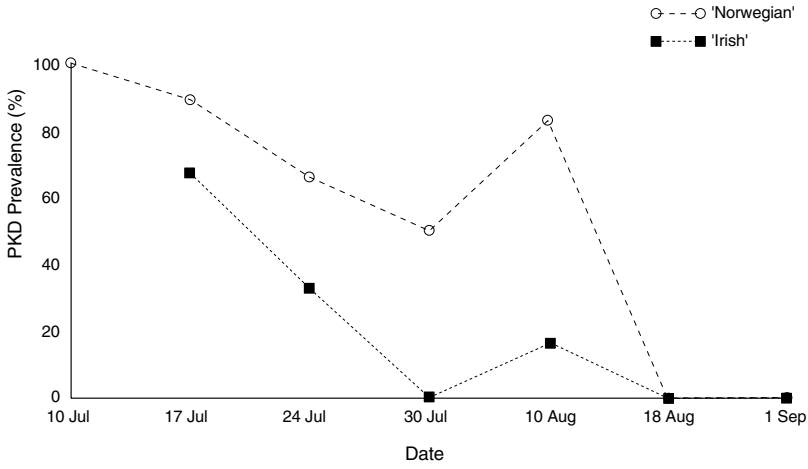

Figure 4: Weekly prevalence (%) of PKD in Norwegian and Irish salmon parr at Carrigadrohid during 1992.

Mortalities increased dramatically during the second week of July and then decreased gradually during the second half of the month (Fig 3). A total of 1·3 million fry died during the PKD outbreak, representing 61·6% of the Norwegian stock at Carrigadrohid and 54·6% of the same stock at Inniscarra. The Irish stock at Carrigadrohid was affected to a much lesser extent (15·6%). Weekly samples (30 fish from each stock) showed that the prevalence of the PKD parasite in both stocks fluctuated throughout the summer but was histologically undetectable by mid-August (Fig 4).

Clinical history in 1993

Based on the experience gained during 1992, the following management strategies were adopted during 1993: stocking densities were kept at a lower level (less than 5 kg/m^3); no grading was carried out between July and October; the water supply was continuously oxygenated throughout the summer; feeding rates and feeding periods were reduced as in 1992; seven consecutive weekly prophylactic bath treatments with malachite green (1·6 ppm for 40 minutes) were administered prior to mid-July (between 13

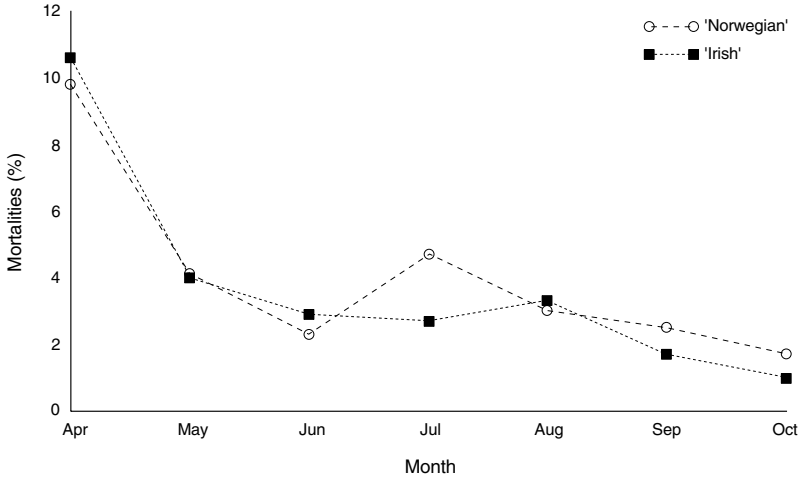

Figure 5: Monthly mortalities (%) of Norwegian and Irish salmon parr at Carrigadrohid during 1993.

May and 9 July); and trials were carried out using fumagillin. No stock was held at Inniscarra throughout the summer of 1993. Samples (30 fish) of the Norwegian stock were analysed on a regular basis for PKD parasites from early April until late October 1993.

Compared with 1992, water temperatures were lower in June and July 1993 but slightly higher in August and September (Fig 2). Cumulative mortalities in the Norwegian and Irish stocks between July and September 1993 (3·8% and 3·3% respectively) (Fig 5) were substantially lower in comparison with deaths experienced during the same period in 1992.

Although some evidence of PKD was found during mid-July, mortalities remained at a relatively low level. However, during the first week of August up to 16% PKD prevalence was found, and although this increased to 50% by mid-August and 66% by the end of the month, no significant mortalities occurred (Fig 6). Although the prevalence of PKD appeared to fluctuate throughout the summer months (as in 1992), the parasite persisted for a longer period during 1993 (up to mid-October).

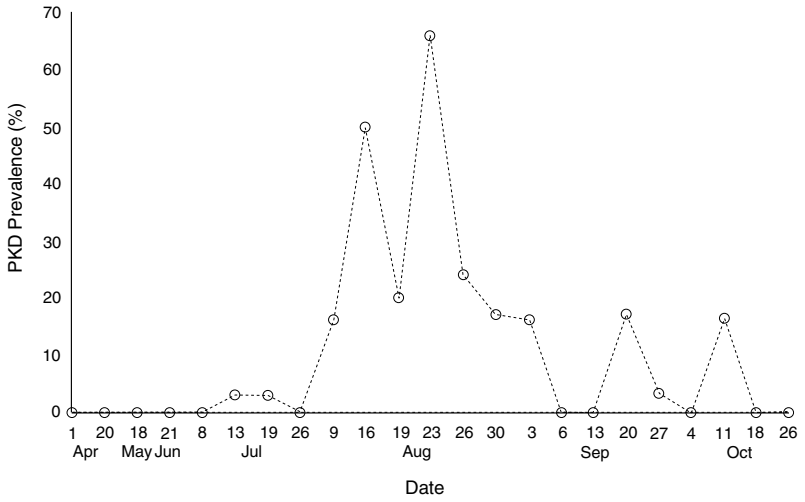

Figure 6: Weekly prevalence (%) of PKD in Norwegian salmon parr at Carrigadrohid during 1993.

Fumagillin trial

During late August 1993 a trial batch of 0+ Norwegian parr (average weight 10 gram) which were exhibiting a 24% PKD prevalence were fed with fumagillin at a dose rate of 6 mg/kg bodyweight per day for 10 days. No PKD parasites were found in the trial batch at the end of the treatment period (early September), but PKD was still present (at 16% prevalence) in the untreated control group. There were no apparent adverse reactions, such as loss of appetite, to the fumagillin treatment.

Discussion

A combination of high water temperatures (over 19°C) and high stocking densities (over 10 kg/m^3) would appear to have precipitated the clinical outbreak of PKD during early July 1992. Although the PKD parasite appeared around the same time in both years (early and mid-July respectively), its prevalence, albeit higher, was of much shorter duration in 1992 (6 weeks)

than in 1993 (12 weeks). Lower water temperatures in June and July 1993 may have delayed the development of the PKD parasite by about one week, but higher temperatures in August and September may have accounted for its persistence until mid-October. Hedrick and others (1993) pointed out that while water temperature is known to greatly effect the initiation and progression of PKD infections, outbreaks can vary markedly in their severity.

Although malachite green did not appear to be as effective in controlling PKD once the disease was established in 1992, it seemed to be more effective when it was applied prophylactically as a bath treatment (at a dose rate of 1·6 ppm for 40 minutes) for seven consecutive weeks prior to the expected appearance of the disease in 1993. Similar results were found by Alderman and Clifton-Hadley (1988) during field trials with rainbow trout.

While the single field trial with fumagillin during 1993 showed that the antibiotic was very effective in eliminating PKD parasites from an asymptomatically infected stock, the results were somewhat inconclusive in the absence of a clinical outbreak in untreated stocks. Further studies on the effectiveness of fumagillin against PKD under Irish farming conditions are clearly required.

Although treatment with malachite green and fumagillin has shown some promise, the use of these compounds has given rise to concerns about toxicity, tissue residues, discharge to the environment and consumer safety. Indeed, because of European Union legislation there are problems with the use of malachite green in European fish farms and the chemical has already been banned in the U.S.A. (Schnick and Meyer 1978). However, an encouraging line of research involving the production of monoclonal antibodies could eventually lead to the production of an effective vaccine against PKD (de Mateo and others 1993).

The Irish stock appeared to have a higher resistance to PKD than the Norwegian stock. Ellis and others (1982) reported similar findings in Atlantic salmon parr in Scotland; they found that a Norwegian stock was more susceptible to PKD than Scottish stocks. The apparent differential susceptibility of various salmon stocks to PKD should be taken into account in the design and comparison of PKD trials. Furthermore, the greater resistance to PKD exhibited by some native salmon stocks could be utilised in selective breeding programmes for commercial aquaculture. The possibilities for

genetic improvement of disease resistance in fish was recently reviewed by Fjalestad and others (1993).

The fact that Irish salmon stocks appear to be more resistant to PKD than foreign stocks would seem to suggest that the PKD parasite has been in Irish waters for a longer period of time than previously thought. Indeed, a recent examination of archival histological material indicates that PKD has been present in Ireland since 1964 (McArdle, unpublished data).

Changes in husbandry and management strategies, including a reduction in stocking densities, feeding rates and handling, delayed grading, increased oxygenation, together with prophylactic treatments with malachite green, reduced the impact of PKD during 1993. Although the overall effect of PKD preventative measures are a reduction in the output and efficiency of the hatchery in terms of growth, food conversion efficiency, parr condition and smolt yield, these negative effects have to be balanced against the opportunity of reducing potentially high mortalities.

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