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An epidemiological investigation of diseases of farmed Atlantic salmon (*Salmo salar* L.) using a relational database.

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INTRODUCTION

A collaborative research project has been established between the Irish Salmon Growers Association (ISGA) and the Veterinary Sciences Division (VSD) of Queen's University, Stormont to develop a computerised database of management, production, disease and environment data relating to the production of farmed Atlantic salmon (*Salmo salar*). The establishment of such a database is considered essential for the development of effective control strategies by the salmon farming industry following outbreaks of disease. Pancreas Disease (PD) is regarded as a serious threat to the economic production of farmed Atlantic salmon in Ireland (Branson, 1988).

PD was initially described in Scotland in 1976 (Munro, Ellis, McVicar, McLay, and Needham, 1984) but the condition is now known to occur in all the major salmon farming countries of Europe as well as in the USA (Kent & Elston, 1987; Poppe, Rimstad and Hyllseth, 1989). In Ireland, a new condition associated with PD termed Sudden Death Syndrome (SDS), has been described (Rodger, Murphy, Drinan and Rice, 1991). Deaths from SDS occur six to eight weeks after an outbreak of PD. It has been proposed by Rodger *et al.*, (1991) that SDS occurs due to nutritional deficiency and exertional stress following an outbreak of PD. Evidence of the infectious nature of PD is widely supported by research workers, although an infectious agent has not been isolated or identified (Raynard Houghton

and Munro, 1992). Consequently it has been difficult to devise control measures for dealing with PD (Raynard *et al.*, 1992).

The main aims of this project are therefore to analyse computerised epidemiological data to identify critical factors, trends or patterns preceding and during disease outbreaks, which may assist in devising practical control measures for diseases such as PD. As with many diseases, an outbreak of PD on a farm is probably a complex interaction between primary and secondary determinants. Conditions inducing stress in farmed fish are believed to influence the susceptibility to and the severity of PD outbreaks (Raynard, *et al.*, 1992). If the principle stressors could be identified and controlled, while not eliminating disease on the farm, this may help to reduce the economic significance of diseases such as PD to tolerable levels.

The information needed for this research, has been collected in varying formats by farmers, diagnostic services and environmental monitoring firms for some years.

MATERIALS AND METHODS

The initial stage of the research was to assess the data which was routinely recorded by salmon producers and to identify those sites which could be used for intensive monitoring. This was achieved using a questionnaire which was mailed out to all ISGA members. From this survey and subsequent contact with ISGA members, permission was granted to allow access to the records from 13 farms which gives the potential to investigate more than 27 sites.

Respondents to the survey were followed up by a series of site visits. These visits were used to collect data, to double check questionnaire information and to assess the accuracy of data recording. Most of the farms record their production and some management data on a variety of computerised spreadsheets. Many sites had retrospective records for the last four to five years. The main disadvantage was that the records were stored in different formats which meant that a lot of time was spent interpreting and standardising the data.

Records were initially interpreted and standardised using spreadsheet software and a personal computer. The standardised records were then transferred to ORACLE, a relational database which is held on a VAX 6320 mainframe. This project has currently collated and standardised the data for 11 sites around the west coast of Ireland, covering a period of up to four years for each site.

Percentage mortality within a site is used as the parameter for measuring profitable production. The period between input and December inclusively during the first year at sea is the interval which is studied. Mortality levels within farms, between farms and between years have been described. Similarly other production parameters, environment, disease and management parameters will be described within farms, between farms and between years.

Analysis of the data is oriented towards identifying factors associated with increased mortality levels. The statistical methods used include the student's t-test, analysis of variance, and regression. Computer packages used include SPSS and a suite of Fortran programmes for time series analysis.

RESULTS AND DISCUSSION

Initial information from the survey indicates that the most important disease conditions observed by salmon producers are sea lice infestation, Pancreas Disease, Sudden Death Syndrome, Vibriosis and Summer Lesion Syndrome, and Furunculosis.

Table 1 shows total mortality for each individual farm. The figures for 1992 are distorted due to unclarified events at one site and an algal bloom at another. Table 1 shows that, although mortality varies between years, there are consistent differences in mortality levels between sites. The block ANOVA carried out on these data (Table 2) showed that there was no significant difference in variation between years but there was a significant difference in variation between sites ($p<0.10$). Although the interpretation of these data requires caution because of the relatively low number of years involved, the result suggests that factors that vary between sites could be more significant in determining mortality than factors that

vary between years. It may be, for example that management factors which vary between sites such, as the practice of single generation rearing, could be more significant in determining total mortality level than variations in temperature or other environmental factors that vary between years. Further work needs to be carried out on this data before any conclusions can be drawn.

The initial analysis of the mortality data was used to determine if patterns in mortality during an outbreak of PD indicate that the disease is primarily caused by an infectious agent.

This involved time series analysis. The hypothesis that successive peaks in mortality between cages were not dependent on each other, i.e. that mortality events in neighbouring cages bear no relation to each other, was tested. The mortality data from a group of 'Polar cirkel' cages which were moored together were used in the analysis (Figure 1). At this site in 1990, transport losses were high (April-May). Mortality between June and July was attributed to outbreaks of Summer Lesion Syndrome. PD was first noticed on site on August 28th.

Adjacent cages were paired and regression analysis was carried out on each paired set of data. To determine if mortality patterns were synchronous the same tests were carried out on mortality figures which had been time-lagged (i.e. staggered) against each other. Regression coefficients and probability values were obtained for time lags of zero to four fortnightly intervals. In the above analysis a straight line was obtained for cage pairs 3 and 70, 70 and 2 and 2 and 4, when the time lag was zero ($p<0.001$). Cages 4 and 5 showed a straight line relationship at lag 2 ($p=0.073$). PD did occur in cage 5, but this cage showed a slower rise in mortality and lower mortality levels overall. A typically significant time lag for Bridgestone cage pairs, where each was moored a distance of approximately 30 metres apart, was 4 weeks.

In summary, the regression analysis of each plot revealed significance at various time lags, depending on the proximity of neighbouring cages and the stage at which PD developed in a cage in comparison to its neighbour.

The analysis described above revealed a number of points about Pancreas Disease:

1. The pattern of mortalities between neighbouring cages were similar during PD outbreaks in all cases tested and the pattern is consistent with that expected of an infectious disease (Austin and Austin, 1989). Sites in which cages were located further apart, showed a slower progression of PD through the cages as would be expected of an infectious disease.

2. The first cage, or cages, in a group of cages to show signs of PD was often the worst affected cage. Out of a total of 39 outbreaks of PD in cage groups, 60.5% showed that the first cage to go down with PD in a group had the highest mortality, 29.0% of cases contradicted this and in 10.0% of outbreaks, the picture was ambiguous due to other events occurring at the time of outbreak. The total number of cases investigated in which two or more cage groups were affected by PD within a site was 15. Of these 53.3% showed that the first cage group to go down with PD in a site was the most severely affected, 26.7% contradicted this, and 20.0% of cases were ambiguous, again because of overlapping events at the site.

The following hypotheses may be responsible for the observed mortality pattern:-

a) The first cage to suffer PD had a higher susceptibility due to the presence of a stress factor(s) as yet unidentified.

b) Management techniques implemented once PD was identified allowed for some control over the severity of the outbreak.

c) Cages which suffer mortalities later in a PD outbreak may have developed a degree of immunity to the infectious agent which is thought to cause PD.

Further analysis of the information that has been collected since the project began will hopefully identify the factors implicated in the observed disease patterns in the near future.

CONCLUSIONS

The results from this study represent the most accurate disease information available for the Irish salmon farming industry. The information from sites distributed throughout

Ireland will enable comparisons to be made in terms of the four different types of parameter; environment, management, production and disease. Comparisons of different sites in terms of these parameters will allow for quantification of the multifactorial aspects of PD and the other economically important diseases of farmed Atlantic salmon.

The results of this study may help aquaculture enterprises to formulate control measures for disease. In the long term, the benefits of the project are that managers making decisions on animal health will have reliable quantitative information on the livestock in their care and this will enable them to implement more selective and effective intervention regimes.

Furthermore, the database can be used not only as a tool for looking at disease on farms, but also for gaining information on other aspects of salmon farming such as efficacy of treatments and long-term trends in mortality at a site. This methodology could also be applied to other salmon producing countries and the production of other aquaculture species.

Ongoing analysis of the database will form a unique tool in maximising profitable production of farmed Atlantic salmon.

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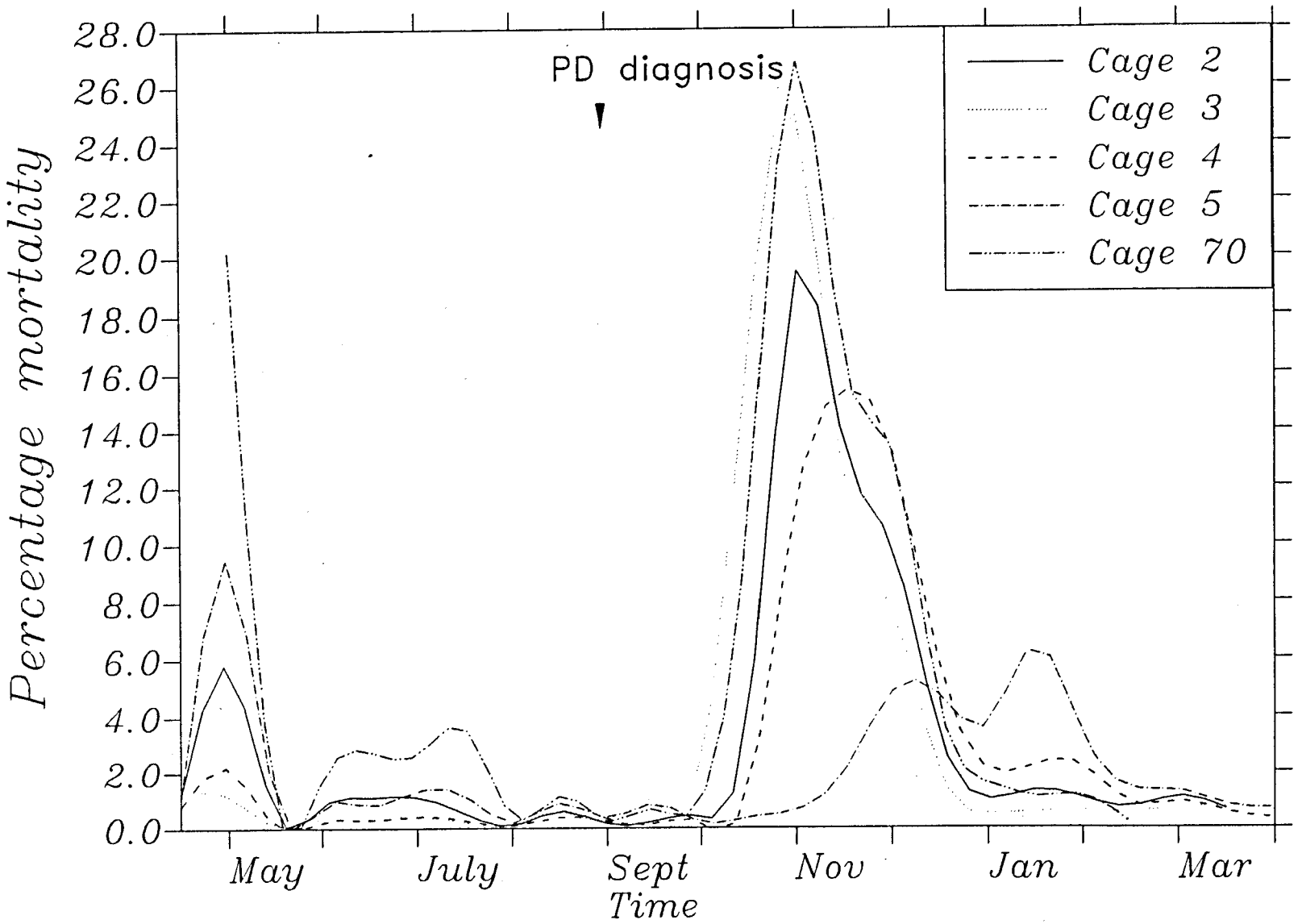

Figure 1:Fortnightly percentage mortality in each cage of a "Polar Cirkel" cage group from input 1990 to March 1991.

Table 1: Total percentage mortality at each site, from input of smolt to the end of December.

SITE	A	B	C	D	E	F	G	H	MEAN	SD
YEAR										
1990	42.19	43.26	17.57	20.57	20.32	11.85	19.77	18.26	24.22	11.75
1991	23.59	46.39	10.90	15.60	11.24	10.19	15.92	28.46	20.29	12.38
1992	21.97	39.59	2.57	59.40	49.89	13.63	34.11	34.94	32.01	18.69
MEAN	29.25	43.08	10.35	31.86	27.15	11.89	23.26	27.22		
SD	11.24	3.40	7.52	23.98	20.21	1.72	9.59	8.41		

Table 2: Results of the block ANOVA on total mortality data between years and between sites.

	Degrees of freedom	Variance (mean square)	F	Probability
Year	2	284.9	1.88	Not sig.
Site	7	338.2	2.24	$p < 0.10$
Residual	14	151.2		