A modelling approach to estimating the economic benefits of intervention for disease in aquaculture

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The Issue:

Salmon aquaculture is a major activity in Scotland
annual production >£550M,
UK’s largest food export 2014
179,022 tonnes 2014
sites of upto 2,500 tonnes consented

Much of this in relatively remote areas
with few year-round employment options

Food and Drink Federation
Disease:

However, disease cause substantial losses
disease approximately 30% of marine losses
occasional big epidemics

Different impacts of different diseases
mortality
reduced productivity
reduced marketability
welfare
treatment costs
Combine two types of modelling:

To assess economic impacts of disease we combine epidemiological models and economic models.

Epidemiological modelling:
- Spread of infection
- Disease from this infection and biological scale of losses
- Effectiveness of controls in preventing spread/disease

Economic model:
- Cost of controls
- Benefits of controls
- Value of losses to disease
- Losses of potential production
So using epidemiological and economic models we assess policy.
An application to Bacterial Kidney Disease

Number of expected cases taken from epidemiological model

Costs of surveillance from MSS Fish Health Inspectors
  inspectors time
  diagnostic testing

Losses of fish per case obtained from industry database

Losses and costs multiplied up by number of cases from epidemiological model

Net cost of alternative scenarios to support decision making
Decision analysis – Evaluating alternative policies

Examples of scenarios
1 baseline (controls until infection cleared)
2 no controls
3 small improvement in surveillance (+)
4 strong improvement in surveillance (++)
5 controls on clinical disease only
EBIT a simplified assessment of the value of losses

Price had fish reached harvest is variable

We do not need to know the factors that drive this variability

Industry publishes EBIT (Earnings before Interest and Taxes)

This is price minus cost of production

Using EBIT we do not have to assess cost of production, losses are simply losses of potential production

There are complications, e.g. reduced cost of production, surveillance costs that do have to be included
Cost relatively stable, price very variable
Pancreas Disease

Widespread, but variable, infection in salmon
Caused by salmonid alphavirus (SAV)
Wild reservoir
Not notifiable in UK and eradication not believed possible
Not case in Norway, where PD free zone is maintained

Epidemiological study of cases in UK carried out
Data from Norway obtained from literature

Model developed of the impact of PD in salmon

Used to assess benefits of alternative farm-level management scenarios
Outline of intervention timing

Risk of infection
Risk of disease

Atlantic salmon life stage

Intervention

selection

vaccination

responsive management measures*

Key

low risk - - - - - high risk

freshwater | marine

* responsive management measures: include inclusion of functional feed, cessation of handling, and/or increased removal of dead and moribund fish as a consequence of disease signs.
Pancreas Disease

Highly aggregated, 7.5% of events account for 50% of losses

Losses biased to large, expensive, fish

Compared with Infectious Pancreatic Necrosis (IPN) which generally kills small fish shortly after put to sea
Detailed model for loss of value of a production cycle due to PD

Intervention for PD
- e.g.: PD-resistant stock;
  - vaccination;
  - functional feed;
  - removal of PD morts

Value of losses due to intervention
- ↑ mortality
- ↓ growth rate
- ↓ stocking density
- ↓ flesh quality

Cost of intervention
- intervention
- administering intervention
- consequential intervention
- cost of capital

Reimbursement from insurance
Total value of losses

Value of losses due to PD
- ↑ mortality
- ↑ discards
- ↓ growth rate
- ↓ flesh quality
Developing a simplified model

Losses are modelled from literature data with mean values and confidence ranges. Literature mean and standard deviations used to create a beta distribution from which parameter values are sampled.

We simplify the intervention costs into a simple constant. In case presented we are assuming 1% of production cost (can be varied).

Value of losses modelled by variation in EBIT. Assumption is cost of production constant, but price varied as shown in EBIT data and this variation affects the value of losses.
Quantifying losses to PD

Losses increase with prevalence of PD and parameter values as selected from beta distribution

Cost of losses sampled from EBIT distribution

Cost of intervention is applied to all sites if a pre-emptive treatment, e.g. vaccination

If intervention is re-active, e.g. functional feed, then can target only infected sites (or at least the true and false positive sites)

Different diagnostic methods for different purposes
Insurance

Insurance is assumed to cap maximum losses a site experiences

Insurance is assumed not PD specific, so not affected by PD prevalence

Risk neutral behaviour assumed

Mean and standard deviation used to derive beta distribution
Mortality >15% intervention for insurance (from industry)
  75% of cases mortality capped at this level
Truncated beta distribution converted back to new mean and SD

Thus big losses generally covered by insurance
Long term low grumbling losses may not trigger payout threshold hence 75% covered
Simplified model for loss-of-value of a production cycle due to PD

1%

Cost of intervention as a percentage of production cost

Key

- Reimbursement from insurance
- Value node
- Uncertainty node

Value of losses due to PD

- ↑ mortality
- ↑ discards
- ↓ growth rate
- ↓ flesh quality

Price - Cost

EBIT
Illustrative Model Scenarios

Illustrative model scenarios for generalised interventions:

• Intervention equivalent to effectiveness of vaccination on a strain similar to PD type III as reported by Bang Jensen et al. (2012)
• Intervention equivalent to effectiveness of vaccination on a strain with half the virulence of PD type III
• Intervention equivalent to half the effectiveness of vaccination on a strain similar to PD type III
• Intervention for equivalent to reduced effectiveness of vaccination on a strain with half the virulence of PD type III

All presented scenarios assume a total intervention cost of 1% of cost of production
Model output example

- Maximum BCR = 11
- Median BCR at 100% PD occurrence
- Median risk of PD occurrence for cost-effective intervention (with 95 percentiles)
- Median BCR
- Lower 95 percentile of BCR
- Break-even BCR
- Risk of PD for production-cycles without intervention
Illustrative model scenario results

**Standard**
- Maximum BCR: 15

**Weak Virus**
- Maximum BCR: 7

**Poor control**
- Maximum BCR: 11

**Weak virus and Poor control**
- Maximum BCR: 4
Conclusions

Intervention benefits depend on virulence of strain and efficacy of control

Benefit of prophylactic intervention depends on underlying risk of infection

Benefit of intervention associated with the price of salmon

Controls suggest where PD risk is high prophylactic vaccination should be carried out
When risk is low, interventions such as functional feed are likely to be more cost effective, even if less effective, if targeted following detection of infection

Simple model can be easily run with managers assessment of cost of intervention, reduction in impact from intervention, and risk of infection