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EX POST BENEFIT/COST ANALYSIS OF TWO FRDC PROJECTS ON THE DIAGNOSIS OF SALMON DISEASES

PROJECT NO: 93/128

Development of molecular probes for use in bacterial disease diagnosis and health monitoring of farmed and wild finfish in Australia

and

PROJECT NO: 95/060

Diagnosis and Identification of Aeromonas salmonicida and Detection of Latent Infections in Carrier Fish

Prepared for the FRDC

June 2001

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1. Introduction

The following two projects were selected by the FRDC for ex-post cost/benefit analysis:

93/128: Development of molecular probes for use in bacterial disease diagnosis and health monitoring of farmed and wild finfish in Australia undertaken by the Department of Primary Industries, Tasmania

95/060: Diagnosis and Identification of *Aeromonas salmonicida* and Detection of Latent Infections in Carrier Fish undertaken by CSIRO Australian Animal Health Laboratory

Both projects are concerned with the development and application of molecular diagnostic techniques for the rapid identification of bacterial fish pathogens for salmonids, and for this reason a combined ex-post cost/benefit analysis was undertaken.

2. Background

2.1 Bacterial Pathogens

One of the major difficulties with aquaculture, especially intensive aquaculture, is disease outbreaks. Disease outbreaks are frequently associated with poor husbandry and adverse changes in environmental conditions. The associated negative economic consequences include increased fish mortality, lower prices, lost markets and increased cost of disease control.

Table 1 outlines the bacterial pathogens and associated diseases examined by the two projects. The major purpose of the projects was to develop molecular probes for use in testing for the presence of the four bacterial pathogens listed in Table 1.

Table 1: Bacterial Diseases Considered in the Project

Bacterial Pathogen	Disease	Symptoms & Consequences
Yersinia ruckeri	Yersiniosis	▪ Exophthalmia (protusion of the eyes) and darkening of skin. ▪ Low-level to high-level mortality
Flexibacter maritimus	Cutaneous erosion disease	▪ Acute to chronic skin erosions. ▪ If untreated can lead to significant losses.
Lactococcus garvieae	Streptococcosis	▪ Exophthalmia and darkening of skin. ▪ Low-level to high-level mortality ▪ Fish are often deformed and discoloured and therefore seldom sold.
Atypical *Aeromonas salmonicida* *Aeromonas salmonicida* subspecies *salmonicida*	Bacterial septicaemia and ulcer disease Furunculosis	▪ ▪ Low-level to high-level mortality

Yersinia ruckeri predominantly causes problems in Atlantic salmon and rainbow trout hatcheries. As well, if smolts are infected when transferred to sea cages, then the stress of transfer can trigger infectious outbreaks in sea cages. Infections are often associated with poor water quality and elevated water temperatures. Clinical signs associated with an outbreak are exophthalmia and darkening of the skin. Generally the disease results in sustained low-level mortality, however large-scale mortalities can occur if chronically infected fish are either stressed during transport or exposed to adverse environmental conditions. The disease can be treated using antibiotics.

Flexibacter maritimus can cause erosion of skin down to the muscle layer and result in mortality, particularly in younger fish (up to 1 kg). The disease is associated with handling stress and can lead to significant loss if untreated. The disease affects salmon in sea cages especially in summer. It is endemic to Atlantic salmon populations in

Tasmania and can spread rapidly. Mortalities can occur, and in the early 1990s mortality was estimated to be around 10% of all fish in infected cages.

Lactococcus garvieae can cause exophthalmia, produce deformed and discoloured fish that cannot be sold for human consumption. The disease is associated with high stocking densities, poor water quality and high water temperatures. Epidemics tend to occur when water temperatures are higher than 20° C. Among the salmonids, rainbow trout is the most susceptible to streptococcosis. Mortality levels can be high and has been the cause in 1991of a farm failure in Tasmania.

Aeromonas salmonicida ssp. *salmonicida* is one of the most important fish pathogens because of its nearly worldwide distribution, diverse host range and economically significant impact on cultured fish. In acute infections, fish usually die within 2-3 days of infection. Sub-acute infection causes scarring of the muscle tissue which makes the fish unmarketable. Latent infections in carrier fish act as reservoirs of the infection. The disease has caused considerable economic losses in Norwegian, Scottish and North American salmon farms[1]. Atypical strains of *A. salmonicida* are becoming of increasing importance worldwide. In Australia three biovars of *A. salmonicida* are known to exist. One of these biovars has been the cause of a disease outbreak in farmed Atlantic salmon.

2.2 Australian Experience with the Four Biological Pathogens

At the time the first project (93/128) was conceived there had been a number of disease outbreaks associated with *Yersinia* and *Flexibacter* in the rapidly expanding Tasmanian salmonid industry.

Since the first project was completed, farm management practices have improved considerably and the incidence of disease outbreaks is thought to have fallen However, as is illustrated in Figure 1, during 1999 and 2000 the number of outbreaks for *Yersinia* and *Flexibacter* has increased. This was attributed to two main stress

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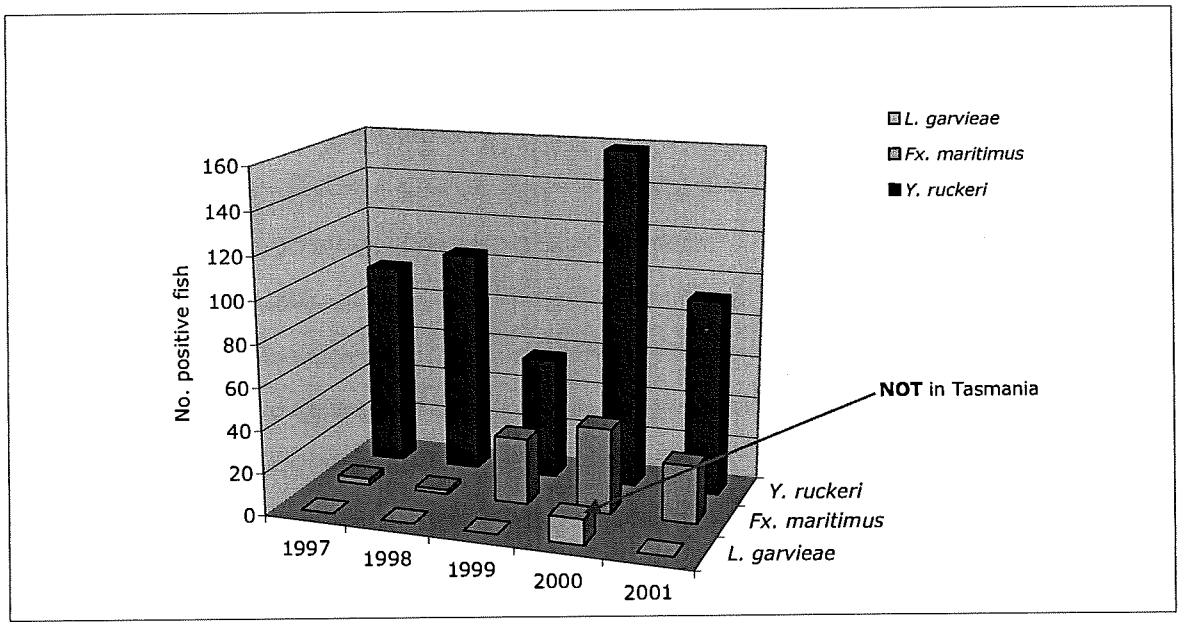
[1] For example, in Norway, 20 Norwegian salmon farms closed for two years in 1988 as the result of the disease, which was accidentally introduced by imported Scottish salmon smolts in 1984. The disease caused more than $100 million in damages when fish on these farms were slaughtered in an attempt to eradicate the disease. By 1992, 550 salmon farms in Norway were infected with furunculosis, a 17-fold increase in the incidence of the disease in four years. (Environmental Media Services)

events in Tasmania: warmer water temperatures and water quality problems due to drought in some areas. It should be noted that the data in Figure 1 is based on submissions only, and may not be an accurate reflection of the incidence of disease experienced by industry.

Figure 1 Detection of fish pathogens from submissions to Fish Health Unit, DPIWE, Tasmania



Source: DPIWE, Tasmania (Jeremy Carson)

Disease associated with *Yersinia*, *Flexibacter* and *Lactococcus* are endemic to Australia. *Aeromonas salmonicida* is a complex group that includes four officially recognised subspecies. One of the subspecies, often referred to as 'typical' *Aeromonas salmonicida*, is exotic to Australia and is the causative agent of the disease furnuculosis (one of the most serious infectious diseases of salmonids). However, some atypical strains are endemic to Australia.

Australia's experience with *Aeromonas salmonicida salmonicida* relates to a trade dispute under GATT (now the World Trade Organisation) which was initiated by Canada and concerned the importation of fresh, frozen and chilled Canadian salmon into Australia. Australia prohibited such imports on the grounds that there was the potential for typical *Aeromonas salmonicida* to be introduced into Australia from fresh, frozen and chilled Canadian salmon imports.

3. Project Objectives and Description

3.1 *Objectives for Project 93/128: Development of molecular probes for use in bacterial disease diagnosis and health monitoring of farmed and wild finfish in Australia*

- Develop procedures for testing fish by molecular probes for the presence of bacterial pathogens
- Develop methodologies using molecular probes for the rapid identification of bacterial fish pathogens recovered by conventional culture techniques.
- Develop molecular probes for enzootic strains of *Aeromonas salmonicida*, *Enterococcus seriolicida*[2], *Flexibacter maritimus* and *Yersinia ruckeri*.
- Develop a secondary confirmation system for PCR assays using internal probes and hybridization
- Formulate the developed test procedures for transfer to, and adoption by, veterinary diagnostic and research laboratories.

At the time of the project, detection of bacterial disease in fish largely relied on conventional bacteriological culture techniques. There was seen to be a need to acquire diagnostic tools to provide for the rapid identification of infectious bacteria during disease outbreaks. This involved taking tissue samples from *infected fish*, culturing the tissues, and then carrying out a series of biochemical tests on the culture. Depending on the pathogen, it took between 2 - 14 days for a confirmed diagnosis. The potential for delay in identifying the pathogen could delay treatment and in turn seriously limit the extent to which an outbreak was controlled.

More importantly, new techniques were also needed to detect bacterial pathogens that were latent in 'carrier' fish. These techniques would allow for the development of surveillance and monitoring programmes.

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[2] Renamed *Lactococcus garvieae.*

The project aimed to develop a rapid, specific and sensitive suite of gene probes for the identification of bacterial pathogens, including diagnostics for the detection of *latent infections* (in fish carriers of the pathogen). Gene probes have been used for the rapid identification of bacteria isolated by conventional culture techniques and also through the direct detection of bacteria in host tissues.

3.2 *Objectives for Project 95/060: Diagnosis and Identification of Aeromonas salmonicida and Detection of Latent Infections in Carrier Fish*

- Characterisation of a comprehensive reference collection of major strains, both exotic and enzootic of *A. salmonicida* subspecies.
- Identify published but non-validated nucleotide sequences with potential for diagnostic use
- Develop diagnostic procedures using molecular technology.
- Validation of molecular diagnostic procedures using experimental infections carried out in the microbiologically secure aquarium facility at AAHL.
- Validation of the molecular diagnostic procedures developed at AAHL using naturally infected populations of salmonids: a short term collaborative project with the National Fish Health Laboratory, West Virginia, USA.
- Determine whether the use of hybridisation-capture PCR would enhance the sensitivity of the test to allow detection of covert infections.
- Field study: a preliminary survey of wild and farmed populations of freshwater and marine fish.

Project 95/128 was not able to develop a molecular probe that could reliably differentiate between *Aeromonas salmonicida* and other bacterial species. Project 95/060 was funded to develop a rapid diagnostic test that was better able both to identify *Aeromonas salmonicida* and to differentiate between typical and atypical subspecies.

4. Research Findings

4.1 Project 93/128

4.1.1 Development of Molecular Probes for Overtly Diseased Fish

Project 93/128 developed diagnostic molecular probes for all four pathogens.

For three bacterial pathogens (*Yersinia ruckeri*, *Flexibacter maritimus* and *Lactococcus garvieae*) the gene probes (using PCR techniques) developed were found to be highly specific and a single bacterial colony could be identified in 1 day (compared with 14 days) for *Flexibacter* and 1 day (instead of 2) for *Yersinia* and *Lactococcus* using traditional biochemical techniques.

However, the probe developed for *Aeromonas* was less specific and was not able to reliably differentiate *Aeromonas salmonicida* from some strains of *A.hydrophila.*

4.1.2 Use of Molecular Probes for Diagnosis in Covertly Diseased Fish

Being able to identify covert infections before there are overt signs of the disease makes an important contribution to the monitoring, managing and control of disease. However, as is noted in the Final Report "Although a PCR format was developed for direct detection of bacteria in fish tissue, realistically the level of detection makes this technique of marginal value if it is to be used for detecting carrier fish." This means that the probes were not sensitive enough to identify carrier fish, and therefore they could not be used as a surveillance and monitoring tool.

4.1.3 Transfer of Test Procedures to Diagnostic Laboratories

One of the project's objectives included the transfer of test procedures to other Australian diagnostic laboratories. A workshop was held with all the major diagnostic veterinary laboratories responsible for fish disease in Australia. The workshop consisted of lectures and laboratory practicals. A manual was prepared that provided information on protocols and reagents. All participants had the opportunity to carry out tests. The workshop received a high approval rating (90%) and 80% of the participants said they would use the techniques for fish disease diagnosis.

4.2 Project 95/060

Use of Molecular Probes Using Experimentally Infected Fish

Project 95/060 undertook an extensive *in vitro* validation and determination of the sensitivity and specificity of PCR tests for *Aeromonas* having collected a wide variety of *Aeromonas salmonicida* isolates from around the world. Two tests (AP, PAAS) appeared to have a high level of specificity and sensitivity for *A.salmonicida* species and one test (MIY PCR) for *A. salmonicida subsp. salmonicida* when used to identify pure bacterial cultures.

The three tests were then evaluated to assess whether they could be used for the direct detection of *A. salmonicida* in tissues from experimentally infected fish. Two tests (AP and PAAS) yielded positive results but the MIY was less sensitive.

4.2.1 Use of Molecular Probes in Naturally Infected Fish

As there are no naturally infected populations of fish in Australia, the project then evaluated these tests using naturally infected fish in cooperation with a US laboratory.

Using overtly infected tissue samples, bacteria isolated from fish were successfully identified as *Aeromonas salmonicida* using two tests (AP and PAAS) and as typical *A.salmonicida salmonicida* using the MIY PCR. These tests take 2 days as opposed to 7 – 14 days for the more classical biochemical testing. Direct testing of tissue samples using AP and PAAS were also capable of detecting the presence of *A. salmonicida* but to a lesser degree than culture.

Using covertly infected tissue samples, culture was a more reliable and sensitive method for detection of *A. salmonicida salmonicida* than direct testing of tissue samples. However, culture alone did not detect *A. salmonicida* in all salmonid populations either. It was concluded that the development of a medium selective for *A.salmonicida* and the use of multiple-point sampling regimes might be able to overcome this problem.

5. Cost/Benefit Analysis

There are two major components of net economic benefit in cost/benefit analysis - producer's surplus and consumer's surplus. Producer's surplus is a measure of net economic benefit generated in the Australian salmonid aquaculture industry from the

research project. Although somewhat simplified, producer's surplus can be thought of as additional profits generated. In addition, if the research findings induce increases in production and employment, then to the extent that previously unemployed labour is hired, the associated wages would also be included as a benefit in producer's surplus.

Consumer's surplus is a measure of net economic benefits to consumers. For example, if a research project induces an increase in product supply that in turn results in a decrease in prices on the domestic market, then domestic consumers would be better off. Consumer surplus is simply a measure of this improvement in consumer well-being.

Cost/benefit analysis involves the calculation of the net economic benefits that are generated from the research investment, which are in turn compared to the initial research investment.

5.1 Project Costs

Total costs of both projects were just under $1.2 million, of which FRDC contributed 36% of total costs (Table 2).

Table 2: Cost of Research Investment

Project No.	FRDC	Other	Total
93/128	178,619	191,800	370,419
95/060	249,873	567,335	797,708
TOTAL	**428,492**	**759,135**	**1,187,627**

5.2 Potential Benefits

Table 3 outlines four categories of potential economic benefits from the research investment in the two projects. Data availability allows us to examine benefits related to the reduction in diagnostic time from the use of probes. In terms of Table 3 this is lower mortality and reduced treatment costs. Benefits are examined for each pathogen separately.

Table 3: Potential Aquaculture Benefits from Research Investment

Benefits	Discussion
Lower mortality and therefore higher farm yields	▪ Faster detection time means fewer deaths from disease, which in turn increases sales revenue and profits. ▪ Detection time refers to disease identification of both acute and latent infections.
Reduced morbidity and consequently higher sales	▪ Reduced disease-related deformities, such as lesions and swellings, increases the number of fish that can be sold (and therefore increases sales revenue and profits).
Higher sales into markets that pay a price premium for fish not subjected to antibiotics.	▪ Japan pays a higher price for salmon that have not been subjected to antibiotic treatment.
Reduced disease impact	▪ Earlier detection may limit spread of disease and the need for quarantine or enforced slaughter of stock
Reduced treatment costs	▪ Earlier detection reduces the number of fish that may need to receive antibiotic or other treatment, and consequently could reduce treatment costs. ▪ .

5.3 Realised Benefits

5.3.1 Yersinia ruckeri

There is a saving of one day in diagnostic time due to the development of the probe. However, there is no saving in treatment costs. If a positive diagnosis is made under either the old or new technique, it is still necessary to provide treatment for 7 days.

Concerning reduced mortality, assuming that no treatment occurs until a diagnosis is made which is accordance with best practice, then one benefit of the reduced diagnostic time is the profit associated with fish that would have died (but now do not because of the probe) while waiting for the extra day for a diagnosis. Table 4 provides information used in calculating these profit savings associated with the probe. One major hatchery manager indicated that in 2000, roughly 25% of his fish were infected with *Yersinia* and of these, 1% died each day without treatment. With total hatchery production in Tasmania at roughly 6 million fish, this implies that 1.5 million fish

carry the infection. As mortalities per day were estimated at 1%, this works out to 15,000 mortalities/year that would be saved by a one-day earlier diagnosis.

Table 4: Calculation of Economic Benefits Associated with the *Yersinia* Probe

Assumptions	Scenario 1	Scenario 2
a. Production (no. of fish)	6,000,000	6,000,000
b. Infected fish as a % of total production	25%	25%
c. Mortalities per day (of infected fish) assuming no treatment	1%	1%
d. Farm gate price $/fish	$2.00	$2.00
e. Before-tax profit rate	20%	30%
f. Yearly production growth	10%	10%
Benefit Calculation		
g. No. of infected fish (a x b)	1,500,000	1,500,000
h. Mortalities saved per year (c x g)	15,000	15,000
i. Revenue saved per year (d x h)	$30,000	$30,000
j. Profit saved per year (e x i)	$6,000	$9,000
Net present value of profits saved – 6 % discount rate and 10% growth in yearly production	$44,400	$66,600

Assuming a farm gate price of $2.00 per fish and a before-tax profit margin of 20%, this implies that the profits saved by the one-day mortality savings is $6,000. Assuming production growth of 10% per year, a 6% discount rate[3], and a 7-year time horizon for benefit accumulation, the net present value of the profit saving is $44,400. This is Scenario 1. A 7 year time horizon for benefit accumulation was chosen given that it is anticipated that ongoing research to identify latent infections will be successful and result in hatchery and disease management practices to prevent

outbreaks of yersiniosis occurring. Scenario 2 employs a 30% before-tax profit rate and provides a net present value of $66,600.

5.3.2 *Flexibacter maritimus*

As with *Yersinia*, antibiotics are an effective way to treat the disease. Antibiotics are prescribed only after a government registered veterinarian has made a farm visit and made a clinical diagnosis of *Flexibacter* (simultaneously samples are sent for laboratory confirmation), or if no diagnosis is initially made, antibiotics are only given after confirmation of *Flexibacter* is received from the DPIWE laboratory. As veterinarians are legally required not to medicate if uncertain of the disease, in the case of *Flexibacter*, it is highly likely that the veterinarian will wait for laboratory confirmation.

The *Flexibacter* probe developed has reduced the diagnosis time from 14 days to 2 days, which has meant that farmers and the government veterinarian are more willing to await results of the test before medicating. In terms of economic benefits, the saving of 12 days in diagnostic time is manifested in savings in treatment costs if there is a wrong diagnosis as well as savings in mortalities. However we have no information on the extent of misdiagnosis, and therefore this potential economic benefit cannot be quantified.

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[3] Discount rate used is the same as that used by BDA Group eSYS in their recent report to FRDC on economic evaluation of FRDC submissions (2001). Public sector discount rate used is often 10%.

Table 5: Calculation of Economic Benefits Associated with the *Flexibacter* Probe

Assumptions	Scenario 1	Scenario 2
a. Mortalities per day per cage per outbreak per farm assuming no treatment (average fish size: 1 kg)	25	100
b. Outbreaks per farm per pear (32-64 outbreaks and 32 farms)	1	2
c. Cages per farm infected	2	5
d. Farm gate price/kg	$7.60	$7.60
e. Before-tax profit rate	20%	30%
Benefit Calculation		
f. Saved mortalities per day per cage per farm (a x b)	25	1200
g. Saved mortalities per day for all cages per farm (c x f)	50	1000
h. Saved mortalities for 12 days per farm (g x 12)	600	12000
i. Revenue saved per farm (d x h)	$4,560	$91,200
j. Profit saved for all 32 farms	$29,200	$876,000
k. Net present value of profits saved – 6 % discount rate and 10% growth in yearly production	$216,000	$6.5 million

Table 5 details the calculated benefits associated with the *Flexibacter* probe. Benefits are related to the extra profits that are made from reduction in fish mortality generated from lowering the diagnostic period by 12 days. The benefit stream has been calculated over 7 years given that there it is anticipated that ongoing research to identify latent infections will be successful and result in disease management practices to prevent outbreaks of cutaneous erosion disease occurring. Discussions with industry and the government veterinarian indicated that 25-100 fish/cage die per day during an untreated outbreak, that for the industry as a whole there are between 32-64 outbreaks per year and that the number of cages per farm varies from 2 to 5. Under Scenario 1, it is assumed that 25 fish die per day per outbreak, 32 outbreaks occur each year and there are 2 cages per farm. Roughly 600 fish are saved per farm

through the 12-day earlier diagnosis. The net present value of the associated profits saved for all farms over 7 years is $216,000. Under Scenario 2, the number of mortalities saved per cage, per farm per outbreak is 100. As well, increasing the number of outbreaks to 64 (2 per farm) and the number of infected cages on each farm to 5 increases the net present value to $ 6.5 million.

5.3.3 Lactococcus garvieae

The probe reduced the time for diagnosis from 2 days to 1 day. Over the last four years, there has been only one known reported outbreak of *Lactococcus* at one of the largest trout farms in New South Wales. No other trout farms have reported a *Lactococcus* outbreak. As soon as the outbreak occurred, the rate of mortality doubled each day starting at 150 kg on the first day of the outbreak. There was no saving in treatment costs, as there was no treatment before diagnosis.

In terms of reduced mortality, the extra day saved 150 kg of fish, which has a revenue value of only $900. The savings in profit would be less. Given the low reported incidence of the disease associated with this pathogen, there appear to be little economic benefits so far associated with the development of this probe.

5.3.4 Aeromonas salmonicida

The development of a 100% specific probe to detect the furunculosis-causing *Aeromonas salmonicida* within 2 days as opposed to up to 14 days using biochemical techniques means that, should an outbreak occur, there is a potential for significant savings in terms of stock losses.

In early 2000, there was a suspected outbreak of furunculosis at Macquarie Harbor, Tasmania. The veterinarian was uncertain of the pathogen, but suspected *Flexibacter.* Before medication was prescribed, samples were sent for testing at DPIWE. Negative tests for *Flexibacter* led the laboratory to screen for *Aeromonas salmonicida* using the probe developed by the first project. This whole process took 3 days. When a positive result was obtained for *Aeromonas salmonicida,* samples were then sent to AAHL for testing to see whether the pathogen was the exotic furunculosis-causing *Aeromonas salmonicida.* Within 2 days of sending the sample to AAHL, a negative result was obtained. The pathogen was found to be atypical *Aeromonas salmonicida* probably carried by wild fish. Overall the process from preliminary diagnosis to diagnostic

confirmation took 5 days. While waiting for the result, some mitigation measures were voluntarily undertaken by the infected farm (destruction of all fish in the infected cage) – which illustrates the degree of concern about this disease.

Table 6: Calculation of Economic Benefits Associated with the *Aeromonas* Probe

Assumptions	Scenario 1	Scenario 2
a. Fish per cage in tonnes	40	80
b. Number of infected cages per farm	1	3
c. Farm gate price per tonne	$7,600	$7,600
d. After-tax profit rate	20%	30%
Benefit Calculation		
e. Revenue saved (a x c)	$304,000	$1.8 million
f. Profit saved on one infected "average" farm (f x d)	$60,800	$547,200
g. Net present value of profits saved – 6% discount rate and 10% growth in yearly production	$273,100	$2.9 million

In keeping with the concern about furunculosis, it is assumed that, without the development of the probe, then all fish in cages with the suspected infection would be destroyed as the farm, as well as adjacent farms, would be unwilling to wait 12 days for the result from the traditional biochemical testing.

Table 6 details the discounted economic benefits from the *Aeromonas* probes' ability to provide faster diagnosis. It is assumed that the average farm gate price of fish is $7,600 per tonne, each cage contains 40-80 tonnes and the number of infected cages per farm varies between 1 to 3. It is assumed that only one farm is affected, Concerning the number of outbreaks of suspected furunculosis, over the last 10 years there have been two cases where there was a suspected outbreak, but testing indicated that the infection was from the atypical species. However, probably as a result of more intensive farming, both cases occurred in the last two years. Therefore in the analysis it is assumed that there would be a "suspected" outbreak at one farm every three years. The profit margin on a tonne of fish is assumed to be 20% to 30%. A 10

year benefit period was selected based on the assumption that by that time, diagnostic techniques would have been developed to identify latent infections, improved management practices would reduce the likelihood of outbreaks and should outbreaks recur, vaccines would be used.

Under the most conservative set of assumptions, the additional profit earned by correct earlier diagnosis is 20%(profit margin)*$7,600(fish price per tonne)*40(tonnes per cage)*1(cages per farm), which equals $60,800.

Under scenario 2's assumptions, the additional profit earned by the ability to diagnosis earlier is 30%(profit margin)*$7,600(fish price per tonne)*80(tonnes per cage)*3(cages per farm), which equals $547,200. The discounted value of benefits under scenario 1 is $273,100 and under scenario 2 is $2.9 million.

5.4 Non-Quantified Benefits

Without early diagnosis, the probability of a wider spread of disease increases. While not included in the analysis, a major outbreak of certain diseases could negatively impact on the recreational sector for some species. This possible source of benefit from the research is not included in the analysis.

5.4.1 Antibiotic usage

The use of antibiotics in aquaculture is of increasing global concern in terms of impacts on human health, the environment and the development of disease resistant strains. Being able to diagnose disease earlier means that smaller quantities of antibiotics are used as the spread of infection and severity of infection is contained. In addition, shorter waiting times for test results means that the farmer/veterinarian may be willing to hold off on medication until results are available.

5.4.2 National diagnostic capacities

Non quantifiable benefits attributed to improved diagnostic capacities includes the increased competency of diagnostic laboratories and improved detection and reporting of proscribed pathogens at the state, national and international (imports and exports).

5.4.3 Future Development of Diagnostics for Identification of Latent Infection

Although the two projects were unable to develop probes to identify latent infection of the four pathogens, the project findings establish the groundwork for future research in this area. Identification of latent infections offers significant potential for disease management by enabling screening of fish before they are transferred to hatcheries or sea cages.

6. Net Benefits

The discounted present values of research benefits are shown in Table 7 at a 6 % discount rate. Under the Scenario 1 sets of assumptions the respective benefit/cost ratios attributed to the FRDC investment in project costs are 0.32:1 and 8:1 under Scenarios 1 and 2 respectively[4].

Table 7: Total Value of Discounted Benefits and Benefit/Cost Ratio

Net Present value of Benefits	Scenario 1	Scenario 2
Yersinia probe	$ 44,400	$66,600
Flexibacter probe	$216,000	$6.5 million
Lactococcus probe	0	0
Aeromonas probe	$273,100	$2.9 million
Discounted Total benefits	$ 533,500	$9.4 million
Benefit/Cost Ratio	0.45	8

[4] FRDC contributed 36% of total project costs, and therefore 36% of total discounted benefits are attributed to FRDC. The benefit cost ratio is the calculated by dividing FRDC attributed discounted net benefits with the FRDC contribution to total costs.