Investments in Environmental Research, Science and Technology: Their Impacts on Irrigation and Mussel Farming

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Summary

MoRST is evaluating the *Environmental Research* output class of the Public Good Science Fund to identify *inter alia* the impacts of Environmental RS&T spending. Three specific questions are: How effective has the funding on Environmental RS&T been? Is Environmental RS&T having a positive effect by delivering real benefits to New Zealand, particularly to the environment? What influences the link between research and tangible positive benefits? This paper reports how case studies applied to irrigated agriculture and mussel farming were used to provide partial answers to these three questions. The case studies proceed by noting the possible benefits that Environmental RS&T may have created, and then tracing the link back to specific research projects that contributed towards the benefits.

Key words

Environmental RS&T, benefits, irrigation, agriculture, mussel farming

Introduction

The Ministry of Research, Science and Technology (MoRST) is performing an evaluation of the *Environmental Research* output class. This evaluation is intended to contribute to ongoing decision-making about the Vote RS&T investment in environmental research. It will consider the effectiveness and efficiency of research carried out by reviewing both past investments and identifying future opportunities. One focus of the evaluation is the impacts of environmental RS&T spending? Is the research having a positive effect by delivering real benefits to New Zealand, particularly to the environment? How effective has the funding on environmental research been? What influences the link between research and tangible positive benefits? This paper reports on two case studies that shed light on those issues.

The Government's total investment in Vote: RS&T is divided into 14 Output Classes, of which six are referred to as Public Good Science & Technology. Environmental research (Output Class 014) contributes primarily to the Government’s Environmental Goal, which seeks to increase our understanding of the environment, including the biological, physical, social, economic and cultural factors that affect it. A total of $88.6 million in research funds were allocated through this Output class in 2003/04. There are 13 portfolios in the Environmental Output class, which support four Environmental Strategic Portfolio Outlines (SPOs).

By definition, the benefits of Public Good Science Fund (PGSF) research are diffuse. As a result, there are generally a number of funding partners facilitating this kind of research. The Environmental Output Class is no exception. Major funding partners in environmental research include the Department of Conservation, the Ministry of Agriculture and Forestry, the Ministry of Fisheries, Regional Councils, industry organisations such as the Animal Health Board and AGMARDT. The financial contribution that these groups make to environmental research varies by research output area, but overall it is significant. In many cases the Output Class 014 money supports the higher-risk, more fundamental research that underpins subsequent applied research. The multiple sources of funding makes it hard to calculate the returns specifically to Output Class 014 as the impact of the individual funding streams cannot be separated.

A considerable amount of research has been completed investigating the social returns to R&D since early work by Griliches (1958) and others. Researchers have used two approaches to estimate the returns to these investments: econometric analysis and case studies. The former approach uses statistical techniques to examine the relationship between R&D and production processes in individual firms, industries or national economies. R&D may impact production processes by way of production costs, output levels or productivity. Total factor productivity (TFP) studies are increasingly popular means of investigating the relationship between R&D and national economies. The high level of aggregation in this approach avoids the need to identify project specific effects on beneficiaries. In New Zealand a recent study by Johnson (2000) uses econometric approaches to estimate the rate of return to New Zealand R&D investment. The study finds low rates of return to public investment in R&D and promising rates of return to private R&D.

Case study research traces the investments made in a selected research programme and the flow of benefits deriving from the research. Analysts then complete a cost benefit analysis of the research programme by calculating the present value of the investments and the present value of the additional benefits the research has delivered compared to a counterfactual of no research investments. A review of the merits of the two evaluation approaches noted that case studies have advantages of transparency, the methodology is readily understandable and the beneficiaries of the research are able to be clearly identified (Industry Commission 1995: QA.15).

Many research programmes in agriculture have been studied using case study evaluations and often they have reported very high returns to the R&D (Marshall and Brennan and 2001). The authors noted some pitfalls to watch for with case study research including:

- Lags between R&D and innovation;
- Lags between innovation and adoption by end users;
- Decaying of stream of benefits from the research;
- The difficulty of modelling benefits if they are influenced by stochastic events;
- Failure to account for the counterfactual ‘without-project’ scenario.

Other issues for case study evaluations include the possibility of selecting highly successful research programmes and hence being unrepresentative of all R&D, the difficulty of identifying and measuring the additional investment costs that may be required after the R&D is completed to achieve adoption. These items may lead to overestimation of the returns to the R&D. Another possibility is the knowledge generated by the R&D may have public good characteristics and be used widely or have spillover benefits that are hard to quantify, and hence the returns to the R&D may be underestimated.

There are clearly strengths and weaknesses of both evaluation methodologies and they may be best used as complements. This research project had limited time and budget available, insufficient for econometric analyses or comprehensive evaluation of the effects of environmental RS&T. Case study methodology was judged to be viable and a series of case studies was used to gain preliminary insights into the research questions. No claim is made that the projects selected for study are representative of the complete suite of investments in environmental RS&T.

A workshop held in 2004 considered how the returns to RS&T might be evaluated. Participants noted that research was focused on benefiting the environment but identified two situations where commercial benefits might also arise:

- Environmental research is directed at providing some knowledge that directly benefits some sectors of the economy.
- Environmental research is directed at producing some knowledge that is subsequently of benefit to some sectors of the economy.

The Workshop identified differing methodologies would be needed to identify and quantify the benefits from environmental research in these two situations. Methodology One identifies the research completed then attempts to identify and quantify the benefits the research has created. Methodology two identifies a particular sector or industry that has benefited from environmental research and attempts to trace the link back to the research that contributed to the benefit. There are differences as to the impact of the two methodologies. The first methodology allows an evaluator to account for all of the research projects that have been identified. In this way, it is possible, at least in theory, to say that all the benefits of a research funding programme have been accounted for. This is true even if some form of sampling is used. Such a finding is not possible with the second methodology. The advantage of the second methodology is that it potentially allows for a better definition of the benefits of environmental research, science and technology. Successfully accounting for all research is contingent on a documented complete (or relatively complete) list of research programmes being available.

In this paper we report on application of Method II to environmental research benefiting irrigated agriculture and mussel farming. This required us:

- Gaining a broad understanding of the context around irrigation and mussel farming development in NZ over the last 10-20 years;
- Determining the nature of the environmental research, science and technology that has contributed to any growth in irrigation/mussel farming and the associated benefits (including to the environment) from that growth;
- Determining what would have happened to irrigation/mussel farming development and to the broader values of society if the environmental RS&T had not been available over this 10-20 year period; and
- Seeking third party comment on these putative benefits from research.

Contribution Of Environmental RS&T To Canterbury Irrigation

Canterbury, the area from the Waitaki River in the south to Kaikoura in the north, was chosen for study because:

- It is the area of New Zealand with the largest scale of irrigation development;
- It is also the area with the largest potential for future irrigation development;
- The region has seemingly abundant water resources for which there are competing instream (and sometimes of out-of-stream) demands, and

- It is a core issue area within the Government’s Sustainable Development Programme of Action with regard to water.

Irrigation, its ongoing development and issues surrounding its development, in Canterbury is not new (Table 1). When the Rangitata Diversion Race, taking water from the Rangitata River to the Rakaia River was built (initially as an employment scheme: M. Doak, MAF Policy, pers. comm.) in the 1930s the first major community irrigation scheme in New Zealand was launched. That scheme and similar smaller government funded schemes, i.e., Morven-Glenavy (Waitaki River), Levels (Opihi River), Greenstreet and Valetta (Ashburton and associated rivers), Glenmark (Weka Creek), Waiau Plains and Waiareka Downs (Waiau River) and Balmoral (Hurunui River) were subsequently established through until the late 1970s-early 1980s when government subsidies were removed from irrigation development projects. Subsequently, private irrigation development, mostly from underground resources has increased dramatically, especially in central Canterbury. Two community supported schemes, the Opuha and Waimakariri-Ashley, have been developed over the past decade.

Table 1. – History Of Community Irrigation Scheme Development In Canterbury

Source Waterbody	Irrigation Company	Location	Start Year	Area, ha
Waiau River	Amuri	North Canterbury	1975	20,500
Hurunui River	Balmoral	North Canterbury	1981	5,250
Waimakariri River	Waimakariri-Ashley	Canterbury	1999	18,000
Rangitata/Ashburton	Ashburton-Lynd	Mid Canterbury	1949	25,000
	Eiffelton	Mid Canterbury	1984	2,300
	Greenstreet	Mid Canterbury	1973	2,100
	Mayfield-Hinds	Mid Canterbury	1949	32,000
	Valetta	Mid Canterbury	1959	7,385
Opihi	Opuha	Canterbury	1998	16,000
	Levels Plain	South Canterbury	1937	3,000
Waitaki	Lower Waitaki	North Otago	1974	18,000
	Upper Waitaki	South Canterbury	1965	490
	Morven-Glenavy-Ikiwai	South Canterbury	1974	20,000

Source: M. Doak, G. Elliot (MAF Policy, pers. comm.), D. Attewell (Irrigation consultant, pers. comm.)

Further major developments are at various stages of investigation and planning for the Hurunui-Waipara areas (incorporating both the Hurunui and Waipara rivers), the Central Plains (incorporating both the Rakaia and Waimakariri rivers), the Barrhill-Chertsey plains in Mid Canterbury (from the Rakaia River), south Rangitata (incorporating both the Rangitata and Orari rivers), the Mackenzie Basin (upper Waitaki catchment rivers), and South Canterbury generally (incorporating flow from the Upper Waitaki (diverted into South Canterbury via Burke’s Pass) and the Lower Waitaki. Existing and potential developments, in terms of land area and farmgate GDP generated p.a. in Canterbury, are shown in Table 2. The waterbodies listed in Table 2 are only those with a contribution to GDP of $5m or greater. Note that while Canterbury has 61% of the country’s irrigated land its contribution to GDP at the farmgate is 32%. Planned irrigation developments would increase the proportion of Canterbury’s contribution to national irrigation output.

Table 2. – Existing And Possible Canterbury Irrigation And Farmgate GDP Benefits.

Water body	Area currently irrigated (ha)	Farmgate GDP generated $ per annum	Possible future community irrigation (ha)	Farmgate GDP generated $ per annum
Waiau	16,500	21,000,000		
Hurunui	4,000	7,000,000	80,000	68,000,000
Waimakariri	11,000	22,000,000	16,800	14,000,000
Central Canterbury Groundwater	56,900	55,000,000		
Rakaia	4,100	8,000,000	107,200	74,000,000
Mid Canterbury Groundwater	50,015	39,000,000		
Ashburton	6,386	7,000,000		
Rangitata	57,474	63,000,000	18,000	22,000,000
Opihi	23,510	17,000,000	3,200	2,000,000
Waitaki	46,060	57,000,000	136,400	115,000,000
Total Canterbury	287,200	296,000,000	361,600	295,000,000
Total New Zealand	475,700	920,000,000	470,000	660,000,000
% Canterbury	61	32	77	45

Source: Adapted from Doak (2004: Tables 4 and 5, for the detailed river-related data) and Doak et al. (2004: Total area and farmgate GDP data).
Note: Farmgate GDP due to irrigation = GDP with irrigation – GDP without irrigation. $2002/03

The central question in this research concerns the extent to which instream flow needs research has contributed (and/or will contribute) or not to the development of irrigation in Canterbury. According to Doak (2004: 3) "… the potential for new irrigation is limited in some cases by existing legislative instruments, for example Water Conservation Orders." This 'limitation' has restricted the size of the potential irrigable area sourced from the Rakaia and is a direct result of research associated with defining the instream flow needs of fisheries (and to a lesser extent wildlife). Such limitations, mostly being minimum river flows set by regional councils and defined using tools generated by this research, have direct economic consequences to the nation but have a range of other benefits (e.g., for tourism, recreation, dilution of pollutants and biodiversity conservation). In the following analysis we examine the nature of the research, its influence on existing irrigation development (or non development), and its potential to contribute to future development opportunities (within a sustainable development approach).

There are three major areas of environmental research that potentially influence irrigation development:

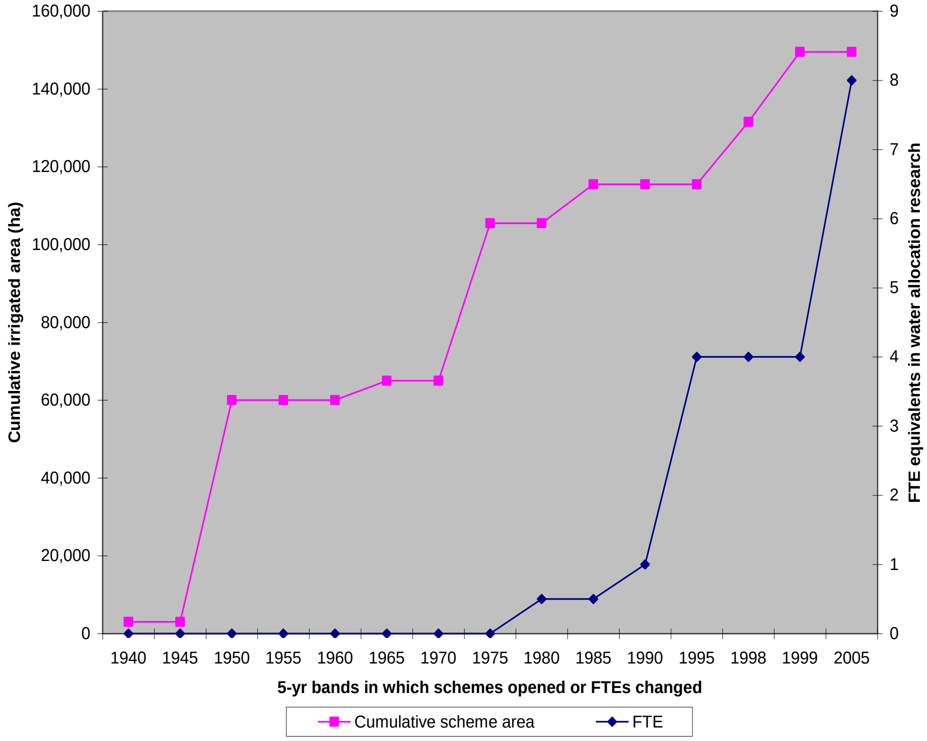
- Water Allocation: Protection of Instream Values – the effects on instream values of water resource development and the associated definition of environmental (minimum) flows, research;
- Nationally Significant Database: Water Resources and Climate – the research that provides information on the amounts of water available, its reliability of supply, on droughts, long term climate trends, etc; and
- Water quality research – research that might indicate irrigation is affecting water quality and that management practices will need to be modified.

Advice from Dr Biggs (NIWA), G McFadden and M Doak (MAF Policy) indicated no decisions regarding irrigation development had been influenced by water quality research hence it was discounted from this research. Information about the Water Allocation research was gained via NIWA records and through interviewing Dr

Biggs, NIWA. For the database and modelling research it was obtained via Dr C Pearson at NIWA. The database programme is summarised in Bicknell et al. (2004).

Water Allocation research began in earnest in the early 1980s and its capacity has slowly increased over the last 25 years (see Figure 1 and Table 3). Units in Figure 1 are based on FTE equivalent researchers working in this field (B. Biggs, NIWA, pers. comm.). Initial work was very focused on utilising US models under New Zealand conditions and almost solely for exotic fish species. Over the past 15 years this work has shifted toward New Zealand conditions, broader ecosystem component issues (e.g., algae, bed load movement) and other taxa (e.g., invertebrates). The focus now is on validating the relationships between predictions and reality and on refining tools to further improve their predictive capacity, over a range of different systems.

Figure 1. – Community Irrigation Scheme Development In Canterbury And Research Effort Into Defining Instream Flow Needs



A comparison of costings from 1992/93 to 2003/04 based on FTE estimates and contract price has been carried out and while there are differences they are not significant given the large size of economic data reported in other analyses in this research.

Research in the Nationally Significant Database: Water Resources and Climate areas began with the 'simple' tasks of recording river flow and other data. This was followed by developing the understanding of the hydrology and geomorphology of river basins across the country, and weather patterns on a national basis. Subsequently the research has moved into high level modelling of fluvial systems, atmospheric processes and rainfall, and intense weather (including droughts), and is now focused on forecasting and mitigating the effects of extreme events.

Outcomes From The Research

The Water Allocation: Protection of Instream Values research has improved the ability of scientists and managers to define environmental flows for maintaining instream needs in streams and rivers, especially for fisheries. In some respects this might, or might not be, considered a negative outcome for irrigation developers. Prior to, and including much of the 1970s, instream flow needs were given scant regard in water allocation decision making. The passage of the 1981 Amendment to the Water and Soil Conservation Act (the Wild and Scenic Rivers legislation) changed the balance of competing interests. For the first time in New Zealand the interests of instream users had real power. Around the same time major irrigation schemes, some being considered as part of 'Think Big', were being proposed. These included the Central Plains scheme, which was going to be supplied from the Rakaia River, and major power development along the lower Waitaki River. Significant research input was made into instream flow needs in these rivers. In the case of the former this became associated with a Water Conservation Order application which was subsequently granted and which has resulted in a major constraint occurring for water resources development from the Rakaia River. As noted by Doak (2004) this regulation constrains irrigation development in Central Canterbury (i.e., it has a GDP cost to the nation). It does however, appear to help protect the instream values of the Rakaia River (which of course has multiple benefits to the nation such as in terms of tourism, clean and green image, meeting Biodiversity Strategy requirements). These same tools have now been used (and are currently being used to define minimum flows in lowland streams in Canterbury) to help set minimum flows for most major waterways in Canterbury (Table 3), again providing a measure of protection for instream users and helping to ensure sustainable development principles are achieved. The research is therefore helping to provide certainty, in two ways:

1. Instream users are becoming increasingly confident that flows set by Environment Canterbury via the tools developed by NIWA will protect their interests; and
2. Out-of-stream users know what water is potentially available for their needs and can design systems of management to meet their requirements.

In the Nationally Significant Database: Water Resources and Climate research there has been a huge improvement in national capability and capacity in the prediction of river levels and weather patterns and events. The database is utilised by a range of PGSF research programmes and by a wide range of users, and contributes to the sustainable management of freshwater resources, amongst a wide range of outcome areas, including for the development of irrigation schemes. This research is used to:

- understand reliability of supply under a range of operational constraints, e.g., variable instream flow regulations; and
- understand the relationship between climatic events and irrigation needs.

In both areas of environmental research industry is playing an increasing role in terms of information requests and funding contributions. This support is likely to increase further if community irrigation schemes are given further support under government economic growth initiatives.

Possible Future Benefits From The Research

In terms of the Water Allocation: Protection of Instream Values research new research can be used to review past decisions. For example, it might (or might not) be that the existing Rakaia Water Conservation Order conditions are too stringent and more than meet instream flow requirements. A review of the Order, subject to application of these tools, might then make more water available for irrigation. On the other hand streams and rivers where flows were never set using contemporary tools are now in the process of having instream flow requirements reconsidered. In Canterbury this seems likely, if the recommendations are implemented by the Regional Council, to lead to restrictions on existing water users. Such restrictions will not, however, necessarily reduce either the area under irrigation or the value of production – more likely they will change irrigation practices and day-to-day management of these takes.

Table 3. – Influence Of Water Allocation Research On Minimum Flow Setting For Major Canterbury Rivers (Based On B. Biggs, NIWA, Pers. Comm.)

River	Use of water allocation research in setting minimum flows	Implications for present and future irrigation development
Hurunui	IFIM[1] used in 1983 to set flows	Forcing developers to think about water storage and transfer options
Waipara	Minimum flow set using NIWA methodologies	Potential constraints on booming olive and grape growing industries - developers investigating storage and diversion of Hurunui flows into the catchment
Ashley	Mid-1980s new minimum flows based on IFIM approach	
Waimakariri	New minimum flows based on NIWA IFIM approach	Both Waimakariri-Ashley scheme still able to be developed and potential use of further water for a Central Plains Scheme still feasible
Rakaia	IFIM approach used in 1980s National Water Conservation Order process	Probably constraining development of Barrhill - Chertsey scheme through added infrastructure costs; also limiting other irrigation development
Ashburton	IFIM based survey and modelling completed, but not implemented?	
Rangitata	IFIM approach used in Water Conservation Order process	Could result in lost development opportunities for South Bank of the Rangitata irrigation
Opihi catchment	IFIM based survey and modelling completed, but not implemented?	
Waitaki	IFIM and related approaches used to define environmental flow regime	NIWA analyses used to help determine how much water potentially available for irrigation

Estimates Of Value Of Outcomes From Environmental Research For Canterbury Irrigation.

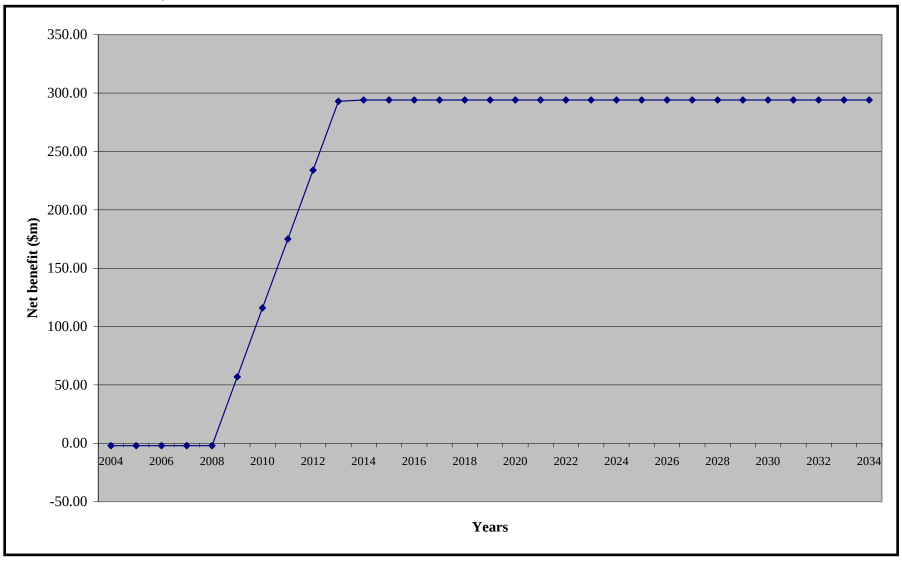
We know the value of irrigation at the farmgate for both Canterbury (see Table 2) and the nation. It seems fair to presume, given the history of irrigation scheme development in Canterbury (Tables 1, 3), that most of the existing schemes have not been greatly influenced by the Water Allocation: Protection of Instream Values

[1] IFIM, or Instream Flow Incremental Methodology is essentially the core tool used in most of the defining of environmental flows work.

research (perhaps with the exception of the Waimakariri-Ashley and Opuha schemes). Equally, it appears likely that little information was necessary from the database records for the original schemes (e.g., those developed in the 1930s and 1940s from the Rangitata and Opihi rivers) to have developed, i.e., a largely 'suck-it-and-see' approach was taken. However, it is becoming increasingly obvious that future schemes are going to rely on careful water management (optimisation) based on reliable information about climate, flows and instream needs. This view is perhaps reinforced by the constraints now being faced by irrigation developers in the face of river environmental flow regimes which are increasingly being based around Water Allocation research (see Table 3).

Much of the water resource availability (database) information and associated tools are now available as a result of FRST (or previous equivalents) funded research. The GDP benefit data in Table 1 can therefore be used in a 'rough' analysis of the future benefits to the region compared with the costs of the research (both historical and future), say over a 5 year implementation period (Figure 2). Clearly, albeit based solely on a very limited and narrow economic evaluation, there is an enormous economic potential to Canterbury and to New Zealand from this research.

Figure 2. – Net Benefit (GDP Minus Annualised Costs Of Research Of Irrigation Development At The Farm Gate In Canterbury) If The Proposed Schemes All Proceed As Planned, Given A Phase In Period Of 5-10 Years.



The projections assume 2003/04 levels of research will continue until the schemes are fully operational; for Water Allocation research 100% funding has been included until 2014 when it is reduced to 20% ongoing funding; for Databases we have modelled on the basis of 30% funding contributing to irrigation planning from 2004 onwards. The 'true' value of the research is the difference in net benefits/costs from the difference between irrigation without the knowledge and irrigation with. Only a proportion of the value of irrigation should be attributed to the research.

Implications And Insights

There are lag effects to research uptake, which seem largely politically driven, in terms of implementing tools from the Water Allocation: Protection of Instream Values research. However, as water resources increasingly come under pressure from competing uses it appears likely that these tools will be relied on more and more in decision making processes.

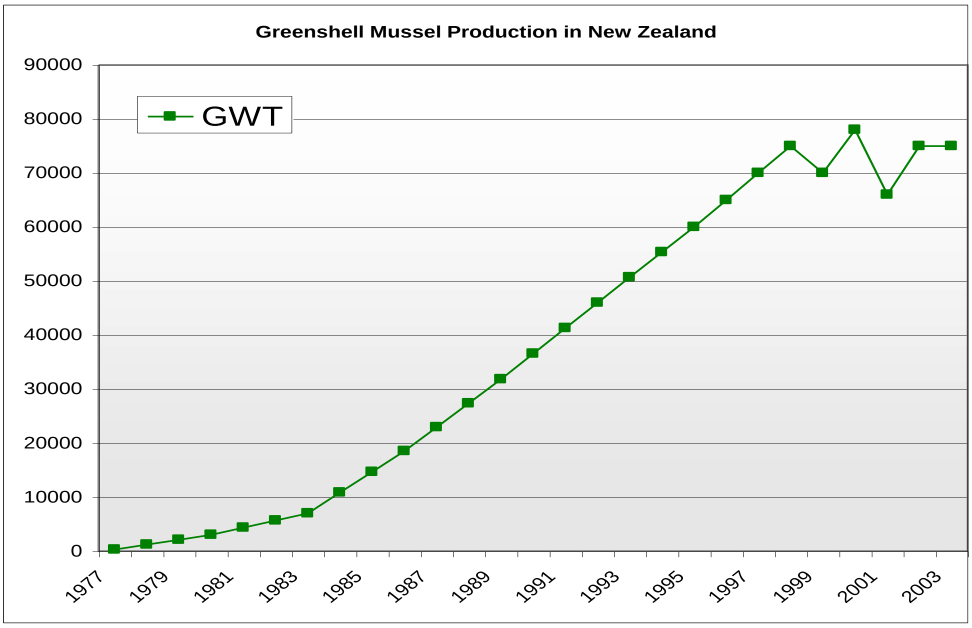
The few more recent irrigation schemes developed and those currently in the planning process are subject to increasing pressure as a result of the implementation of Water Allocation research derived management tools. Future schemes will require the tools that have been and continue to be developed by NIWA (and others in future) and because of competing demands from instream users they will require accurate information about river flows, reliability, etc. Planning for new schemes will be about certainty and this research is helping provide the tools necessary to achieve that goal. If the government, or other funding organisation, supports the range of existing community irrigation scheme proposals then it seems more than likely under current legislation that these tools will need to be used in decision making processes. Otherwise, it appears likely that the very powerful instream lobby groups will successfully challenge decisions in court, based around arguments that decision makers did not use the best available information, etc., or that a more precautionary approach should be taken in water management decision making. In this sense then, while the existing Water Allocation research appears to have had little influence on most of the present irrigation in Canterbury it is strongly influencing current planning and will continue to do so given the current focus on sustainable water resource development.

The Nationally Significant Database: Water Resources and Climate is equally important when debates about scarce resources are occurring. Increased certainty around issues of resource availability and planned developments are increasingly the focus of Council planning, developer planning and in Environment Court deliberations (KH, pers. obs.). Databases, including river flows, have contributed to the development of irrigation schemes in Canterbury, including the Opihi River flow augmentation scheme. Again, it is an absolute certainty that all future water resource development in Canterbury will require ongoing database information.

Environmental R,S&T And Marlborough Sounds Mussel Farming

Several new locations for growing mussels have developed in the last fifteen years including Golden Bay, Hauraki Gulf, Coromandel and Banks Peninsula. In the Marlborough Sounds there has been growth in the total area of mussel farms but no change in the number of bays farmed. The total farmed area reached 2500 hectares in 1998, with 1,840 hectares (74%) in Marlborough and 100 hectares in Nelson (4%). The total annual harvest in green-weight for the year ending March 1998 was 68,478 tonnes. For Marlborough these figures were 52,699 tonnes (76.9% of national output). Nelson farmed 2,400 tonnes (3.5% of national output). Figure 3 shows the growth in Greenshell™ mussel production since 1977. By 2002 the Greenshell™ mussel industry with 78,000 green-weight tonnes output contributed more than 70 percent of New Zealand’s marine farming tonnage of output. The mussels were harvested from around 4,700 hectares of marine farms employing around 2,000 people for farming and processing. Total sales were around $220 million in 2002, and export receipts were $185 million in 2002. Most of New Zealand’s Greenshell™ output (around 85 percent) is destined for the export market.

Figure 3. – Greenshell™ Mussel Production



The main driver of the growth in New Zealand aquaculture production and exports is demand for the Greenshell™ mussel products. This growth has slowed recently due to the downturn in the US economy, a weak Asian market, SARS and other world market factors. Greenshell™ mussels are not a high value product and the profit margins are typically small, a consequence of the national and international industry structure and the current world market.

The productivity of mussel farms unexpectedly sagged in 1997-98, in Marlborough Sounds and in Stewart Island. There was speculation over the cause of the productivity decline, including the possibility that aquaculture was exceeding the carrying capacity of the bays. Investigation to determine the explanation for the productivity decline was completed by NIWA's shellfish sustainability programme. It used findings developed in the NIWA Ocean Ecosystems programme in the Hauraki Gulf where similar ecosystem behaviour had been observed. The research identified that El Nino weather was effecting ecosystem behaviour and 'environmental forcing' is believed to provide the best explanation for the productivity sag (A.Ross, pers. comm. 06/05/04). With an explanation available for the productivity decline and other NIWA research showing that small existing mussel farms had only localised effects on the marine ecosystem, mussel farm investors had a scientific basis to support expansion of the industry.

Environmental RS&T Relevant To Mussel Farming.

Research programmes relevant to mussel farming have pursued two main themes: How can we understand the environment to help managers make aquaculture more productive; How does aquaculture effect the environment. NIWA has been the main recipient of PGSF/PGS&T funds for environmental research looking into the effects of mussel farming and influences upon mussel farming. Table 4 provides a summary of the funding received for this work.

The Cawthron Institute received some funds for these purposes. The Mussel Industry Council (MIC) and Cawthron used industry funds for conducting such research. John Willmer (SeaFIC pers. comm.) noted that most research in this area is driven by the MIC, the Aquaculture planning group at MFish as well as by Regional Councils. SeaFIC is not a research provider. Neville Smith (MFish pers. comm.) stated that MFish did not do a lot of environmental impact research. Any research would have only started recently, likely to be focused on the effects of increased mussel farming on local fish populations and not funded by PGSF/PGS&T. Daniel Lees (MFish pers. comm.) confirmed that MFish is not doing its own research but requires applicants to provide more information on cumulative effects of mussel farming since MFish considers current impact analysis as inadequate.

Table 4. – FRST Funding To NIWA For Aquaculture (in '000)

Programme Title	Contract	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02
Sustainability of cultured and enhanced fisheries	C01431	208							
Sustainability of cultured fisheries	C01504		187						
Ecosystem Dynamics in Estuaries (part)	C01517		125	125					
Sustainability of Cultured Shellfisheries	C01604			250	250				
Vertical Processes and Phytoplankton Dynamics in Coastal Inlets	C01630			145	269				
Sustainability of Coastal Ecosystems and Cultured Shellfisheries	C01604					644	680		
Sustainability and Enhancement of Cultured and Wild Shellfisheries	C01X0003							660	660
Total		208	312	520	519	644	680	660	660

The research projects identified begin as early as 1994. One major project is "Sustainability and enhancement of Coastal Ecosystems and Cultured Shellfisheries" conducted by NIWA and first initiated in 1994. It went through several name changes and has at least a couple of sub-projects, "Bivalve food supply…" and "Natural and anthropogenic change in coastal ecosystems". The "Sustainability" project partially uses a database created with the "Vertical Processes and Phytoplankton Dynamics in Coastal Inlets" project. A further big project "Ocean Ecosystems: Their contribution to New Zealand Marine productivity", also conducted by NIWA, does not have its primary focus on mussel farming, but its outputs feed into the findings of the "Sustainability" projects. Some of this research has been supported by industry input, either through monetary support or through FTE (data collection). There are active communication channels between the different research providers and end users. These support the furthering of the research as well as the implementation of the results.

The Cawthron Institute presently has two areas of research involving the mussel industry; mussel production systems and environmental interactions (impacts) of farming. The first programme is largely FRST-funded although there are significant contributions from industry. The second programme is funded from other sources (industry, stakeholders, regulators). The themes of this work are sustainability and carrying capacity of mussel farming, effects of mussel farms on the seafloor environment as well as effects of mussel farms on fishing and fishery resources.

This programme commenced in earnest around three years ago and is ongoing. More importantly, the work has been performed in response to direct demand from stakeholders and results of the work have been extensively used in resource consent hearings and in the Environment Court. The budget is of the order of many hundreds of thousands of dollars per year. It is also possible that some of this work duplicates PGSF work. Table 5 summarises annual investments in Environmental RS&T.

The MIC comments that the best outcomes from funding into environmental issues have been the development of their Environmental Management System (EMS) which was funded by the New Zealand MIC, the MfE Sustainable Management Fund, Marlborough District Council and Environment Waikato. The EMS (Environmental Policy) released in 1997 and the Environmental Code of Practice released 1999 are world leading and underpin the ability of the New Zealand mussel industry to be self managed, environmentally sustainable, internationally marketable.

Table 5. – Present Value Of Annual Investments In Environmental RS&T

	Actual value			**Present value**	
Year	**SUM p.a.**	**CPI adj**	**3%**	**6%**	**10%**
1995	$1,544,000	$1,830,719	$2,388,673	$3,092,962	$4,316,740
1996	$1,689,000	$1,946,555	$2,465,838	$3,102,513	$4,172,613
1997	$1,749,000	$1,964,751	$2,416,396	$2,954,259	$3,828,744
1998	$4,318,000	$4,811,733	$5,745,461	$6,825,536	$8,524,279
1999	$4,080,000	$4,528,352	$5,249,601	$6,059,956	$7,292,956
2000	$3,933,000	$4,343,502	$4,888,650	$5,483,571	$6,359,321
2001	$4,110,900	$4,366,357	$4,771,237	$5,200,402	$5,811,622
2002	$3,614,510	$3,770,630	$4,000,261	$4,236,680	$4,562,462
2003	$3,346,000	$3,397,995	$3,499,934	$3,601,874	$3,737,794
Total	$28,384,410	$30,960,594	$35,426,051	$40,557,752	$48,606,531

The information in Table 5 has to be interpreted with caution. The environmental RS&T includes the multi-million dollar projects focused on the ocean ecosystems and the sustainability research (both conducted by NIWA). Both of the research projects deal with mussel farming or impact mussel farming, but aquaculture activity is only one part of the research. The other research included in Table 5 is also not only regarding mussel farming. As sub-projects feed off each other and transfer results, it is difficult to determine how much of the above research directly looks at the environmental impact of mussel farming.

A key judgement is that growth of the mussel industry would have plateaued or even declined if there had not been knowledge about the influences on mussel farm productivity provided by environmental RS&T. Increasing public concern about the possible impact of mussel farming on the marine environment could have halted growth of the industry in the Marlborough Sounds. Production could have stagnated on 1996 hectares and tonnages.

An economic outcome of the research is the knowledge about factors affecting mussel farm productivity provided investors with enough certainty to continue investing during the 1990’s and expand Greenshell™ mussel production. The research results helped strategic decision making for economically and environmentally sustainable growth of the industry. We have modelled the production from the industry and compared the Present Value of actual output to the Present Value of output if production did not increase above its 1996 level. Table 6 presents the results of that modelling. Three discount rates (three, six and ten percent) are used to test the sensitivity of the PV to variation in that factor. Table 7 illustrates that at each discount rate the PV of loss in production and earnings over a eight year period is very large.

These possible foregone production and earnings Present Values must be treated with considerable caution as there is no way to check if the counterfactual we have modelled would have occurred in the absence of the environmental research. Further, the production and earnings PV that did occur since 1996 were achieved after major investments in production systems, harvesting, processing and marketing. Finally the foregone economic surpluses from production (rather than gross earnings) since 1996 would provide a more accurate measure of the net benefits obtained as a result of the environmental research.

Table 6. – PV Of Output Foregone If Production Stable At 1996 Level. 2004 $ M.

PV (May 04)	1996	1997	1998	1999	2000	2001	2002	2003	May 04 sum
Discount rate 3%									
GWT value m$, adj EPI	0	32	53	31	97	14	66	74	***366***
Discount rate 6%									
GWT value m$, adj EPI	0	39	62	36	109	15	69	76	***407***
Discount rate 10%									
GWT value m$, adj EPI	0	51	78	43	126	17	75	79	***469***
Underlying data:									
Export prices/t	3.641	3.097	3.566	4.024	6.057	6.991	6.422	6.422	
GWT produced	63750	71250	75000	70000	78000	66000	75000	75000	
netGWT value m$	0	23	40	25	86	16	72	72	
netGWT value m$ EPIadj	0	26	44	27	86	13	62	72	

How does the research cost compare to the possible benefits that we have estimated? As mentioned above, the level of FRST investments into environmental RS&T looking at marine mussel farming is hard to determine. However, Table 7 shows that even if the full amount of FRST environmental RS&T were taken into account, the benefits would be greater than the costs of this research. This assumes that the industry would not have been able to grow since 1996 without the support from FRST investments. It should be noted that the industry itself had to invest considerable amounts into contracting research such that it would be allowed to produce or expand. FRST has also invested at least a similar amount of money into production enhancing research that it has invested into environmental research.

Table 7. – PV Of Environmental RS&T And Possible Forgone Mussel Output

Discount rate	3%	6%	10%
FRST investments m$	35	41	49
netGWT value m$, adjEPI	366	407	469
% FRST/GWT	*9.67%*	*9.96%*	*10.36%*
m $ FOB	305	331	369
% FRST/FOB	*11.63%*	*12.26%*	*13.18%*
m $ FOB, adjEPI	234	257	290
% FRST/adj FOB	*15.13%*	*15.79%*	*16.76%*

FRST investments calculated from 1994/95 onwards

Industry developments calculated from 1996 onwards

Conclusions

Overall then it is clear the environmental research in these two case studies is benefiting New Zealand in multiple ways. Instream users, including biodiversity conservation interests, can be increasingly reassured their needs will be met in water management decision-making. And, irrigation interests can plan for management more satisfied that instream needs have been clearly and substantively defined, and that flow and climate information is as certain as the databases and their interpretation can provide for. Mussel farmers are being provided knowledge that demonstrates mussel farming at current levels is environmentally sustainable. Regional governments have information that allows them to judge the merit of resource consents for further mussel farm ventures.

Some general conclusions can also be drawn. RS&T contributes by increasing our knowledge about selected components of ‘the environment.’ The additional knowledge reduces the level of uncertainty that investors, government (local regional, national) and individuals face and enables then to make better informed decisions. In some cases the knowledge gained has unexpected value that may not be recognised for some time after the research has occurred. This provides an argument for long-term data collection in cases such as river flow levels, meteorological data, indicators of the state of land, air and water.

Investors, individuals and government choose when to make use of the new information and in some of the case studies the lag between information availability and consequent action has been two or more decades. Political decisions, including inaction, often plays a major role determining when benefits are derived from research. Research that results in new knowledge may reduce the room for politicians to prevaricate and delay acting on research. Capturing benefits from RS&T very often involves further investments including constructing irrigation races and spray systems, new mussel farms. Once these additional investments have occurred there will be varying length time lags before the additional benefits reach their maxima.

The case studies provide some insights into the magnitude of the benefits from their specific RS&T. The case studies provide incomplete basis for evaluation of the Benefit:Cost ratio for RS&T as they do not include estimates of the additional investments required to realise the potential benefits. In all five case studies the benefits from the RS&T (or a substantial percentage of them) will occur in the future.

The case studies reported are not claimed to be representative of all New Zealand environmental RS&T. We do not argue that additional investments in environmental RS&T would achieve similar benefit:cost ratio to these case studies.

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