ABALONE AQUACULTURE SUBPROGRAM

FRDC SUBPROGRAM PUBLICATION

Abalone Aquaculture Subprogram
Project No. 2003/202

FISHERIES RESEARCH & DEVELOPMENT CORPORATION

Abalone Aquaculture Subprogram: Facilitation, administration and promotion

Project No. 2003/202

Dr. Ann Fleming

ABALONE AQUACULTURE SUBPROGRAM

Australian Government

Fisheries Research and Development Corporation

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OBJECTIVES:

Operational objective

1. Development and implementation of strategic plans and the facilitation of research and extension to assist the development of abalone aquaculture in Australia.

2. Coordination of a wide range of discipline-based (i.e. nutrition, health, genetics, husbandry) research projects for the two commercially valuable species of abalone.

3. Facilitate the delivery of outcomes from the Abalone Aquaculture Subprogram in the form of annual workshops, workshop proceedings, the subprogram's website, the subprogram's newsletter, trade journal articles, final reports, and scientific publications

4. Provide a single point of contact for abalone aquaculture research in Australia.

5. Facilitate the functions of an Abalone Aquaculture Steering Committee to ensure ongoing research programs have a high degree of industry relevance and focus

6. Undertake an independent review of the subprogram in partnership with FRDC. The results to be used as input into the strategic planning process and subprogram procedures.

7. To continue the abalone selective breeding program.

NON TECHNICAL SUMMARY

OUTCOMES ACHIEVED

In an external, independent review of the performance of the subprogram over the past 6-7 years, the industry strongly endorsed the FRDC in managing the subprogram. This endorsement included the selection of R&D topics of high strategic and commercial importance to industry, use of appropriate research providers and appropriate apportionment of available funds across the 12 projects. Respondents also endorsed subprogram management and research providers in the shared responsibilities of establishing and maintaining generally adequate to high standards of communication, collaboration and consultation with industry.

Research relevance and acceptance

FRDC has been recognised for their leadership in facilitating the development of abalone aquaculture in Australia as it has created one of the few truly national programs for developing an aquaculture species. Since its inception in 1993 the Abalone Aquaculture Subprogram (AAS) has ensured that the FRDC's investment in R&D, in partnership with the industry, has resulted in a significant and economically viable industry. The collaborative relationship with industry has led to highly commercially focused research outputs that responded to the changing R&D needs of the industry as it matured. The AAS has achieved this by implementing operational processes that ensure industry members themselves identify R&D needs and, through the Steering Committee, subsequently manage research projects. The benefits arising from this have been significant as measured by: quality of science, industry planning of R&D, partnership approach to R&D execution, comprehensive extension program using novel media formats (e.g., interactive CD ROMs) and a high level of adoption. The AAS has also fostered the development of human capital within the Australian research community through actively seeking to link its R&D with postgraduate students, and to promote first-hand industry experience by conducting research and extension workshop on commercial farms where feasible.

The subprogram has achieved a high degree of research coordination between states and an extensive communication strategy to ensure service delivery to the industry. The subprogram has added value to the FRDC's research investment by managing its project portfolio in this way. None of this would have been possible without an independent subprogram leader and a highly responsive Steering Committee that is strongly represented by industry members across southern Australia.

Research efficiency and output

The presence of a coordination component within the AAS has resulted in savings in the operation of new and existing projects far exceeding $500,000. This has been achieved by improving project adoption, ensuring projects are appropriately costed, coordinated travel and workshop budgets combined with more efficient use of limited research funds.

In recognition by the industry of the subprogram's value, the recently formed national peak body, the Australian Abalone Growers Association, will seek to continue an R&D planning and management body as part of its operational processes. It is anticipated that AAGA will work with FRDC to develop an alternative model, such as an R&D subcommittee under AAGA, which may be co-funded by both FRDC and AAGA

During the past three years, the FRDC funded an additional two projects within the subprogram. Of the eleven active projects managed by the subprogram from 2003 – 2006, all due final reports and extension materials have been submitted.

Knowledge, processes and technology developed by the subprogram

Following are some of the key outputs during the current project 2003/202 over the past 3 years. These outputs are sampled from across the chain of supply to show where the subprogram has been effective in delivering outcomes.

Nutrition: Extension materials to enable access to diet research
It was recognised in recent years that the results of the research work on nutrition and diet formulation was somewhat disperse, and not in a form that could be readily taken up by feed formulators and farmers. As a result the Nutrition Subprogram was contracted by the Abalone Aquaculture Subprogram to develop a simple abalone diet formulation software, using Microsoft's excel, that brings together all the data produced in Australia and other relevant data from overseas.

Husbandry and its effect on immune health
In project 2002/200 the industry was concerned that the ingredients in feeds were causing summer mortality during high temperature peaks due to undigested feeds fermenting in the gut and acting as a site for bacterial proliferation. This project showed that lab animals fed commercial diets were capable of surviving high summer temperatures. It was concluded that farmed animals were more susceptible due to other stresses (such as stocking density, poor water quality, handling and anaesthetics) impacting on their immune health. Consequently the project redirected its objectives to produce a manual on water quality, providing farmers with known tolerances by abalone for various parameters, how these impact on health, and how to conduct a monitoring program of critical parameters to assess husbandry management practices on farm.

Health
In 2002 funding was approved to undertake a survey of Australian abalone diseases along the southern coastline of Australia (2002/201). The resultant extensive database has provided vet pathologists with a comprehensive histological atlas of abalone disease pathology and is currently being used by them to facilitate the development and scope of state-based industry-funded health surveillance programs.

There has been a strong shift in focus from performance to health over recent years. Increasingly, the industry is looking at how health might be improved to enable stock to better cope with intensive farming practices. It is recognised that intensive farming exposes the stock to stresses resulting in a multitude of physiological stress responses, some of which compromises the animal's ability to cope with additional stresses (such as summer temperatures) and some compromise the immune system leading to a reduced ability to fight infections, such as *Vibrio*. Consequently the subprogram is currently managing a project that aims to gain some fundamental understanding of how the immune system responds to stress in abalone (2004/203) and to identify immune parameters that might lead eventually to a stress test for assessing the health status of stock.

Genetics
The projects funded from 2000 to 2001 (2000/201) and 2001 to 2002 (2001/254) on selective breeding of abalone on-farm provided a structured genetic improvement program that had a high degree of industry involvement and ownership. These projects provided a significant entry to the development of a comprehensive selective breeding program for the future.

The breeding program had a major setback in early 2006 with the loss of the majority of its families through the viral outbreak in Victoria. This, and the loss of the capability of farms to re-enter the program for some time, has led to the collapse of the Victorian initiative for the time being.

Prior to the viral outbreak, the Victorian industry was working to increase their investment in the breeding program by moving towards a phase of full commitment. The subprogram was facilitating their move to put in place a strategic breeding plan and business structure that would ensure a high

number of families established each year to meet the scientific requirements of a good breeding program. This methodology of distributing share equally between participants and allowed for cooperative work on research was a major breakthrough in overcoming the issues of how to share IP between industry participants.

Despite the setback, a new initiative in selective breeding has developed within the Tasmanian industry. They recognise that due to their state's greater restrictions on stock imports, they were unlikely to gain access to selective bred stock from the mainland. Thus industry members sought to form a partnership with CSIRO and their Food for Futures program to develop their own state-based breeding program. One Victorian farm, Great Southern Waters, is also a partner in the program, accessing breeding advice from CSIRO.

Biotechnology
The 2000/202 project on sperm cryopreservation produced a how-to manual for industry. This was published by the subprogram and sent to every farmer in late 2005. This offers the industry the ability to cross specific individuals for selective breeding purposes and allows greater predictability and control of the hatchery process.

The recently completed project (2002/202) on the development of genetic markers for various traits affecting profitability in the industry, such as growth rate and meat to shell weight ratio, has provided fundamental knowledge and a database of marker occurrence in abalone that is critical information for the downstream applicability of markers in breeding selection.

Nursery systems
In 2003 funding was approved (2003/203) to identify alternative algal species or nursery strategies that would ensure adequate supply of feed for the latter phase of nursery production. This work highlighted the need to balance suitable algal feeds with the economics of culturing and delivering them on plates. Cost/benefit analysis of the economic performance of juveniles raised on nursery plate systems using diatoms compared to weaner systems using manufactured feeds suggests that animals be moved into a weaner tank system once they reach 7 mm. Indeed, farmers are now developing such techniques themselves, some even using smaller weaner tanks as a transitional phase before growout.

Extension of research

Annual Workshops: The subprogram has organised four annual workshops between 2003-2006. The attendance rate at these meetings has been exceptionally high, with 80-90% of the industry attending each year.

Proceedings: Workshop proceedings have been produced from each of the 4 workshops. These are distributed to workshop delegates and are subsequently available through the subprogram.

Manuals: Manuals released during the last three years:
- *Protocol for the cryopreservation of abalone sperm*
- *Manual on the effects and management of water quality on abalone farms*
- *Practical nutrition for abalone aquaculture farmers*

CD ROMs: CD-ROMs released during the last three years:
- *NOMAD: Abalone feed formulation software*
- *Diseases of Australian abalone (Due March 2007)*
- *Abalone Nursery Manual: Algal culture methods for commercial abalone nurseries: Updated (Due March 2007).*

Website: The subprogram launched its own website at the 9th Annual Workshop in July 2002. It has been well received both within the research and industry sectors. The address is: www.frdc.com.au/research/programs/aas/

Human Capital Development

PhD: 10; Masters: 2; Honours: 4

Industry Training

As part of the extension strategy of the nursery management and algal culture project (2003/203), industry participants of the 2005 annual workshop attended a 0.5-day training workshop on *Ulvella* culture techniques.

As part of the cryopreservation of sperm project (2000/202), industry participants of the 2003 annual workshop attended a practical demonstration of cryopreservation techniques.

As part of the selective breeding project (2001/254), the PI visited participating farms to provide a practical demonstration of the techniques for spawning, fertilizing and settling selectively bred stocks.

Subprogram management and operating procedures

Subprogram Leader
The role of the subprogram leader is to ensure that abalone aquaculture R&D is managed and coordinated to make the most efficient use of available resources and to integrate industry and research providers by providing a productive, cooperative, national research framework. The leader must ensure that the AAS addresses industry R&D requirements and that effective and efficient communication is maintained.

Steering Committee
To ensure that research conducted within the subprogram is relevant and meets the current and future R&D needs of the industry, a Steering Committee is supported to: provide industry feedback and views; review existing research based on FRDC contractual obligations; prioritise new proposals and provide a priority list for other agencies; ensure outcomes are commercially focused; coordinate industry and research provider involvement - optimum use of resources; facilitate extension and technology transfer.

Operational Procedures

Strategic Planning
Strategic planning for the AAS is based on outcomes from the existing research program and ongoing consultation between the subprogram leader and members of industry and researchers in Australia. The strategic plan is maintained and updated biennially. The strategic planning process identifies those factors that represent restrictions to the growth of abalone aquaculture in each state (e.g. health, nutrition), and then utilised a relative ranking score to prioritise national priorities across the various states.

Development of new research proposals
New research proposals are developed through the use of facilitated strategic planning meetings. Using priorities published in the AAS Strategic Plan, the subprogram leader convenes meetings with the steering committee and relevant researchers and research institutions to define objectives,

manage the budget, identify the most suitable research providers by actively commissioning R&D, promote collaboration and ensure commercial focus.

Research Management
The subprogram leader works to provide a productive, cooperative, national research framework for all Australian abalone aquaculture researchers through a range of activities that increase collaboration between researchers and industry, provides a focus of knowledge, attract other resources to draw on, maintain a high level of national cooperation and openness between industry members and between industry and researchers.

R&D Outcomes Management
To ensure all planned research is industry focused and the science is of a high standard, the leader manages a project reporting system that ensures researchers submit a comprehensive experimental preschedules to the steering committee prior to the commencement of all experiments. The steering committee may provide direction to the researcher in relation to changes to the experimental plan.

A major function of the steering committee is to ensure all progress within projects has met contracted milestones and ensure that the research program is making a valuable contribution towards the achievement of the subprogram objectives. The steering committee may make recommendations to the FRDC Board in relation to potential changes to the objectives of the research program, or instances where project progress is unsatisfactory.

External review of subprogram performance
An external review of the performance of the subprogram conducted in early 2006 reported that the industry strongly endorsed the FRDC in managing the subprogram. This endorsement included the selection of R&D topics of high strategic and commercial importance to industry, use of appropriate research providers and appropriate apportionment of available funds across the 12 projects reviewed. Respondents also endorsed subprogram management and research providers in the shared responsibilities of establishing and maintaining generally adequate to high standards of communication, collaboration and consultation with industry.

KEYWORDS: Abalone, aquaculture, industry, subprogram, *Haliotis rubra, Haliotis laevigata*.

BACKGROUND

On occasion, the FRDC recognises that a planned R&D outcome could be achieved more successfully if a number of related projects were managed more intensively by employing higher levels of coordination, integration and communication than for individual projects. In that event the FRDC, either on its own initiative or at the request of a stakeholder group, establishes a managed subprogram. The FRDC established the Abalone Aquaculture Subprogram in July 1993 following consultation with industry and scientists.

The Subprogram coordination project no. 2003/202 commenced in July 2003 and was due to finish 30th September 2006. The subprogram has run for 13 years and integrates almost all research on abalone research in Australia, either directly (FRDC funded projects) or by forming affiliations with projects funded by other sources.

Subprogram mission and content

The subprogram was established with the following objective or "mission":

"To provide excellent, timely and responsive research to the Australian abalone aquaculture industry so they can be profitable and internationally competitive, and can pursue ecologically sustainable development".

World Status

The aquaculture industry has grown in many countries worldwide, particularly in Taiwan and China (FAO 2000a,b; P. Cook, pers. comm.) (Table 1, Fig. 1). In 2002 over 8,300 tonnes of farmed abalone was produced (assuming South Africa produces at least 450 tonnes), equating to three quarters of the wild caught production in that year (10,385 tonne).

Table 1
World cultured abalone production: short term trends 1994 – 2004 (t)

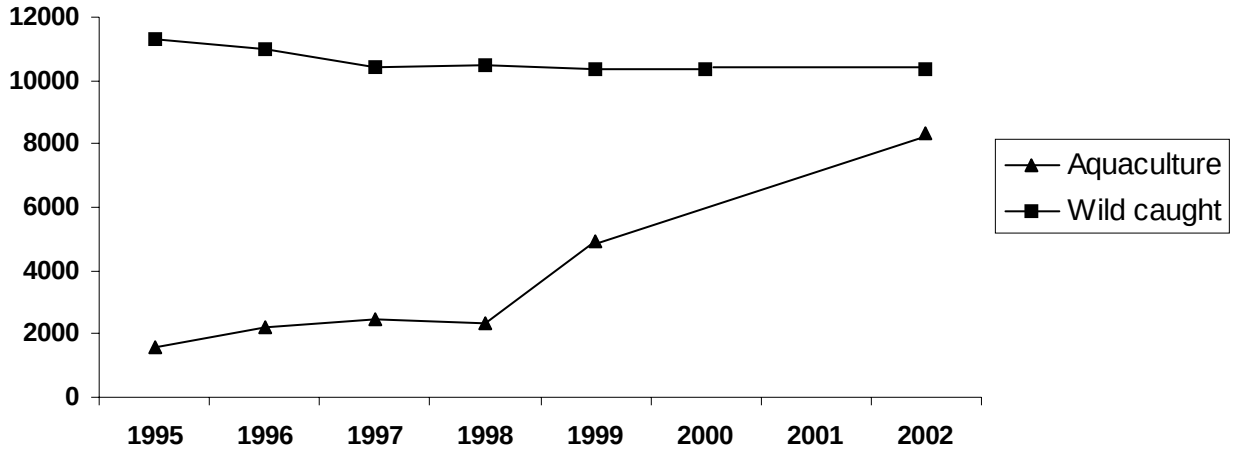
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Chile	.	.	8	1	1	48	66	73	113	81	247
China	.	.	.	.	.	.	.	.	.	11,206	15,446
Iceland	.	-	-	-	1	8	15	23	24	6	6
Korea, Republic of	.	-	84	.	.	.	20	29	85	1,065	1,260
Mexico	.	<0.5	1	<0.5	4	2	9	16	25	25	25
New Zealand	.	.	.	.	.	.	.	.	.	2	<0.5
Taiwan Province of China	1048	1582	1814	2270	2312	1799	2458	2496	2325	1084	1300
United States of America	.	-	265	265	.	.	.	.	.	.	262
Australia	<0.5	<0.5	<0.5	.	.	21	40	58	47	83	207
South Africa	1	1	7	10	22	27	100	220	320	515	760
Channel Islands	.	-	-	-	-	1	2	2	1	.	.
TOTALS	**1049**	**1583**	**2179**	**2546**	**2340**	**1906**	**2710**	**2917**	**2940**	**14067**	**19513**

Source: FAO 2004

Fig. 1

Comparison of volume produced by aquaculture and wild caught (t)

Source: Wild caught data: FAO 2000a,b; Farmed data: as for Table 1



Despite the volume of product farmed in Taiwan and China, the prospect for Australian abalone producers is considered bright. The question from a marketing perspective is whether we can assess the current world market's demand for abalone and calculate a shortfall in supply that could be met through aquaculture. The answer is probably no, as demand is so fluid and dependent on so many socially, economically, environmentally and politically uncontrollable factors. However, the past world peak demand of the 1960's and the growing wealth of many Asian countries with their continued preference for seafood points to an optimistic future for abalone suppliers. In particular the opportunities in China are large, demonstrated by the 94% increase in seafood consumption over the past four years to an annual 24kg/ person (Brown and Connell 2001). A comparison of this figure to the 60 kg/person consumed by Hong Kong people and the 70 kg/person consumed by the Japanese suggests the potential for growth in the Chinese market. In addition, demand is likely to increase in a number of non-traditional countries as product becomes more accessible. In particular, Europe is seen to offer great potential in this respect.

The capacity for world supply of abalone aquacultured product is difficult to gauge. Some Asian countries, such as China and Taiwan, have the capacity to produce large volumes of its own, preferred species. Australia will not compete directly with this product but will compete with other imported less-preferred species, such as South African product, for a market share. South Africa is beginning to establish a foothold in the market place and will likely be a significant competitor against Australian aquacultured product in the next few years. Its main advantage is its capacity to produce abalone cheaply due to low labour, cheap feed and favourable exchange rates. Nevertheless, for many social, political, environmental and health reasons Australian producers have a competitive advantage over their international counterparts that put then in a position to access and hold niche markets and demand premium prices. For example,

- Australia is relatively free of infectious diseases that limit or prevent aquaculture in other countries. Australia has in place quarantine procedures to help maintain this disease free status.
- Regular environmental monitoring by industry and government largely ensures that aquaculture production in Australia is carried out in an ecologically sustainable manner and in a clean and green environment.

- Australian product, in general, has a reputation overseas of coming from a "clean and green" environment and being of a high quality and safe to eat. The opportunity is there for Australian producers to exploit this perception.
- The capacity to produce 'out of season' with northern hemisphere producers and wild fisheries offers Australian producers another opportunity to gain a foothold in niche markets.

Australian status of abalone aquaculture

Two species of abalone are farmed in Australia; the greenlip, *Haliotis laevigata* and the blacklip, *H. rubra.* The hybrid of these species is beginning to be farmed extensively in Tasmania and Victoria due to its superior meat weight.

Tasmania, South Australia and Victoria have well-established industries; Victoria's first farm was established in 1995, South Australia's in 1993, and Tasmania's in 1987. Today there are five land-based and two sea-based farm in South Australia, five land-based and one sea-based farm in Victoria, six land-based and two sea-based farms in Tasmania (Table 2). The industry in Western Australia began later than the other states and has two land-based facilities in Albany. A land-based farm will begin construction in the Port Stephens region, NSW in 2007. Currently Australia has a total of 18 land-based farms and 5 sea-based farms.

Table 2

Number of facilities by state

	No. of hatcheries	On-shore (growout & hatchery)	On-shore (growout only)	On-shore (hatchery only)	Off-shore
SA	5	5	0	1	2
VIC	5	4	1	1	1
TAS	4	3	3	0	2
WA	2	2	0	0	0
NSW	0*	0*	0	0	0
TOTAL	**16**	**14**	**4**	**2**	**5**

* construction for a new farm in NSW will begin in 2007.

The Australian abalone aquaculture industry can now be regarded as an emerging sector with a total commercial production of approximately 370 tonne in 2004/05, worth about $15.3 million (Table 3). This significant leap from previous years marks the beginning of full production capacity for some farms. Production is expected to grow at 20% per year as more farms reach commercial production levels and others increase their production targets. Expected production in 2006/07 is approximately 550 tonne, worth $24.5m.

Table 3

Production data for farmed abalone by state

	1997/98		1998/99		1999/2000		2000/01		2001/02		2002/03		2003/4		2004/5	
	Pdn '000kg	*Value $'000'000*	*Pdn '000kg*	*Value $'000'000*	*Pdn '000kg*	*Value $'000'000*	*Pdn '000kg*	*Value $'000'000*	*Pdn '000kg*	*Value $'000'000*	*Pdn '000kg*	*Value $'000'000*	*Pdn '000kg*	*Value $'000'000*	*Pdn '000kg*	*Value $'000'000*
SA	n/a	n/a	21.0	0.9	40.0	2.0	53.0	2.6	34.0	1.9	59.0	3.1	105.0	4.2	160	6.4
VIC	0.0	0.0	0.0	0.0	id	-	5.0	0.2	13.0	0.6	24.0	1.0	102.0	36	120	5.0
TAS	3.0	0.1	3.9	0.2	3.8	0.2	9.0	0.5	19.5	0.9	16.9	0.7	42.8	2.7	88.1	3.5
WA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	10.0	0.4
NSW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	**3**	**0.1**	**29**	**1.0**	**50**	**2.2**	**68**	**3.3**	**66.5**	**3.4**	**99.9**	**4.7**	**249.8**	**10.5**	**368.1**	**15.3**

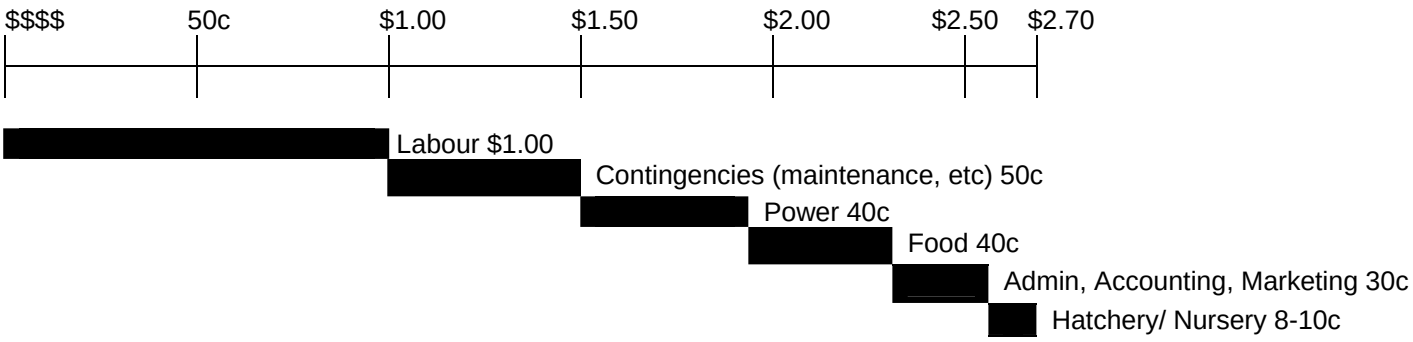
In recent years many of the larger farms have undergone a consolidation phase where they have established the long-term viability of their production systems and, in some cases, converted to new, recently developed technology or alternative abalone species. This has meant that the growth of the industry was slower than predicted in the earlier business plans and that investors have had to sustain a longer period before they see a financial return. However, with the widespread acknowledgement that the technological issues have been resolved and a transition within the industry from biologists managing farms to experienced farm mangers of intensive farming systems, the expected increase in production predicted last year has been realised. What has not been realised is the expected increase in investor confidence for new ventures as a result of a number of model farms becoming financially successful.

Where R&D has been invested in the past 13 years

Over the past 13 years the industry has continued to focus its R&D objectives within areas of high production cost. Figure 3 presents a rough breakdown of the costs associated with growing an animal to a market size of 80mm. The growout phase (10mm to 80mm) poses the greatest cost for farmers due to the high cost of feed, labour and electricity. In the early days of the industry the estimated growout period was about 4 to 4.5 years. Since then farmers have continued to seek to reduce the time for animals to reach market size through improvements in feed, system design, environmental conditions and, in more recent years, through genetic improvement. This has resulted in a significant reduction in production time down to 3.5 years and is expected to further decrease as genetic improvements are applied. This intense focus on the cost of production is highlighted in Figure 4, which outlines the relative amount of FRDC funds spent on each stage of production from 1993 to 2006 (hatchery, nursery and growout and on health, food quality/safety and R&D management). Approximately 44% of funds have been invested in the growout phase compared to only 28% in the juveniles phase and 14 % in the hatchery phase, reflecting the areas where R&D offers the greatest potential for commercial benefit.

Fig. 3

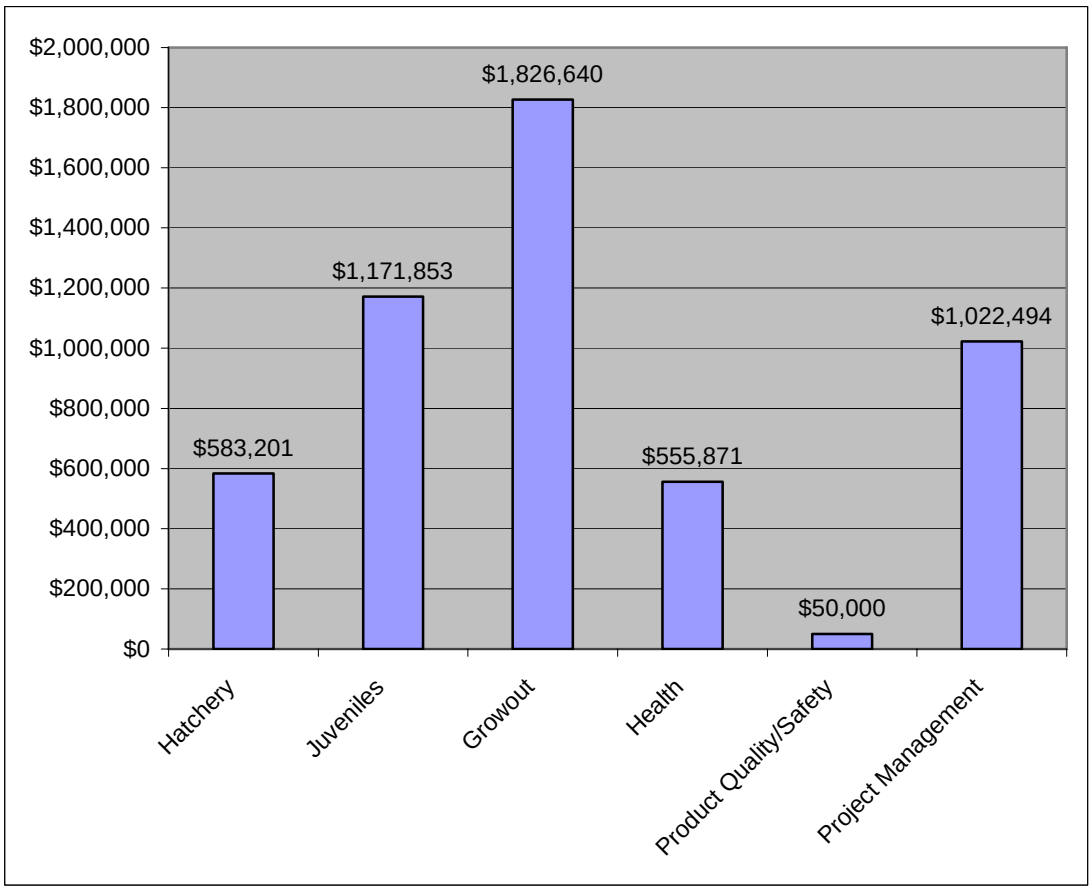
The cost of producing an 80mm animal*



*from Morrison, pers. comm.

Fig. 4

Breakup of R&D spending in abalone aquaculture 1993 - 2006 (FRDC contribution only)



The main issues confronting the industry today

Formation of a cooperative marketing group

Once production technologies were largely established and proven by the early 2000s and some farms approached their production targets, the industry began to turn their attention to issues relating to the business environment in which they operated. A significant issue faced by the industry was that of marketing and maximising product value. Many farms selling product in the early 2000s directly to Asian markets were experiencing difficultly in holding their price in the face of competing farms either within their state or interstate. Another problem occurred when some farms dumped small product onto the market place. This occurred when the farm experienced cash flow crises and/or mass mortalities during high summer temperatures. This dumping of product gave the Australian market a bad reputation that led to a weakening of trust between buyer and seller. In 2004 a group of five farmers started a cooperative marketing group called Ausab. AusAb, which aims to operate from a national perspective and sell under the one initiative so ensuring volume, consistency of supply and product quality.. Today it continues to attract new members.

Development of a peak body and voluntary R&D contribution

During 2003 the industry held a number of discussions at the national level on the need to form a national peak body that would address a range of issues that require national agreement and commitment. In June 2004 the national growers association (Australian Abalone Growers Association) was registered. AAGA held its second AGM and elected it second committee at the 13th workshop in late August 2006.

During 2005/06 AAGA collected $43,500 in voluntary R&D contribution via an additional fee on feed purchased. This represents about 70% of total industry capacity. At the 2006 AGM members agreed to alter the current system of calculating voluntary contribution, where members pay a $5,000 joining fee to cover operational expenses ($200 for corporate members) and a $0.05c/kg voluntary contribution attached to food purchase.

The new system will ask for $1,000 subs from farms that produce 25 tonnes or less and a voluntary contribution of $0.07c/kg for farms that produce more than 25 tonnes. In addition, the total amount a farm contributes to R&D will be capped once it purchases 150 tonne of feed or more. It is hoped that these changes will attract more members to join AAGA and contribute to R&D investment.

AAGA uses the funds received at its discretion but, generally, subscriptions fund administration, NAC and Seafood Experiences Australia membership, and the voluntary contribution is sent to the FRDC to match these funds for R&D investment.

AAGA addresses operational issues under the following portfolios:

- R & D
- Promotion to Industry, Public, Govt
- Generic Marketing
- Regulatory
- Communications
- Collaboration including Annual General Workshop and Meeting

In time AAGA will seek an Executive Officer who will progress these operational issues. Until then, the committee will address priority tasks. AAGA has joined the National Aquaculture Council (NAC). It is proposed that the Executive Director of NAC will represent AAGA where possible, particularly in relation to many of the industry's regulatory issues.

Once through the initial consolidation phase, the association will seek to take advantage of government opportunities for investment. The association recognises the potential business opportunity it now has to maximise government investment in the sector, particularly through leverage opportunities with state research and commonwealth agencies. AAGA recognises that if FRDC is to continue to invest in the sector at the level it has in the past, they must present a good business model that maximises alternative funding sources and forms strategic partnerships with key organisations. The recently agreed MOU with FRDC to commit to a voluntary contribution provides a positive message that the industry is keen to form long term partnerships that offer business opportunities.

AAGA to take over R&D planning and management

At the 2005 annual workshop, the FRDC director indicated to industry members that the subprogram would not be funded in its current form after September 2006. It was anticipated that the Australian Abalone Growers Association (AAGA), would take over all R&D operations after this time. During 2005/06 AAGA worked informally with the subprogram to decide on current R&D priorities and project submissions.

During February to April 2006 the subprogram underwent an independent review of its performance and within the recommendations to the director of FRDC was that a further period of handing over of the role of R&D management was required in order to maintain the skilled capacity for R&D planning and management that has been built up over the past 13 years by the Abalone Aquaculture Subprogram. It was recognised by the reviewer that the technical expertise of the R&D manager in facilitating the committee to make *informed* decision regarding strategic planning, project development and research management is a key component in ensuring the highest commercial return to the industry through investment by the FRDC. As a consequence the director extended the funding for the current coordination project 2003/202 until December 2007. After this time AAGA will work with FRDC to develop an alternative model, such as an R&D subcommittee under AAGA, that may be co-funded by both FRDC and AAGA.

Industry member of the CRC for Seafood

AAGA was successful in becoming an industry partner to the CRC for Seafood. It has agreed to contribute $20,000 pa into R&D over the next 7 years. This amounts to $1 million plus for industry R&D investment.

New company offers more feed options to the industry

In June 2006 Skretting Australia announced the release of their abalone feed, Halo; the only extruded feed on offer to the industry. This news was well received by farmers some of whom feel they do not have a workable relationship with the existing two companies. Skretting state they are keen to work closely with the industry developing and testing new products over the next few years and providing information on feed content and specifications. The cost of the feed comes in just below that of current feeds.

Main issues/activities of the industry that were facilitated by the subprogram: 2003 - 2006

In the early years of the industry's development the most significant obstacle to achieving a viable industry was the problems associated with efficient, affordable and reliable production technology, in particular tank technology and suitable feeds. Thus the R&D invested in the industry primarily focused on improving production efficiency through nutrition/feed development and technology systems/husbandry management.

The shift in focus on genetics and health that occurred during the 2000-2006 reflects the industry's continued push to target significant and quantum leaps in production improvement, but at the same time being aware of the need to properly manage the risks of disease. Selective breeding was seen as an opportunity to considerably reduce the time of production. The other genetic projects managed by the subprogram in the past; cryopreservation of sperm, genetic markers and broodstock conditioning, can be regarded as tools to aid the breeding program.

In the final report of 2000/200 it was stated that it is only a matter of time before the Australian industry experienced disease problems that will lead to ongoing losses, similar to that experienced in other countries. At that time farmers continually recognised the need to implement sound health surveillance systems to routinely monitor the health status of stocks. The disease survey project aimed to survey abalone diseases across southern Australia and was seen as the first step towards the development of a health surveillance system for the industry. But lack of suitable vet pathologists, farmers' unwillingness to fund a health program themselves and lack of agreement on how to structure the program meant that progress was stalled. It was not until the outbreak of the abalone virus in Victoria that health monitoring programs were put back on the top of the agenda.

The following discussion within various research areas outlines the core activities of the subprogram during 2003 – 2006. The summary serves to provide an overview of how the subprogram sought to become involved in facilitating progress in various areas that the industry saw important to their development.

Fig. 5
The slab tank in operation at SA Seafoods

Selective breeding

At the commencement of the subprogram project 2003/202 the selective breeding program had been in operation for 3 years. The first project (2000/201) was an 18 month pilot trial to test the viability of establishing families on-farm and funded a single spawning season to establish families. The second project (2001/254) funded the second and third cycle of spawnings to establish families. These projects provided a significant entry to the development of a comprehensive selective breeding program. However, in 2003 the FRDC board rejected continuation of funding due to

concerns that there was no clear indication industry had the capacity to support a selective breeding program and that industry had not progressed towards developing a business plan. In response, the Abalone Aquaculture Subprogram sought a decision by the board to allocate to the subprogram $70K of bridging funds for the 2004/05 period to ensure the program had access to genetic expertise to develop a breeding plan and continue to collect valuable data from the existing families. The subprogram also proposed an action plan that would see this proposal realised; that the national peak body, with support from the subprogram, would seek funds to develop and implement a business plan. The board approved this additional funding and objective 7 (To continue the abalone selective breeding program) was added to the subprogram.

During 2004-2005 the Victorian industry was working to increase their investment in the breeding program by moving towards a phase of full commitment. The subprogram was facilitating their move to put in place a strategic breeding plan and business structure that would ensure a high number of families established each year to meet the scientific requirements of a good breeding program. The Victorian participants had agreed on a methodology for the group production of family lines that provided security of broodstock, gave equal ownership amongst participants, allowed for R&D to be conducted collaboratively and provided a commercially robust structure that encourages investment from both industry and government. And lastly and importantly, the structure allowed entry and exit of groups nationally so that new participants could decide to participate where they have elected not to before. This methodology of distributing share equally between participants and allowed for cooperative work on research was a major breakthrough in overcoming the issues of how to share IP between industry participants. During the spawning seasons of 2005 and 2006 the group produced their first selectively bred stock under the new structure.

The breeding program had a major setback in early 2006 with the loss of the majority of its families through the viral outbreak in Victoria. This, and the loss of the capability of farms to re-enter the program for some time, has led to the collapse of the Victorian initiative for the time being.

Despite the setback, a new initiative in selective breeding has developed within the Tasmanian industry. They recognise that due to their state's greater restrictions on stock imports, they were unlikely to gain access to selective bred stock from the mainland. Thus industry members sought to form a partnership with CSIRO and their Food for Futures program to develop their own state-based breeding program. One Victorian farm, Great Southern Waters, is also a partner in the program, accessing breeding advice from CSIRO.

Translocation

In 2006 Dr Brian Jones of WA Fisheries completed his work on developing a protocol for the translocation of abalone in relation to diseases. This project was critical to the success of the selective breeding program, as translocation policies in each state did not allow the cross breeding of pedigree stocks between states. During the course of his project he conducted a workshop with disease experts and industry members where all known disease issues were raised. This was followed by a formal risk assessment analysis and, in some cases, risk management strategies were proposed.

As a consequence of state agencies expressing concern over genetic issues in relation to translocation, the subprogram and Vic Fisheries held a meeting in 2005 with state policy makers in an attempt to progress this issue. WA, SA and Victoria reported that, based on the current literature available, their departments considered the level of genetic risk to be minimal when moving animals between land based facilities. They advised that the new policies on abalone translocation would be likely to allow such movement between these states.

Translocation then came under intense scrutiny as a consequence of the Victorian viral outbreak in early 2006. Translocation of stocks between farms will be subject to rigid requirements for disease certification. Quarantine facilities are now required in Victoria where all wildstock and stock from

other farms must be located in special holding facilities and effluent water must be passed through UV sterilisation. The current work on developing Codes of Practice for abalone virus management will formalise procedures for movement of stock between the wild sector, farming operations and processors. Similar moves are in the planning stage in Tasmania. Other states will no doubt follow.

Access to diet formulation data

Despite a move in recent years for industry to broaden their attention to issues other than production efficiency, farmers still continues to focus on driving down the cost of production. As the second highest ongoing cost (after labour) feed is an expensive component of production. Members believed that the cost of feed per kg is high, far higher than it should be given the cost of the component ingredients. In 2002 farmers expressed their need to access the nutrition data and feed ingredient information developed by the subprogram over the past 10 years. They wanted to be able to formulate diets in partnership with local feed suppliers to test on their farms. If they can develop an alternative feed with such a company they may seek to establish a alternative suppliers to the existing feed companies. In addition, the larger feed suppliers, such as Skretting, began to attend industry meetings and indicated that they might start producing abalone feed in the near future. Although the nutrition and ingredient information is published in numerous proceeding and scientific papers, it was not accessible in a user friendly format. As part of the current subprogram project, Dr Rob van Barneveld was contracted by the subprogram to modify software that he developed for the finfish industry, which formulates diets for finfish feed producers. The software incorporates all known nutrition and ingredient parameters into a simple excel program ensuring that formulations meet nutritional requirements and any other specifications you want to factor in. This software was developed for abalone and offers a comprehensive database of all abalone nutrition information collated into a single source. It can be used by farmers and feed companies to formulate diets and can be used to conduct economic assessments of cost versus animal performance. An early version was presented by Dr van Barneveld at the 2004 workshop in Hobart and was published in December 2005.

Viral outbreak in Victoria

From February to April 2006, two land-based farms in Victoria, Southern Ocean Mariculture (SOM), Port Fairy and Coastal Seafarms (CS), Portland, were infected with a herpes-like virus, known as ganglioneuritis as it causes inflammation of the nervous tissue. Two smaller outbreaks were reported in sea-based facilities in eastern Victoria. Three of the four outbreaks can be traced to live abalone movement between facilities. Both SOM and CS had to completely destock, and undergo thorough disinfection and cleaning of all farm infrastructure and settlement ponds.

The Abalone Aquaculture Subprogram and the Aquatic Animal Health Subprogram worked together to identify immediate and longer term research priorities for the management of the virus. The FRDC allocated $20K towards immediate trials that would provide an elementary understanding of the epidemiology of the disease. At this stage the Victorian Department of Primary Industries (DPI) formed a committee to develop codes of practice for the farming, wild and processing sectors (discussed further below).

The Victorian DPI is also responsible for monitoring and surveillance of adjacent reefs along the Port Fairy/Portland coast. The DPI has continued a Fisheries Notice until 15 December, which prohibits the collection of abalone and other shellfish from an area between the Crags and Kilarney Beach Car Park. Surveillance of Portland and Western Port continues to be negative for ganglioneuritis.

SOM completed a sentinel trial in August 2006 and no animals became infected. CS is also currently undertaking a sentinel trial.

Codes of Practice for disease management

The DPI, Victoria held a Risk Assessment workshop in October 2006 as part of the FRDC funded project "*Development of Management Strategies for Herpes-Like Virus Infection of Abalone*". The specific objectives of this project are to develop codes of practice for the abalone aquaculture, wild harvest and processing sectors to prevent and control the introduction and spread of herpes-like virus. The risks associated with the transfer of herpes-like virus between the abalone aquaculture, commercial fishing and processing sectors were assessed at the workshop. The risk assessment process provided a prioritised list of risks from which control measures will be developed. These control measures will now be incorporated into standard operating procedures in consultation with the relevant industry sector and used in the development of codes of practice for the control and management of herpes-like virus in abalone.

Strategic R&D planning for virus management on-farm

The Abalone Aquaculture has been working closely with the Aquatic Animal Health (AAH) Subprogram to identify strategic R&D that will assist the farming industry to better manage the disease on-farm. The subprogram invited Dr Mehdi Doroudi, Research Director of DPI and Dr Mark Crane, leader of the AAH Subprogram, to attend the annual industry workshop in August 2006 and report on the activities and planned research into the disease and to allow industry the opportunity to contribute to discussions on R&D priorities. It is unanimously agreed that the first priority for research is to develop a reliable detection tool for the virus and to address issues associated with its use, reliability and practicality. The DPI Victoria held a Scientific Forum in late September that brought together expertise from around Australia and overseas. This enabled valuable discussion from the world's best abalone health researchers and aquatic animal vet pathologists on future control management and R&D strategies. Drawing on these inputs from industry and health experts, Dr Mark Crane submitted (through the AAH Subprogram) an application for developing a detection tool. In February 2007 the FRDC Board approved funding to develop a PCR for the abalone virus.

Health Monitoring

It is well recognised that the Australian abalone farming industry is vulnerable from a lack of knowledge of abalone diseases present in Australian waters. The recent viral outbreak has been a wakeup call to industry members that biosecurity and health/disease monitoring is a critical element of sound risk management practices. The recently completed survey of abalone diseases within southern Australian waters has been an excellent first step in addressing this knowledge gap. The information from this project will be collated into an atlas of abalone diseases on CD that will present images and descriptions of the morphology and pathology of known pests and diseases. This information can now be used as the basis of a sound health monitoring program on farms. Farmers see the benefits of a health monitoring program in:

1) Early detection of disease outbreak and health problems allowing for early response and so minimizing the loss of production efficiency and/or stock,
2) Providing a history of health accreditation for farms, enabling farmers to translocate stock between states and
3) Assist compliance with international export requirements and provide valuable market assurance to international consumers (freedom from major pathogens and toxic substances).

Industry members in Tasmania, Victoria and SA are moving towards establishing programs in their states. They have worked with key health professionals to identify pathologists that are willing to take on the role of collecting and processing samples and who are suitably trained to analyse and provide reports to the farmers on disease and health status. The Tasmanian industry in particular has been proactive in getting a health monitoring program underway. They have worked within a project to develop an EMS framework for the Tasmanian aquaculture industry (oysters, salmon and

abalone) and have committed funds to its development and will fully fund the cost of the on-going monitoring program.

Nutrition and health

During June to August 2006 the subprogram undertook a review of its nutrition R&D strategy. The committee of AAGA met with the leader of the Nutrition Subprogram, Dr Rob van Barneveld, on a number of occasions, which culminated in the submission by him of a proposed nutrition research program for the short and long term. At a meeting in late August, Dr van Barneveld highlighted the areas of research that would most likely provide the highest return on investment, measured in production efficiency and risk minimisation.

The key nutrition research target selected by the committee of AAGA as their R&D priority was to better define the relationship between nutrition and abalone health. In particular, research completed to date has demonstrated that some diet ingredients or diets can influence the integrity of the intestinal epithelium. As the primary point of entry of nutrients and the first barrier against disease challenges, maintenance of the intestinal epithelium is a priority. In addition, a significant body of research in terrestrial species is emerging to suggest that damage to the intestinal epithelium is a primary cause of heat stress. The relationship between gut integrity and long term production efficiency is unclear, as is the capacity of the intestinal epithelium to regenerate following damage. The economic consequences of reduced immune health are significant and far reaching. The most costly impact is the economically significant stock losses during summer months as a consequence of *Vibrio* infection. Farmers also believe that a persistent, sub optimal health status is impacting on the growth performance of stocks leading to a higher cost of production across the industry.

Given that the production time for abalone is so long (3-4 years), and the cost and risks of production are very high compared with other farmed species, it is very important that diets do not compromise growth or health of stock. This research area was identified as most likely to provide the greatest economic benefit across the industry. The outcome of this work would be recommendations regarding use of various ingredients that would enable feed manufacturers to reformulate diets to ensure optimal gut health. The subprogram worked with the AAGA committee, Dr Rob van Barneveld and the feed companies to assist Dr Meegan Vandepeer of SARDI to develop an application to FRDC for consideration.

NEED

Research relevance and acceptance

FRDC has been recognised for their leadership in developing abalone aquaculture in Australia. To ensure that this investment in R&D in partnership with the industry results in a significant abalone aquaculture industry, it is important that this partnership is maintained. FRDC has created one of the few truly national programs for developing an aquaculture species. The benefits arising from this have been significant as measured by: quality of science, industry planning of R&D, partnership approach to R&D execution, comprehensive extension program using novel media formats (e.g., interactive CD ROMs) and the high level of adoption.

The AAS has fostered a truly collaborative relationship with industry that has led to highly commercially focused research outputs for the Australian abalone aquaculture industry. Since its inception in 1993 the subprogram has delivered highly focused research outputs that have responded to the changing R&D needs of the industry as it matured. The AAS has achieved this by implementing operational processes that ensure industry members themselves identify R&D needs and, through the Steering Committee, subsequently manage research projects.

The subprogram has achieved a high degree of research coordination between states and an extensive communication strategy to ensure service delivery to the industry. The subprogram has added value the FRDC's research investment by managing its project portfolio in this way. None of this would have been possible without an independent subprogram leader and a highly responsive Steering Committee that is strongly represented by industry members across southern Australia.

Research efficiency and output

The presence of a coordination component within the AAS has resulted in savings in the operation of new and existing projects far exceeding $500,000. This has been achieved by improving project adoption, ensuring projects are appropriately costed, coordinated travel and workshop budgets combined with more efficient use of limited research funds.

In recognition by the industry of the subprogram's value, the recently formed national peak body, the Australian Abalone Growers Association, will seek to continue an R&D planning and management body as part of its operational processes. It is anticipated that AAGA will work with FRDC to develop an alternative model, such as an R&D subcommittee under AAGA, that may be co-funded by both FRDC and AAGA.

During the past three years, the FRDC funded an additional two projects within the subprogram (Table 4). Of the eleven active projects managed by the subprogram from 2003 – 2006, all due final reports and extension materials have been submitted.

Table 4.

Projects managed by the subprogram during the current project 2003/202

Project ID	Project Title	Organ Name	Status of project
2000/202	Development of spermatozoa cryopreservation techniques in farmed abalone	SARDI	Final report submitted and published Workshop held. Protocol published.
2000/204	The commercial control of spawning in temperate abalone	University of Tasmania	Final report submitted and published
2000/205	Potential for antibiotic use in abalone for disease control	University of Tasmania	Final report submitted and published
2001/254	Selective breeding of farmed abalone to enhance growth rates II	SARDI	Final report submitted
2002/200	Preventing summer mortality of abalone in aquaculture systems by understanding interactions between nutrition and water temperature	SARDI	Final report submitted and published. Manual published.
2002/201	A national survey of diseases of commercially exploited abalone species to support trade and translocation issues and the development of health surveillance programs	University of Tasmania	Final report submitted and published. CD pending (March 2007).
2002/202	Use of marker assisted genetic breeding to improve abalone and abalone products	Natural Resources and Environment	Final report submitted and published.
2003/202	Subprogram: Development of NOMAD software and nutrition manual	Abalone Aquaculture Consultancy P/L	CD published. Manual submitted.
2003/203	Improvement and evaluation of abalone hatchery and nursery production	Department of Fisheries Western Australia	Final report submitted. CD pending (March 2007).
2004/233	Investigating the immunology of stressed abalone (Haliotis species)	University of Melbourne	Project still active
Dec 2005	Identification of a commercialisation model and business structure for the selective breeding program	Ridge Partners Pty Ltd	Terminated due to loss of breeding stock from virus

OBJECTIVES

1. Development and implementation of strategic plans and the facilitation of research and extension to assist the development of abalone aquaculture in Australia.

2. Coordination of a wide range of discipline-based (i.e. nutrition, health, genetics, husbandry) research projects for the two commercially valuable species of abalone.

3. Facilitate the delivery of outcomes from the Abalone Aquaculture Subprogram in the form of annual workshops, workshop proceedings, the subprogram's website, the subprogram's newsletter, trade journal articles, final reports, and scientific publications.

4. Provide a single point of contact for abalone aquaculture research in Australia.

5. Facilitate the functions of an Abalone Aquaculture Steering Committee to ensure ongoing research programs have a high degree of industry relevance and focus.

6. Undertake an independent review of the subprogram in partnership with FRDC. The results to be used as input into the strategic planning process and subprogram procedures.

7. To continue the abalone selective breeding program.

METHODS

Subprogram management and operating procedures

One of the main aims of the subprogram is to ensure that abalone aquaculture research and development is coordinated to make the most efficient use of available resources and integrate industry and research providers. To ensure that the AAS continues to address the proposed industry requirements and that effective and efficient communication is maintained the following administrative arrangements have been set in place and have proved to be effective vehicles to achieve their aims.

A. Administrative Structure

Subprogram Leader

The subprogram achieves its aims through the subprogram leader who is governed by the decisions of the steering committee.

The aims of the leader are to manage the AAS to ensure that:

- Milestone objectives are met on time,
- Projects are coordinated and integrated efficiently to ensure national collaboration of research,
- Meetings and workshops are organised efficiently and effectively,
- Reporting structures are set in place,
- Subprogram reports and newsletters are coordinated and delivered,
- An appropriate and approved (by the steering committee) media policy is developed,
- Advice is provided to both the steering and scientific committees,
- New funding applications are sought and coordinated,
- The R&D Strategic plan is relevant and current to reflect industry's research needs, and
- Subprogram outcomes are promoted through effective and efficient extension.

The Director of the FRDC chooses the subprogram leader. Tenure is for the life of the project (3 years).

Steering Committee

The aim of the Steering Committee is to provide management direction for the subprogram; namely to identify development opportunities, to develop research priorities and establish their relevance, to ensure no duplication of efforts, and to assess the subprogram's outcomes in terms of meeting objectives and benefits to industry.

The AAS is highly responsive to the views of industry and understands the need to accommodate both the research requirements of the future and the current needs of the aquaculture industry. To ensure that research conducted within the subprogram is relevant and meets the above criteria, a Steering Committee is supported to:

1. Provide industry feedback and views;
2. Review existing research based on FRDC contractual obligations;
3. Prioritise new proposals and provide a priority list for other agencies;
4. Ensure outcomes are commercially focused;
5. Coordinate industry and research provider involvement - optimum use of resources;
6. Facilitate extension and technology transfer.

Since the formation of AAGA the committee of AAGA has become the steering committee of the subprogram. The Steering Committee consists of Ann Fleming (Chair), Patrick Hone (FRDC), Nick Savva, Anton Krsinich, John Hall, Mark Gervis, Shane McLinden.

The Steering Committee meets 3-4 times each year to review project progress and establish research priorities. This consists of two face-to-face meetings and teleconferencing when needed to discuss specific project progress and issues. Advice from the Steering Committee is sent to relevant Fisheries Research Advisory Bodies so that they are aware of the subprogram's research priorities. All new projects relating to abalone aquaculture are assessed by the Steering Committee and are submitted to the FRDC Board via the subprogram and endorsed by AAGA.

B. Operational Objective

The following management procedures relate to the Operational Objective of the subprogram: To efficiently and effectively manage the Abalone Aquaculture Subprogram to maximise the contribution of FRDC-funded R&D towards the growth, viability and economic benefit of the abalone aquaculture industry.

In late 2005 the FRDC announced that it would not continue to fully fund the subprogram after September 2006. The industry and the FRDC were keen to maintain the skilled capacity for R&D planning and management that had been built up over the past 13 years by the Abalone Aquaculture Subprogram. It was anticipated that the newly formed national peak body, the Australian Abalone Growers Association, would take over the role of R&D management in the future. The simplest structure would appear to be an R&D subcommittee that would sit beneath the AAGA committee proper, consisting of industry representatives and an R&D manager. However, it was important that a transitional period was provided to give the association time to become skilled in this new role. The hand over of the responsibilities of the subprogram's steering committee has easily moved to that of the newly elected members of the AAGA committee. This is to be expected, as it has always been recognised that industry itself is best suited to identify commercially-driven research priorities, to determine how the research should be conducted and how results should be communicated. However, the technical expertise of the R&D manager in facilitating the committee to make *informed* decision regarding strategic planning, project development and research management is a key component in ensuring the highest commercial return to the industry through investment by the FRDC. This expertise requires a sound understanding within a range of areas, such as funding and research organisation processes and structures, research provider expertise and activity, establishing effective consultative processes that ensure a high standard of science and allow sound cost benefit analysis of research proposals. In early 2006 FRDC commissioned an independent review of the subprogram and one of the recommendations was that the handing over period be extended to allow the AAGA chair and committee to become fully effective in R&D planning and management. Consequently, the FRDC decided to extend funding for the subprogram until December 2007.

Strategic Planning

Related Strategy: By developing and maintaining strategic R&D directions.

Methods: Strategic planning for the AAS is based on outcomes from the existing research program and ongoing consultation between the subprogram leader and members of industry and researchers in Australia. The strategic plan is maintained and updated biennially. The strategic planning process identified those factors that represent restrictions to the growth of abalone aquaculture in each state (e.g. health, nutrition), and then utilised a relative ranking score to prioritise national priorities across the various states.

Every two year the subprogram reviews its strategic R&D directions through a consultative process with industry. A letter is sent to each state association (WA, SA, Victoria, Tasmania) asking that a discussion be held at their next meeting to compile a list of their state's R&D priorities. The subprogram leader collates, summarises and identifies R&D priorities on a state-by-state basis and on a national level. R&D priorities are sent to the steering committee and to each state growers association.

Performance Indicators:
- To effectively manage an R&D priority setting cycle every two years.
- To be successful in gaining funding for projects submitted under the subprogram.

Development of new research proposals

New research proposals are developed through the use of facilitated strategic planning meetings. Using priorities published in the AAS Strategic Plan, the subprogram leader convenes meetings with the steering committee and relevant researchers and research institutions to:

1. Define the planned outcomes and outputs of the new proposal;
2. Manage an indicative budget for the research as defined by the Steering Committee;
3. Identify which researchers/institutions are best placed to undertake the research;
4. Promote collaboration between researchers and institutions where appropriate;
5. Seek external expertise and inputs as required.
6. Ensure the new proposal meets the objectives of the subprogram and that the research remains relevant and focused.

The subprogram leader ensures new research proposals are distributed to FRABs and the AAS Steering Committee for comment and ratification before approval for submitting the proposals to FRDC, or facilitating adjustments to the proposals prior to submission.

Related Strategy: By developing new projects to meet strategic R&D directions.

Methods: Once the FRDC identifies budget spending on abalone aquaculture for the next funding cycle, the steering committee meets and identifies projects to be supported based on industry's R&D priorities (both state and national needs) and budget. The steering committee defines the planned outcomes of the new proposal and may identify the broad objectives of the projects and allocate an indicative budget to each proposal. The state FRABs are then notified of R&D priorities and dates of submissions. The subprogram leader distributes a call for expressions of interest to researchers/industry members with expertise in the field. Applicants submit a project pre-proposal and the steering committee selects the successful applicant based on research capacity, facilities, in-kind contribution, and industry involvement. External experts may be contracted to provide advise to the steering committee on applicant selection. The successful applicants then writes a full draft application, which are sent to the relevant state FRABs and the steering committee. The subprogram leader and steering committee reviews the applications and makes requests for changes if necessary. External experts may be contracted to provide advise to the steering committee at this stage. The full applications are submitted to the FRDC with a letter of endorsement by the Abalone Aquaculture Subprogram.

Performance Indicators:
- To implement and manage a projects development cycle annually.
- To engage research based on the subprogram's R&D strategic plan.
- To be successful in gaining funding for projects submitted under the subprogram.

Research Management

Related Strategy: By providing a productive, cooperative, national research framework for all Australian abalone aquaculture researchers.

Methods:
The subprogram leader has been active in providing a framework that allows a high level of collaboration between researchers, industry and stakeholders. This has been achieved in the following manner:

- Directs researchers to draw on a broad range of expertise. During project development the subprogram leader identifies other researchers with expertise and directs researchers to establish collaborative links (e.g. as co-investigators, informal advisors at planning meetings, exchange of technicians in laboratories, etc). These collaborations are detailed in project applications. Researchers are also provided with linkages to less directly related projects that may complement and enhance the outcomes of some components of their research.
- Continued to maintain a comprehensive knowledge of the research work done on abalone aquaculture in the past and currently, both in Australia and overseas. This ensures that R&D is not duplicated and researchers can form an informal association with other research groups so that they can access a broad information base.
- Advise on scientific methodology where experiments require a uniformity of approach.
- Provide an informal information service on accessing knowledge and expertise.
- Actively encourage other research projects to become informally affiliate with the subprogram.
- Actively seek other funds for high-priority research not funded by the FRDC.
- Actively gather other knowledge bases and disseminate relevant information.
- Facilitate the hosting of research at commercial facilities where appropriate and feasible.

Performance Indicators:
- To increase the level of collaboration between researchers and between researchers and industry.
- Effectively maintain a high level of national cooperation and openness between industry members, and between industry and researchers.
- To provide consensus between researchers and between researchers and industry.
- To provide a focus of knowledge.
- To attract other resources; such as researchers, funds, knowledge.

R&D Outcomes Management

Related Strategy: By ensuring timely R&D outcomes according to industry requirements.

Methods: To ensure all planned research is industry focused and the science is of a high standard, the following reporting system is followed. The subprogram leader directs researchers to submit comprehensive experimental preschedules prior to the commencement of all experiments. Project applications must state the scheduled time for submitting each preschedule to the subprogram leader. Researchers are required to use the Subprogram Experimental Preschedule format for setting out preschedules. The subprogram leader sends the preschedule to the steering committee and, if necessary, to others who can advise on certain aspects of the scientific merit of the preschedule. Comments are sent to the researcher and required changes are implemented. Where it is deemed that the researcher needs advice on certain aspects of the proposed research, the subprogram leader provides a linkage to a researcher with the appropriate expertise.

Performance Indicators:
- To implement and manage a reporting system between the subprogram leader and researchers.
- To implement and manage a reporting system between the subprogram leader and industry.
- To ensure research is industry focused and the science is of a high standard.

- To report to researchers on industry's views on project progress.

C. Communication Objective

The following management procedures relate to the communication objective of the subprogram: To maintain a high level of effective communication between the subprogram leader, its stakeholders, researchers and the FRDC.

FRDC, Researcher and Industry Communication

Related Strategy: By providing effective communication and consultation between the subprogram leader, it's stakeholders, researchers and the FRDC.

Methods: *Review of research progress and direction:* The subprogram leader convenes meetings with the steering committee on an as-need basis. A major function of the committee meetings is to ensure all progress within projects has met contracted milestones and ensure that the research program is making a valuable contribution towards the achievement of the subprogram objectives. The steering committee may make recommendations to the FRDC Board in relation to potential changes to the objectives of the research program, or instances where project progress is unsatisfactory. The following reporting system is followed:

Milestone reports are submitted to the subprogram leader and distributed to the steering committee for comment. If the subprogram leader or the steering committee does not think the objectives of the experiments reported have been met, then the researcher must address these concerns. Milestone reports and project progress are reviewed at the steering committee meetings. The subprogram leader must approve the milestone report before it is sent to the FRDC. Milestone reports are then sent to the FRDC.

The subprogram leader is the conduit for communications between FRDC and subprogram participants in relation to project contracts, project reports, new submissions and general correspondence. The subprogram leader also represents the AAS at the annual FRDC FRAB and subprogram meetings in Canberra.

Performance Indicators:
- To communicate and consult regularly with FRDC, stakeholders and researchers.

Promote Project Outcomes

Related Strategy: By providing effective media to ensure that project results/outcomes are widely known as soon as they become available.

Methods: One of the major roles of the subprogram leader is to ensure that outputs from individual projects are developed and extended according to industry requirements. The methods of communications used by the subprogram have been very effective in the past and well supported by industry.

Annual workshop and workshop proceedings
A major function of the subprogram leader is the organisation and delivery of an annual research workshop to highlight the activities and outputs of the AAS. Workshops are convened with presentations from invited speakers and researchers aimed at delivering key messages to end-users for use in abalone aquaculture.

Newsletter and website

Early in the course of project 2003/202 it was decided that the time spent producing a quarterly newsletter and updating the website would be better spent assisting the industry in issues they recognised as of high priority to their growth, such as translocation policy between states and developing a business structure for the selective breeding initiative. Thus the subprogram leader focused on facilitating meetings, seeking expert advice, contracting consultants and sourcing funds to progress such issues. Refer to Background Section titled "Main issues/activities of the industry that were facilitated by the subprogram: 2003 – 2006" for reporting on these issues.

Performance Indicators:

- To widely and effectively disseminate information on research outcomes in a timely manner during the course of the projects.

Promote Output Extensions

Strategy: By ensuring that project outputs (extension products) are provided by researchers in a form that is quickly disseminated and easily adopted by industry.

Methods: *Coordination of research reports:* The subprogram leader reviewed, edited and collated progress and final reports from projects within the subprogram for delivery in a common format to FRDC. These reports were distributed to members of the steering committee for comment and review.

Facilitation of research uptake: The subprogram directs researchers to extend their results in various formats, depending on the project outcomes and industry needs. The steering committee has input into methods of extension when reviewing new applications prior to submission to the FRDC. The subprogram leader ensures that researchers have allocated an appropriate budget to the production of extension materials and activities.

Information is developed in different formats depending on the intended target audience (government managers, new investors, other researchers, general public, media (press), etc). The subprogram primarily targets its extension strategy to the farmer as the primary user of the information. It is essential that information be in a form that is easily understood, has the complete technical information necessary and is suitable as a working information source (e.g., poster, handbook, etc). The majority of abalone farmers have an excellent knowledge of science and scientific process that means information sources can use most of the more technical terms and technology. The subprogram reviews all information to ensure appropriate standards are met and the extension sits within the subprogram's communication objective. All extension products were advertised and sold through the subprogram's communication media.

Performance Indicators:

- To consult industry on the most appropriate research outputs.
- To direct researchers to provide the research outputs required by industry.
- To ensure that project budgets have appropriate fund allocation for the production of outputs.

Annual Operating Plan

Related Strategy: By reporting to the FRDC annually on the operations and activities of the subprogram (Annual Operating Plan):

Methods: Reported within the AOP is:

A) Activity description for last 12 Months

A brief background on the current operating environment - how the sector is progressing any new legislative requirements etc, Provide a description of operating procedure, meetings/workshops, summery of how each research project is going.

B) Summary of Strategic Plan or directions
A description of the main points of the strategic plan.

C) Communication and technology transfer activities
Description of activities, including reports published, newsletters, new technologies, etc.

D) Proposed New Research
Provide a ranking/priorities for applications that relate to the subprogram.

E) Budget
Provide a summary of budget and anticipated forward budget estimates based on continuing and proposed new projects.
Provide a description of any proposed budget changes that require Board approval.

Performance Indicators:

- To report to the FRDC on subprogram operation and activities.

RESULTS

Knowledge, processes and technology developed by the subprogram

Table 5 contains a list of the projects managed under the subprogram from 2003 - 2006. The subprogram managed 11 research projects, two of which were funded during that time. The outputs and the effectiveness of these projects in delivering industry outcomes are detailed in the discussion section.

Table 5

Projects managed under the subprogram during 2003– 2006

Project ID	Project Title	Organ Name
2000/202	Development of Spermatozoa cryopreservation techniques in farmed abalone	South Australian Research and Development Institute
2000/204	The commercial control of spawning in temperate abalone	University of Tasmania
2000/205	Potential for antibiotic use in abalone for disease control	University of Tasmania
2001/254	Selective breeding of farmed abalone to enhance growth rates II	South Australian Research and Development Institute
2002/200	Preventing summer mortality of abalone in aquaculture systems by understanding interactions between nutrition and water temperature	South Australian Research and Development Institute
2002/201	A national survey of diseases of commercially exploited abalone species to support trade and translocation issues and the development of health surveillance programs	University of Tasmania
2002/202	Use of marker assisted genetic breeding to improve abalone and abalone products	Natural Resources and Environment
2003/202	Strategic planning, project management and adoption: Development of NOMAD software and nutrition manual	Abalone Aquaculture Consultancy P/L
2003/203	Improvement and evaluation of abalone hatchery and nursery production	Department of Fisheries Western Australia
2004/233	Investigating the immunology of stressed abalone (Haliotis species)	University of Melbourne
Dec 2005	Identification of a commercialisation model and business structure for the selective breeding program	Ridge Partners Pty Ltd

Extension materials produced by the subprogram

Annual Workshops: The subprogram has organised four annual workshops between 2003 and 2006. The attendance rate at these meetings has been exceptionally high, with 80% of the industry attending each year. The last two workshops each attracted about 70 registrations each, representing a 90% industry attendance rate.

Proceedings: Workshop proceedings have been produced from each of the workshops. These are distributed to workshop delegates and are subsequently available through the subprogram.

Manuals: All manuals are either downloadable from the subprogram's website or can be ordered through it. Samples of manuals that are available follow. Those in italics were released during the last three years.

- Abalone Hatchery Manual For Australia
- Quality Assurance Manual
- Conditioning Australian Abalone Broodstock: Best Practice Manual
- Australian Abalone Mudworms: Avoidance and Identification. A Farm Manual
- An Industry-led Workshop on Live Transport
- *Protocol for the cryopreservation of abalone sperm*
- *Manual on the effects and management of water quality on abalone farms*

- Practical nutrition for abalone aquaculture farmers

CD-ROMs: The subprogram strives to utilise novel media formats and encourages researchers to publish project outputs in such a way. Samples of CD-ROMs follow. Those in italics were released during the last three years.

- Abalone Histology Atlas
- Abalone Nursery Manual: Algal culture methods for commercial abalone nurseries.
- *NOMAD: Abalone feed formulation software*
- *Diseases of Australian abalone (Due for release in March 2007)*
- *Abalone Nursery Manual: Algal culture methods for commercial abalone nurseries: Updated (Due Dec 2006)*

Human Capital Development

The following lists PhDs, masters and honours theses published under the subprogram during the past 13 years. Those in italics were part of research managed by the subprogram during the past 3 years.

PhD:

Baronski, M. The development and application of genetic markers to the genetic improvement of abalone for aquaculture. Deakin University, Victoria.

Coote, Tom A., 1998. The protein, energy and lysine requirements of greenlip abalone (*Haliotis laevigata*). Ph.D. Dissertation (Science). University of Tasmania, Australia.

Grubert, M. Factors influencing the reproductive and larval development of blacklip and greenlip abalone and their hybrids. Ph.D. Dissertation (Science), University of Tasmania.

Harris, James O., 1999. Chronic effects of adverse water quality on the greenlip abalone, *Haliotis laevigata* Donovan. Ph.D. Dissertation (Science). University of Tasmania, Australia, 128pp.

Hindrum, Stephen, submitted. Factors affecting growth and water quality in abalone growout systems. Ph.D. Dissertation. University of Tasmania, Australia.

Hooper, C. The immunology of abalone. University of Melbourne, Australia.

Kemp, Robert, submitted. Assessment of the effect of abalone manufactured diets on the brush border vesicles of intestines. University of Adelaide, South Australia.

Lleonart. M. 2002. Management of spionid mud worm infestations of Tasmanian cultured abalone. Ph.D. Thesis, University of Tasmania.

Vandepeer, M.E., 2002. An assessment of alternative protein sources and feeding strategies for juvenile greenlip abalone *Haliotis laevigata* Donovan. Ph.D. Dissertation (Science), Flinders University, Australia.

Strain, L. In prep. Algal diets for juvenile abalone nutrition. Murdoch University, Perth, Australia.

Masters:

Krsinich, Anton, 2000. Effects of seeding with the macroalga (*Ulvella lens*) and inoculation with a benthic diatom (*Navicula* sp.) on the settlement, growth and recruitment of abalone (*Haliotis rubra*) under commercial conditions. Master's dissertation (Applied Science in Aquaculture). University of Tasmania, Australia.

Honours:

Higham, Jason, 1998. The effect of different flow rates in low volume culture tanks, on growth in juvenile greenlip abalone, *Haliotis laevigata* (Donovan). University of Adelaide, South Australia.

Strain, L. 2004. Algal sporelings for abalone aquaculture. Murdoch University, Perth, Australia.

Hair, S. 2005. The role of bacteria in the nutrition of postlarval abalone. Murdoch University, Western Australia.

Shipway, M. 2005. Investigation into reproductive conditioning and fertilization processes in the culture of greenlip abalone Haliotis laevigata Donovan. The University of Western Australia.

Industry Training

As part of the extension strategy of the nursery management and algal culture project (2003/203), industry participants of the 2005 annual workshop attended a 0.5-day training workshop on *Ulvella* culture techniques.

As part of the cryopreservation of sperm project (2000/202), industry participants of the 2003 annual workshop attended a practical demonstration of cryopreservation techniques.

As part of the selective breeding project (2001/254), the PI visited participating farms to provide a practical demonstration of the techniques for spawning, fertilizing and settling selectively bred stocks.

DISCUSSION

Value-adding FRDC's investment in R&D

FRDC has been recognised for their leadership in developing abalone aquaculture in Australia. The AAS has ensured that this investment in R&D, in partnership with the industry, has resulted in a significant and viable industry. FRDC has created one of the few truly national programs for developing an aquaculture species. The benefits arising from this have been significant as measured by: quality of science, industry planning of R&D, partnership approach to R&D execution, comprehensive extension program using novel media formats (e.g., interactive CD ROMs) and the high level of adoption.

The AAS has fostered a truly collaborative relationship with industry that has led to highly commercially focused research outputs for the Australian abalone aquaculture industry. Since its inception in 1993 the subprogram has delivered highly focused research outputs that have responded to the changing R&D needs of the industry as it matured. The AAS has achieved this by implementing operational processes that ensure industry members themselves identify R&D needs and, through the Steering Committee, subsequently manage research projects.

The subprogram has achieved a high degree of research coordination between states and an extensive communication strategy to ensure service delivery to the industry. The subprogram has added value the FRDC's research investment by managing its project portfolio in this way. None of this would have been possible without an independent subprogram leader and a highly responsive steering committee that is strongly represented by industry members across southern Australia.

Research efficiency and output

The presence of a coordination component within the AAS has resulted in savings in the operation of new and existing projects far exceeding $500,000 and it is likely that this trend will exist in the future. This has been achieved by improving project adoption, ensuring projects are appropriately costed, coordinated travel and workshop budgets combined with more efficient use of limited research funds.

In recognition by the industry of the subprogram's value, the recently formed national peak body, the Australian Abalone Growers Association, will seek to continue an R&D planning and management body as part of its operational processes. It is anticipated that AAGA will work with FRDC to develop an alternative model, such as an R&D subcommittee under AAGA, that may be co-funded by both FRDC and AAGA.

During the past three years, the FRDC funded an additional two projects within the subprogram. Of the eleven active projects managed by the subprogram from 2003 – 2006, all due final reports and extension materials have been submitted.

Achievement of planned outcomes

The following tables (Tables 6a-d) outlines the research outputs from the projects managed under the subprogram from 2003 to 2006 and summarises the annual planned outcomes that have been transferred to industry each year.

Table 6a

How outputs in 2003 contributed to planned outcomes	Planned outcomes
1998/306: Early life history of abalone: settlement, survival and early growth Project status: Final report published. The production of a CD-ROM effectively extended the results to industry. CD-ROM for sale through subprogram. Critical Output: Knowledge and methodology on plate management during settlement and early juvenile growth; application to commercial-scale conditions. High adoption of methodology by industry (80%).	➢ Improved settlement system through improved settlement, consistency and survivorship; ➢ Improved nursery system through manipulating microalgal diets to meet the changing dietary needs of early post-settlement juveniles. ➢ High adoption of results by industry (80%)
2000/202: Sperm cryopreservation Project status: Established a successful protocol for the cryopreservation of sperm that provides 80% viability of larval using thawed sperm. Presented protocol to industry at a hands-on demonstration workshop in November 2003. Draft manual of methodology written. Final report due January 2004. Manual publication due February 2004. Critical Outputs: Knowledge of methodology to cryopreserve sperm.	➢ Increased efficiency of hatchery operations through availability of male gametes on demand; ➢ Facilitates selective breeding of superior stock as both sexes do not have to be sexually mature at the same time; ➢ Reduces risk of disease transfer.
2000/204: Broodstock conditioning Project status: Final experiment on reconditioning abalone broodstock continues. Final report due March 2004. Critical Outputs: The methodology finalised in 2003 has enabled farmers to spawn with a higher rate of response, and extend the natural spawning season. A high percent of farmers are now conditioning their broodstock routinely. The information on reconditioning will allow farmers to assess the potential for animals to spawn repeatedly (possibly for many years) within the broodstock conditioning facility.	To reliably spawn broodstock at any time and in so doing: ➢ Extend the natural spawning season and spawn out of season; ➢ Reduce risk of spawning failure; ➢ Increase efficiency and predictability of production; ➢ Increase efficiency of use of hatchery/nursery operations; ➢ Facilitates selective breeding of superior stocks.
2002/200: Preventing summer mortality Project status: After two attempts to induce bloat in the laboratory and extensive discussions with industry, the PI concluded that nutrition did not play a primary role in the summer mortality problem. Further discussions with industry resulted in the proposal that remaining funds be allocated towards the publication of a simple how-to manual on monitoring water quality. A first draft has been submitted to the subprogram and presented at the annual workshop. After review it will be published and sold through the subprogram.	➢ An understanding of the interactions between abalone health, water quality, water temperature and stress and preventative actions to optimize health and production efficiency. ➢ Routine monitoring of water quality parameters that will provide information to farmers on where management must focus its efforts to improve water quality and health status.

Critical Outputs: Knowledge of how to monitor water quality on-farm and how to mange water quality through management practices.	
2002/201: A national survey of diseases Project status: The PI has identified the necessary personnel and collection processes in each state. State based sample collection program underway although slow in some states due to staffing difficulties in state pathology agencies. Critical Outputs: Early data on disease occurrence in wild abalone in some states.	➢ Knowledge of abalone diseases present in Australia and moderate knowledge of their current distribution and prevalence. ➢ Significantly improved diagnostic capability available to both abalone aquaculture and wild fisheries managers. ➢ Surveillance programs for the abalone farming sector to provide cost-effective access to diagnostic services, improved feedback for addressing on-farm factors affecting abalone health, and better assurances with regard to abalone health for farm planning, supply of other farm customers, and market access. ➢ Reduced production costs from reduction in losses and improved health. ➢ A sound basis for decision making with regard to movement and testing protocols for interstate and intra-state movements, quarantine issues, and reseeding operations, which will benefit both the farmed and wild abalone industries, and improve public confidence in farming and reseeding operations. ➢ A significantly improved basis with regard to trade access issues, claims of disease freedom, and likely disease related quality risks to trade. ➢ Improved knowledge of the likelihood of paralytic shellfish poisoning issues occurring in abalone ➢ A sound basis for prioritising future research needs such as further investigation of specific diseases, or extending parts of the survey to meet international standards for official freedom from certain diseases
2002/202: Genetic markers Project status: The production of 103 new markers has provided substantial groundwork for the 150 markers targeted. The identification of two potential markers for growth provides exciting evidence for the feasibility of the work to enhance the selection process within the breeding project. Critical Outputs: More markers for blacklip and greenlip abalone than were created by others before the project started. First ever identification of potential markers for growth in abalone.	➢ Establishment of a comprehensive advanced genetic selection program based on the integration of phenotypic data and genetic markers. Likely 3% annual improvement in API for private growers adopting the technology. ➢ Augmentation of existing microsatellite markers to give a total of at least 150 markers with coverage including every abalone chromosome. ➢ Formulation of an Abalone Profit Index (API) in consultation with the abalone industry. Use of the index will ensure selection for a more profitable industry, benefiting private growers and enhancing Australia's reputation for quality seafood in overseas markets ➢ Completion of a comprehensive genome scan and identification of quantitative trait loci affecting the API. The benefit to industry is a set of gene markers that can be used to fast-track the rate of genetic improvement in the commercial sector. ➢ Measurements of genetic diversity within and between cultured stocks.

Table 6b

How outputs in 2004 contributed to planned outcomes	Planned outcomes
2000/204: Broodstock conditioning Project status: Final experiment on reconditioning abalone broodstock completed. Final report and extension manual in press. Critical Outputs: Methodology to condition and recondition broodstock to achieve a high rate of spawning response and to extend the spawning season. Contribution to planned outcomes: The methodology finalised in 2004 enabled farmers to spawn with a higher rate of response, and extend the natural spawning season. A high percent of farmers are now conditioning their broodstock routinely. The information on reconditioning will allow farmers to assess the potential for animals to spawn repeatedly (possibly for many years) within the broodstock conditioning facility.	To reliably spawn broodstock at any time and in so doing: ➢ Extend the natural spawning season and spawn out of season; ➢ Reduce risk of spawning failure; ➢ Increase efficiency and predictability of production; ➢ Increase efficiency of use of hatchery/nursery operations; ➢ Facilitates selective breeding of superior stocks.
2002/200: Preventing summer mortality Project status: The remaining funds in this project have been allocated towards the publication of a simple how-to manual on monitoring water quality. A number of drafts have been submitted to the subprogram, but the steering committee has not approved it. The subprogram has asked FRDC for approval to contract James Harris of Flinders University to take on the role of writing the manual. The subprogram is still awaiting FRDC advice on this. Critical Outputs: Outputs from this project have shown farmers the complexity of the summer mortality issue. After failing to induce bloat in the laboratory after two attempts by manipulating temperature and water quality, it is apparent that other causal factors are involved. Farmers have been advised on the need to address their water quality management throughout the whole year to improve the health and immune status of animals. Some farmers are now implementing water monitoring to assess which parameters are problematic.	➢ An understanding of the interactions between abalone health, water quality, water temperature and stress and preventative actions to optimize health and production efficiency. ➢ Routine monitoring of water quality parameters that will provide information to farmers on where management must focus its efforts to improve water quality and health status.
2002/201: A national survey of diseases Project status: State based sample collection program completed in all states except a small amount still to be collected from SA. Examination of samples near completion in all sates. CD of pathology underway. Final report due March 2005. Contribution to planned outcomes: Outputs from this project will provide farmers with a sound knowledge of abalone diseases that occur in Australian. This information will be used to make informed decisions about health surveillance protocols, translocation	➢ Knowledge of abalone diseases present in Australia and moderate knowledge of their current distribution and prevalence. ➢ Significantly improved diagnostic capability available to both abalone aquaculture and wild fisheries managers. ➢ Surveillance programs for the abalone farming sector to provide cost-effective access to diagnostic services, improved feedback for addressing on-farm factors affecting abalone health, and

protocols, health certification methodology, etc.	better assurances with regard to abalone health for farm planning, supply of other farm customers, and market access. ➢ Reduced production costs from reduction in losses and improved health. ➢ A sound basis for decision making with regard to movement and testing protocols for interstate and intra-state movements, quarantine issues, and reseeding operations, which will benefit both the farmed and wild abalone industries, and improve public confidence in farming and reseeding operations. ➢ a significantly improved basis with regard to trade access issues, claims of disease freedom, and likely disease related quality risks to trade. ➢ Improved knowledge of the likelihood of paralytic shellfish poisoning issues occurring in abalone ➢ a sound basis for prioritising future research needs such as further investigation of specific diseases, or extending parts of the survey to meet international standards for official freedom from certain diseases
2002/202: Genetic markers Project status: The majority of the 127 microsatellite markers new to science were successfully genotyped across all families. At least 28 potential gene markers showing linkage to growth rate have been individually genotyped, and analysis of seven markers has resulted in highly significant associations between animal weight and the inheritance of particular alleles being found. Critical Outputs: More markers for blacklip and greenlip abalone than were created by others before the project started. First ever identification of potential markers for growth in abalone.	➢ Establishment of a comprehensive advanced genetic selection program based on the integration of phenotypic data and genetic markers. Likely 3% annual improvement in API for private growers adopting the technology. ➢ Augmentation of existing microsatellite markers to give a total of at least 150 markers with coverage including every abalone chromosome. ➢ Formulation of an Abalone Profit Index (API) in consultation with the abalone industry. Use of the index will ensure selection for a more profitable industry, benefiting private growers and enhancing Australia's reputation for quality seafood in overseas markets ➢ Completion of a comprehensive genome scan and identification of quantitative trait loci affecting the API. The benefit to industry is a set of gene markers that can be used to fast-track the rate of genetic improvement in the commercial sector. ➢ Measurements of genetic diversity within and between cultured stocks.

2003/203: Broodstock diets and nursery management

For nursery management work:

Project status: This year the identification of suitable macroalgae and diatoms as feed during the latter phase of nursery production has met the primary outcome of this work. Further work is planned to investigate a broader range of algal species.

Experimental results showing very promising growth rates achieved on plates covered with the alga, *Ulva*, indicated that *Ulva* sp. germlings might be a suitable and practical additional food source for advanced juveniles in a commercial nursery.

Growth rates achieved on a new isolate of *Cocconeis* sp. were promising and further trials are planned to compare a combination of *Ulvella lens* plus *Cocconeis* sp. to an *Ulvella lens* plus natural diatom mix, which is the most widely used by industry

For broodstock diet work:

Project status: The greenlip abalone broodstock conditioning trial, involving a range of conditioning diets, has been operating for 9 months. Three spawning rounds have been conducted and a fourth spawning is scheduled for September 2004.

Initial results have not shown a clear effect of diet treatment on spawning parameters and larval survival parameters. The experiment is continuing so that broodstock undergo a number of conditioning cycles while fed the diet treatments.

For broodstock diet work:

- Improving spawning success and offspring performance of farm-grown abalone
- Successful conditioning and spawning of farm-grown broodstock.
- Improved survival of offspring spawned from farm-grown broodstock.
- Improved conditioning diets.

For nursery management work:

- Evaluation of alternative feeds and nursery systems during the latter phase of abalone nursery production.
- Identification of suitable micro- and macro-algal food species.
- Increased growth rates.
- Reduced variance in growth.
- Reduced mortality at weaning.
- Long term enhanced performance (survival and growth) in the growout phase through improved nutritional and health status of animals during the later nursery phase.
- Cost-benefit analyses: The analyses will provide farmers with a decision making tool with respect to the choice of alternative nursery systems.

2004/233: Immune biology and immune response to stress

Project status: Project commenced in July 2004. Review of literature underway. Pilot trials to assess methodology underway.

As the project has run for only 6 months no outputs have been achieved to date.

- To improve understanding of methods to assess abalone health, leading to increased productivity and profitability.
- Establish normal variation in abalone immune parameters to provide a standard for use in future studies and any routine health monitoring program.
- To provide an assessment of the relative value of adding immunological parameters to the basic histological assessment used in the South African abalone health monitoring program.
- Provide an assessment of the effect of particular stressors on immune function, possibly leading to specific recommendations for minimizing stress and maximizing health under stressful conditions on abalone farms.

Table 6c

How outputs in 2005 contributed to planned outcomes	Planned outcomes
2002/201: A national survey of diseases Project status: State based sample collection program completed in all states. Examination of samples completed in all sates. Draft final report submitted to subprogram for review. CD of pathology underway. Critical Outputs: Comprehensive database on disease occurrence in Australian wild stocks and on farms. Final report due February 2006.	➢ Knowledge of abalone diseases present in Australia and moderate knowledge of their current distribution and prevalence. ➢ Significantly improved diagnostic capability available to both abalone aquaculture and wild fisheries managers. ➢ Surveillance programs for the abalone farming sector to provide cost-effective access to diagnostic services, improved feedback for addressing on-farm factors affecting abalone health, and better assurances with regard to abalone health for farm planning, supply of other farm customers, and market access. ➢ Reduced production costs from reduction in losses and improved health. ➢ A sound basis for decision making with regard to movement and testing protocols for interstate and intra-state movements, quarantine issues, and reseeding operations, which will benefit both the farmed and wild abalone industries, and improve public confidence in farming and reseeding operations. ➢ a significantly improved basis with regard to trade access issues, claims of disease freedom, and likely disease related quality risks to trade. ➢ Improved knowledge of the likelihood of paralytic shellfish poisoning issues occurring in abalone ➢ a sound basis for prioritising future research needs such as further investigation of specific diseases, or extending parts of the survey to meet international standards for official freedom from certain diseases
2002/202: Genetic markers Project status: All of the 127 microsatellite markers new to science were successfully genotyped across all families. Changes to the objectives were made to further test and validate marker segregation between low and high performing animals within selectively bred families. In addition, the construction of a microsatellite marker linkage map is being undertaken to better identify the marker distribution, genome size and QTL location, which is critical information for the downstream applicability of markers in selection. This is a key resource for future research into QTL development. Critical Outputs: Fundamental knowledge and database of marker occurrence in	➢ Establishment of a comprehensive advanced genetic selection program based on the integration of phenotypic data and genetic markers. Likely 3% annual improvement in API for private growers adopting the technology. ➢ Augmentation of existing microsatellite markers to give a total of at least 150 markers with coverage including every abalone chromosome. ➢ Completion of a comprehensive genome scan and identification of quantitative trait loci affecting the API. The benefit to industry is a set of gene markers that can be used to fast-track the rate of genetic improvement in the commercial sector.

abalone that is critical information for the downstream applicability of markers in breeding selection.

- Measurements of genetic diversity within and between cultured stocks.

2003/203: Broodstock diets and nursery management

For nursery management work:

Project status: This year's work broadened the range of algal species identified as suitable macroalgae and diatoms as feed during the latter phase of nursery production. Growth trials continued during 2004/05 to identify suitable 3D diatom species provided on vertical plates for juvenile greenlip abalone and to compare the economics of raising juvenile abalone in traditional nursery tanks with diatom covered plates versus transferring them at 7mm to weaner tanks with formulated feeds.

Ulva germlings and *Navicula* provided adequate feed for larger juveniles during the latter phase of nursery production. Results suggest that juvenile abalone can only be successfully maintained on a diatom diet for 10 weeks (to ca. 7 mm in SL). After 10 weeks growth was higher in weaner tanks due to better food availability, although mortality due to transfer to the new system was higher (20 $\pm$ 1.38 %) during the first month.

Substantially more labour is involved in culturing and maintaining algae for larger juveniles in the nursery systems compared to the weaner system, suggesting that juveniles should be moved into the weaner system as early as possible.

Critical outputs: Cost/benefit analysis of the economic performance of juveniles raised on nursery plate systems using diatoms compared to weaner systems using manufactured feeds suggests that animals be moved into a weaner tank system once they reach 7 mm. Animals should be provided with a diatom film in addition to the formulated feed for the first few weeks to reduce the stress of the weaning process. There may be an advantage, in terms of reducing mortality associated with the stress of transfer, of feeding *Ulva* germlings on the plates prior to the transfer.

For broodstock diet work:

Project status: A new greenlip abalone broodstock conditioning trial, utilising farm grown F1 broodstock, was commenced in 2005. Two spawnings have been conducted and some successful F2 batches were settled. A final spawning is scheduled for August 2005.

For broodstock diet work:

- Improving spawning success and offspring performance of farm-grown abalone
- Successful conditioning and spawning of farm-grown broodstock.
- Improved survival of offspring spawned from farm-grown broodstock.
- Improved conditioning diets.

For nursery management work:

- Evaluation of alternative feeds and nursery systems during the latter phase of abalone nursery production.
- Identification of suitable micro- and macro-algal food species.
- Increased growth rates.
- Reduced variance in growth.
- Reduced mortality at weaning.
- Long term enhanced performance (survival and growth) in the growout phase through improved nutritional and health status of animals during the later nursery phase.
- Cost-benefit analyses: The analyses will provide farmers with a decision making tool with respect to the choice of alternative nursery systems.

2004/233: Immune biology and immune response to stress

Project status: The first step in this project was to identify an immune assay using phagocytosis, as the literature review suggested that phagocytosis was the most

- To improve understanding of methods to assess abalone health, leading to increased productivity and profitability.
- Establish normal variation in abalone immune parameters to

worthwhile immune function test to concentrate on. The outputs for 2005 were preliminary work towards the first listed objective of this project: defining the normal range of parameters for hemolymph and immune function in abalone.

Critical Outputs:

- Review of literature completed and submitted for publication in the journal "Diseases of Aquatic Organisms".
- Carried out experimental trials on the efficacy of anticoagulants on abalone blood and assessed the best methods to count blood cells (haemocytes) and maintain them in a functional state.
- Defined the cell types in abalone blood via flow cytometry
- Commenced work to define an immune assay using phagocytosis, as the review suggested that phagocytosis was the most worthwhile immune function test to concentrate on.
- The above outputs are preliminary work towards defining the normal range of parameters for hemolymph and immune function in abalone, which will be achieved in 2005/06.

provide a standard for use in future studies and any routine health monitoring program.

- To provide an assessment of the relative value of adding immunological parameters to the basic histological assessment used in the South African abalone health monitoring program.
- Provide an assessment of the effect of particular stressors on immune function, possibly leading to specific recommendations for minimizing stress and maximizing health under stressful conditions on abalone farms.

Table 6d

How outputs in 2006 contributed to planned outcomes	Planned outcomes
2002/201: A national survey of diseases Project status: Final report published October 2006. CD of Pathology due March 2007. Critical Outputs: Outputs have provided farmers and aquatic animal pathologists with a sound knowledge of abalone diseases that occur in Australian wild stocks and on farms. This information can now be used to make informed decisions about health surveillance protocols, translocation protocols, health certification methodology, etc.	➢ Knowledge of abalone diseases present in Australia and moderate knowledge of their current distribution and prevalence. ➢ Significantly improved diagnostic capability available to both abalone aquaculture and wild fisheries managers. ➢ Surveillance programs for the abalone farming sector to provide cost-effective access to diagnostic services, improved feedback for addressing on-farm factors affecting abalone health, and better assurances with regard to abalone health for farm planning, supply of other farm customers, and market access. ➢ Reduced production costs from reduction in losses and improved health. ➢ A sound basis for decision making with regard to movement and testing protocols for interstate and intra-state movements, quarantine issues, and reseeding operations, which will benefit both the farmed and wild abalone industries, and improve public confidence in farming and reseeding operations. ➢ A significantly improved basis with regard to trade access issues, claims of disease freedom, and likely disease related quality risks to trade. ➢ Improved knowledge of the likelihood of paralytic shellfish poisoning issues occurring in abalone ➢ A sound basis for prioritising future research needs such as further investigation of specific diseases, or extending parts of the survey to meet international standards for official freedom from certain diseases
2002/202: Genetic markers Project status: Final report submitted and approved by subprogram. Critical Outputs: The identification of 28 potential markers for growth provides exciting evidence for the feasibility of the work to enhance the selection process within the selective breeding project in the future.	➢ Establishment of a comprehensive advanced genetic selection program based on the integration of phenotypic data and genetic markers. Likely 3% annual improvement in API for private growers adopting the technology. ➢ Augmentation of existing microsatellite markers to give a total of at least 150 markers with coverage including every abalone chromosome. ➢ Completion of a comprehensive genome scan and identification of quantitative trait loci affecting the API. The benefit to industry is a set of gene markers that can be used to fast-track the rate of genetic improvement in the commercial sector.

- Measurements of genetic diversity within and between cultured stocks.

2003/203: Broodstock diets and nursery management

For nursery management work:

Project status: In 2006 an extensive trial compared newly isolated algal species for their ability to provide sufficient food biomass for 5-15mm juvenile abalone in the nursery system of a commercial abalone farm. Three propagation methods were investigated. In addition a feeding trial was conducted to investigate the dietary value of a fragmented red alga, *Laurencia* sp., compared to the currently used commercial diet consisting of the green alga *Ulvella lens* plus the diatom species *Navicula cf. jeffreyi* and a manufactured diet for juvenile greenlip abalone. Final report submitted to subprogram and under review.

Critical Outputs: Vegetative reproduction by fragments appears to be a suitable method to produce red algal diets on a commercial nursery scale. Substantial work still needs to be done to optimise fragment regeneration and growth rates before red algal fragments can provide juvenile abalone with a suitable diet in the later nursery phase.

Broodstock Diets:

Project status: Two long-term broodstock conditioning experiments were conducted in 2006 to identify specific nutritional components that improved spawning success and offspring performance. The experiments evaluated different formulated conditioning diets and a red seaweed diet in terms of spawning success and offspring performance.

In the first experiment using wildstock, there was no difference in spawning success between the treatments. The second experiment compared farm-grown F1 broodstock. Results from this trial suggest that the ratio of the PUFA ARA/ EPA in abalone eggs may be important for the performance of abalone offspring. In addition, abalone eggs contained lower relative amounts of protein during times of lower spawning success. A pre-spawning screening test of broodstock gonad tissue may be possible using relative amounts of protein to predict spawning success.

Females feeding on formulated diets spawned larger batches of eggs than females feeding on red seaweed but a higher percentage of eggs derived from formulated feed treatments were not fully developed. The PI concluded that other vital ingredients present in red seaweeds are potentially missing in formulated diets. Final report submitted to subprogram and under review.

For broodstock diet work:

- Improving spawning success and offspring performance of farm-grown abalone
- Successful conditioning and spawning of farm-grown broodstock.
- Improved survival of offspring spawned from farm-grown broodstock.
- Improved conditioning diets.

For nursery management work:

- Evaluation of alternative feeds and nursery systems during the latter phase of abalone nursery production.
- Identification of suitable micro- and macro-algal food species.
- Increased growth rates.
- Reduced variance in growth.
- Reduced mortality at weaning.
- Long term enhanced performance (survival and growth) in the growout phase through improved nutritional and health status of animals during the later nursery phase.
- Cost-benefit analyses: The analyses will provide farmers with a decision making tool with respect to the choice of alternative nursery systems.

2004/233: Immune biology and immune response to stress

Project status: Progress in this project, in terms of meeting planned objectives, has been slow over the past year. The nature of the work is such that a lot of lab work can lead to unclear and inconclusive results. In addition the staff have focused some of their time on the abalone virus outbreak in Victoria. However, outputs need to be delivered in 2007 and the steering committee will monitor the work done to determine if a closer control on delivery of outcomes is necessary. A request from the PI has been made to alter the original objectives. A review by the subprogram leader, the steering committee and an independent expert has been scheduled for December 2006.

Critical Outputs:

The first step in this project was to identify an immune assay using phagocytosis, as the literature review suggested that phagocytosis was the most worthwhile immune function test to concentrate on. The outputs for 2006 continued the earlier work towards the objective of defining the normal range of parameters for hemolymph and immune function in abalone and how these vary in stressed abalone. Work on haemocytes and flow cytometry analysis has shown differences in these parameters between stressed and healthy abalone, although the differences remain obscure.

- To improve understanding of methods to assess abalone health, leading to increased productivity and profitability.
- Establish normal variation in abalone immune parameters to provide a standard for use in future studies and any routine health monitoring program.
- To provide an assessment of the relative value of adding immunological parameters to the basic histological assessment used in the South African abalone health monitoring program.
- Provide an assessment of the effect of particular stressors on immune function, possibly leading to specific recommendations for minimizing stress and maximizing health under stressful conditions on abalone farms.

BENEFITS

Outcomes achieved

Planned outcomes achieved during this project include:

1. Improvement in production technology for the successful commercial culture of the two commercially valuable abalone species, and knowledge and processes that allow the successful feeding, health management, husbandry, genetic improvement, harvesting and sale of abalone from larva to market size through the implementation and facilitation of strategic research and extension for the net benefit of the Australian abalone aquaculture sector.

2. Reductions in the cost of conducting highly focused research into abalone aquaculture while improving the quality and quantity of outputs from the research program for the net benefit of the Australian abalone aquaculture sector.

3. Improvements in the extension of research results arising from research into abalone aquaculture.

Direct benefits and beneficiaries

Coordination of existing and new projects in abalone aquaculture will result in continual savings in the operation of projects with a common research goal (through coordinated travel and workshop budgets combined with more efficient use of limited research funds). As stated previously, the current subprogram coordination project has resulted in savings exceeding $500,000. Industries benefiting from the existence of the AAS include the aquaculture sector, abalone feed manufacturers, aquaculture infrastructure and equipment, and end-users of abalone products.

External review of benefits of subprogram to industry

As part of the cessation of the subprogram in September 2006 and handing the role of R&D management over to industry, FRDC funded an external, independent review to assess the performance of the subprogram over the past 6-7 years and to assist the industry in identifying a mechanism that would ensure they continued to achieve the objectives of the subprogram into the future. Namely to maximise the practical benefits of R&D through better strategic planning and prioritization that is responsive to changing circumstances of the industry, that avoids duplication, that optimizes selection of research providers and methodology, that promotes closer collaboration and communication between research providers and industry and promotes and facilitates the earliest and most widespread commercial adoption of research outputs. The reviewer was also asked to provide recommendations on how FRDC may best invest in the sector in the future, including possible management models for research, and identify key challenges and associated deliverables/outputs for the sector for the next 5-10 years.

The review evaluated twelve FRDC funded projects managed by the Abalone Aquaculture Subprogram since 1999. In achieving the above aims the review comprised seven tasks:

- A review and evaluation of projects managed by the subprogram since 1999,
- An assessment of the degree that these projects have met their objectives,
- As assessment of the benefits to end-users,
- An assessment of the management of these projects by the subprogram,
- Identification of bottlenecks that have affected the timely adoption of research outputs.

The industry strongly endorsed the FRDC in managing the subprogram. This endorsement included the selection of R&D topics of high strategic and commercial importance to industry, use of appropriate research providers and appropriate apportionment of available funds across the 12 projects. Respondents also endorsed subprogram management and research providers in the

shared responsibilities of establishing and maintaining generally adequate to high standards of communication, collaboration and consultation with industry.

The review highlighted the difficulty that industry had with research providers in delivering outputs in what they deemed to be a timely manner. They were also concerned that some researchers were driven by the “publish or perish” imperative, which meant that commercial objectives were relegated to second priority.

The AAGA committee was consulted on their views for the future of R&D planning and management. They support a similar model to the subprogram where all industry members are consulted on R&D priorities. The committee decides on projects to be submitted and then seeks the appropriate research provider for the work either through direct invitation or calls for expression of interest. Projects are managed by milestone reporting and results communicated via an annual workshop and regular email updates. The committee stressed that selection of research providers will be by track record, consultation with FRDC advice, speed of delivery and practical outputs. They will explore ways to foster on-farm based R&D and ways to redress the negative impact of “publish or perish imperative” borne by many research providers.

The review also recommended to the director of FRDC that a further transitional period was required in order to maintain the skilled capacity for R&D planning and management that has been built up over the past 13 years by the Abalone Aquaculture Subprogram. It was recognised by the reviewer that the technical expertise of the R&D manager in facilitating the committee to make *informed* decision regarding strategic planning, project development and research management is a key component in ensuring the highest commercial return to the industry through investment by the FRDC. As a consequence the director extended the funding for the current coordination project 2003/202 until December 2007. During the interim period AAGA will work with FRDC to develop an alternative model, such as an R&D subcommittee under AAGA, which may be co-funded by both FRDC and AAGA.

FURTHER DEVELOPMENT

During early 2006 the subprogram underwent an independent review of its performance and within the recommendations to the director of FRDC was that a further period of handing over of the role of R&D management was required in order to maintain the skilled capacity for R&D planning and management that has been built up over the past 13 years by the Abalone Aquaculture Subprogram. It was recognised by the reviewer that the technical expertise of the R&D manager in facilitating the committee to make *informed* decision regarding strategic planning, project development and research management is a key component in ensuring the highest commercial return to the industry through investment by the FRDC. As a consequence the director extended the funding for the current coordination project 2003/202 until December 2007. In recognition by the industry of the subprogram's value, the recently formed national peak body, the Australian Abalone Growers Association, will seek to continue an R&D planning and management body as part of its operational processes. During the interim period AAGA will work with FRDC to develop an alternative model, such as an R&D subcommittee under AAGA, which may be co-funded by both FRDC and AAGA.

PLANNED OUTCOMES

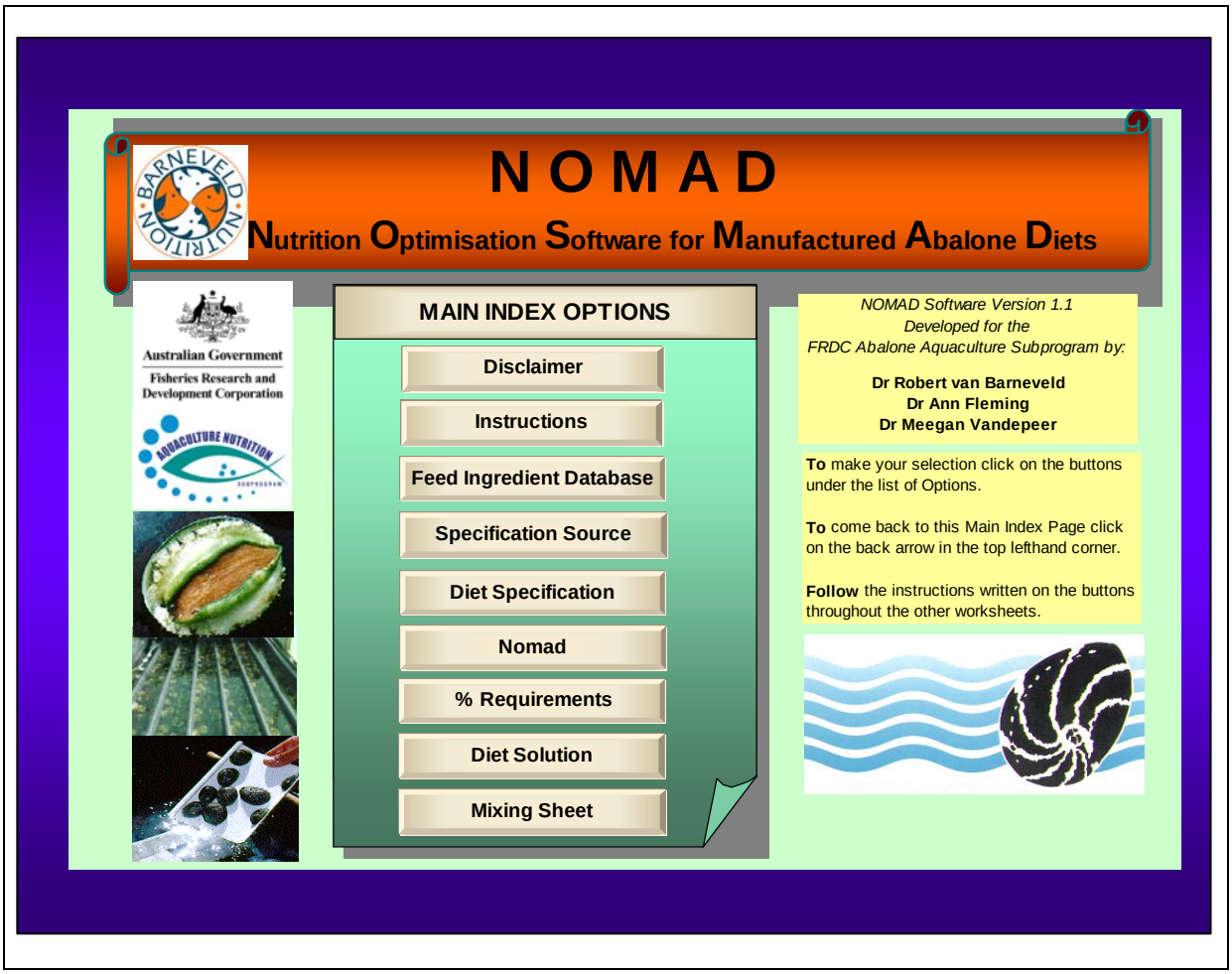
Nutrition: Cost effective feed that meets the nutritional requirements for growth

A reliable diet source was the greatest barrier to the expansion of an abalone aquaculture in Australia in 1993. The development of a manufactured diet under the management of the subprogram broke this barrier between 1993-96 and produced a diet demonstrated to be world class.

The cost of ingredient inclusion in the manufactured diet has reduced from $2.40/kg in 1993 to $1.30 in 1996 to $<1.00/kg in 2002. The cost of feed for the farmer has reduced from $5.50/kg (1993) to $3.50 (1993) to $1.96 – 2.27/kg (2006) representing a 60% cost reduction. Feed accounts for approximately 30% of costs, therefore this has saved farmers approximately 16.5% of total production costs.

Farmers are able to achieve annual average growth rates between 70-100 μm/day. This is a significant improvement on the average of 30-85 μm/day achieved in 1993.

A key component of the Abalone Aquaculture Subprogram's role is to ensure adoption of results from nutrition research by delivering data in a form that is easily usable by feed manufacturers and farmers. It was recognised in recent years that the results of the work on diets was somewhat disperse, and not in a form that could be readily taken up by feed formulators and farmers. As a result the Nutrition Subprogram was contracted by the Abalone Aquaculture Subprogram to develop a simple abalone diet formulation software, using Microsoft's excel, that brings together all the data produced in Australia and other relevant data from overseas. This software is called NOMAD, for Nutrition Optimisation Software for Manufactured Abalone Diets. This was sent to all farmers and feed companies in mid 2005.



Nutrition: Effect on immune health

The industry is now matured to a point where the primary nutrition focus has shifted from fundamental issues, such as basal diet development, to improvements in nutritional efficiency. This approach addresses the key nutritional drivers of profitability. In recent years the key driver of profitability in terms on nutrition has focused on boosting the health/immune status. In project 2002/200 the industry was concerned that the ingredients in feeds were causing summer mortality during high temperature peaks due to undigested feeds fermenting in the gut and acting as a site for bacterial proliferation. This project showed that lab animals fed commercial diets were capable of surviving high summer temperatures. It was concluded that farmed animals were more susceptible due to other stresses impacting on their immune health (such as stocking density, poor water quality, handling and anaesthetics) (see *Husbandry* for further discussion).

Tank Technology

One of the earliest outcomes of the subprogram was the enormous stride that was made in developing more cost-effective land-based tanks for abalone growout. Farmers themselves undertook this work, with the subprogram providing the scientific methodology and rigour. The outcome of this work provided the basis for the continual development of growout tanks that has occurred since. Today there is a range of state-of–the-art growout tanks that are commercially available and meet the biological and economic specifications set by the industry in earlier years.

The concurrent development of growout tanks and manufactured feeds have led to a reduction in production time (to a market size of 70-80mm) from 4-5 years in 1993 to 3.5 years in 2006.

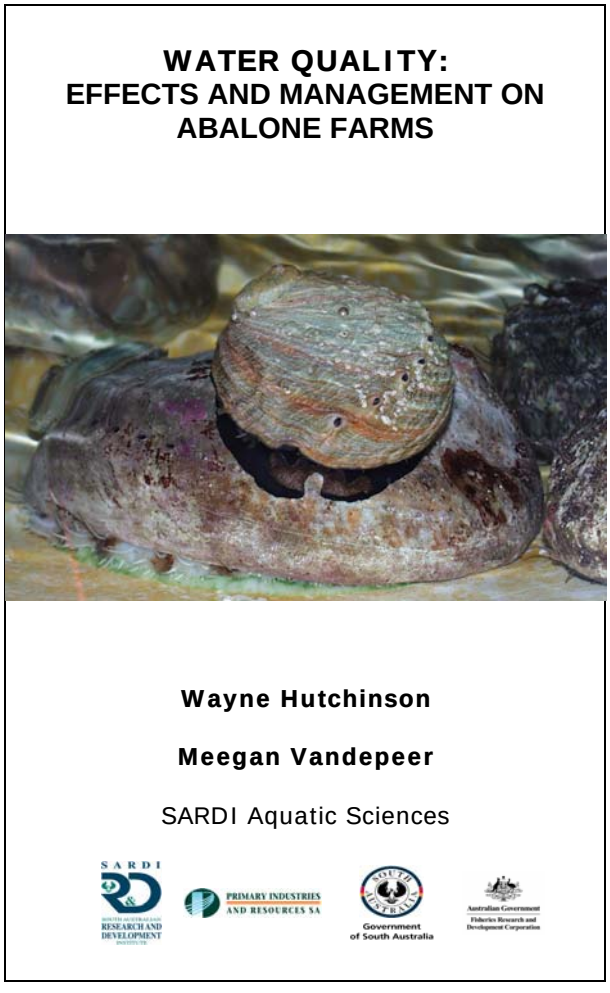
Slab tank at Kangaroo Island Abalone, 2005

Since the slab tank was developed in 2000 it has become the main system used in Australia. Some farmers use concrete while other use welded plastics. The size and dimension differ between farms and some farms have experimented with cascading the tanks to use water more efficiently. During the past 3.5 years farms have experimented extensively to determine the best management strategies for these tanks to ensure high water quality and growth performance.

Husbandry

Basic husbandry techniques have been improved at commercial facilities through a better understanding of abalone environmental requirements (for parameters such as ammonia, nitrates, nitrites, Ph, oxygen, etc). Abalone are particularly sensitive to various wastes common in growout tanks. Farmers have had to learn that tank management is critical to the health of animals (through stress caused by too high stocking density, poor water flow characteristics across tanks, oxygen depletion down the length of the tank, nitrogenous waste and bacterial buildup in areas of the tank, etc). This was shown to be a critical aspect of the high summer mortality associated with *Vibrio* outbreaks experienced on many farms, but in particular in SA. The stresses act to compromise the immune system and when the additional stress of high temperature is imposed, animals are unable to withstand this additional stress. This makes them vulnerable to *Vibrio* attach which lead to mass mortalities.

The project on the effect of diet on summer mortality (2002/200) highlighted this relationship between poor water quality and health. Manufactured diets probably contribute to mortality and bloat as they are excellent media for bacterial growth, but were not the primary cause of mortality. Consequently the project redirected its objectives to produce a manual on water quality, providing farmers with known tolerances by abalone for various parameters, how these impact on health, and how to conduct a monitoring program of critical parameters to assess husbandry management practices on farm.



Health

The first health projects to be funded under the subprogram were a project on mudworm biology and eradication methods and a project on antibiotic effectiveness and delivery mechanisms.

In 2002 funding was approved to undertake a survey of Australian abalone diseases along the southern coastline of Australia (2002/201). The resultant extensive database has provided vet pathologists with a comprehensive histological atlas of abalone disease pathology and is currently being used by them to facilitate the development and scope of state-based industry-funded health surveillance programs.

Funding was also provided in 2002 to determine the role that nutrition played in the recurrent summer mortality problems experienced by some farmers. This work has highlighted the need for farmers to monitor and manage water quality during summer to reduce stress and maintain immune health. Poor water quality management has been identified as the primary cause of *Vibrio* outbreak (see *Husbandry* for further discussion).

Over recent years there has been a strong shift in focus from performance to health. Increasingly, the industry is looking at how health might be improved to enable stock to better cope with intensive farming practices. It is recognised that intensive farming exposes the stock to stresses, such as high density, suboptimal water quality, anaesthetics, handling. This stress results in a multitude of physiological responses, some of which compromises the animal's ability to cope with additional stresses (such as summer temperatures) and some involve the immune system leading to a reduced ability to fight infections, such as *Vibrio*. Consequently the subprogram is currently managing a project that aims to gain some fundamental understanding of how the immune system works in abalone (2004/203) and to identify immune parameters that might lead eventually to a stress test for assessing the health status of stock. Over the past year the subprogram has facilitated the development of a strategic plan for nutrition research. Within this plan, one of the key nutrition targets identified by the industry as of high priority was the interaction between nutrition and health status. It is anticipated that future research will focus on this key target, as the industry believes that it offers the greatest return on their R&D investment.

Genetics

The projects funded between 2000 - 2001 (2000/201) and 2000 - 2002 (2000/254) on selective breeding of abalone on-farm provided a structured genetic improvement program that had a high degree of industry involvement and ownership. These projects provided a significant entry to the development of a comprehensive selective breeding program and the development of an economically viable and sustainable abalone breeding company for the future development of the industry.

The abalone selective breeding program had a major setback in early 2006 with the loss of the majority of its families through the viral outbreak in Victoria. This, and the loss of the capability of farms to re-enter the program for some time, has led to the collapse of the Victorian initiative for the time being.

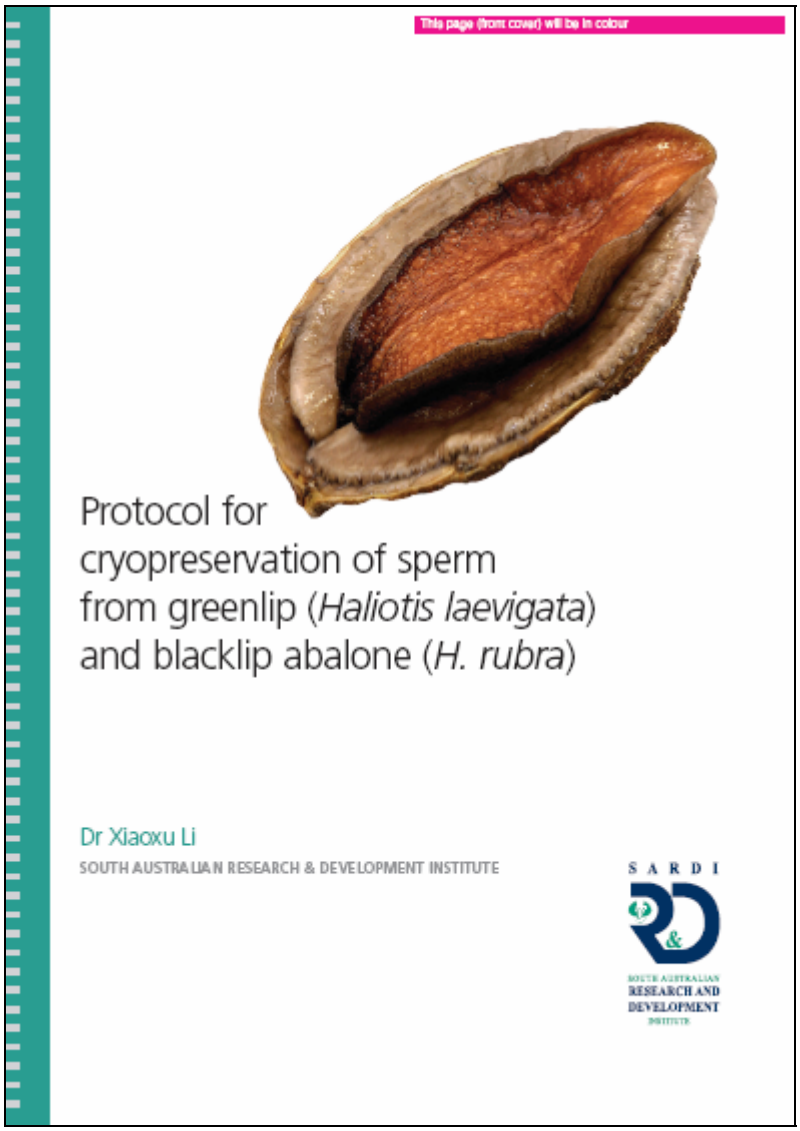
Prior to the viral outbreak, the Victorian industry was working to increase their investment in the breeding program by moving towards a phase of full commitment. The subprogram was facilitating their move to put in place a strategic breeding plan and business structure that would ensure a high number of families established each year to meet the scientific requirements of a good breeding program. The Victorian participants had agreed on a methodology for the group production of family lines that provided security of broodstock, gave equal ownership amongst participants, allowed for R&D to be conducted collaboratively and provided a commercially robust structure that encourages investment from both industry and government. And lastly and importantly, the structure allowed entry and exit of groups nationally so that new participants could decide to participate where they have elected not to before. This methodology of distributing share equally between participants and

allowed for cooperative work on research was a major breakthrough in overcoming the issues of how to share IP between industry participants.

Despite the setback, a new initiative in selective breeding has developed within the Tasmanian industry. They recognise that due to their state's greater restrictions on stock imports, they were unlikely to gain access to selective bred stock from the mainland. Thus industry members sought to form a partnership with CSIRO and their Food for Futures program to develop their own state-based breeding program. One Victorian farm, Great Southern Waters, is also a partner in the program, accessing breeding advice from CSIRO.

Biotechnology

The 2000/202 project on sperm cryopreservation produced a how-to manual for industry. This was published by the subprogram and sent to every farmer in late 2005. This offers the industry the ability to cross specific individuals for selective breeding purposes and allows greater predictability and control of the hatchery process.



The recently completed project (2002/202) on the development of genetic markers for various traits affecting profitability in the industry, such as growth rate and meat to shell weight ratio, has provided fundamental knowledge and a database of marker occurrence in abalone that is critical information for the downstream applicability of markers in breeding selection. The molecular markers will be

used to assist breeding through the identification of sibship, identification of polyploid individuals, marker assisted selection, and identification of other sources of variation in the wild.

Nursery systems

Early research into settlement queues of young juveniles has significantly improved the settlements rate from 1-10% to 30-35%. Most farms in Australia now use the green alga *Ulvella* lens extensively as a settlement queue. Research has also shown *Ulvella lens* (used with naturally occurring diatoms) to be a suitable food for animals up to 5mm. Farmers can now provide adequate feed for optimal growth and health up to this stage of development. The greater control and predictability farmers now have over settlement and food supply has significantly improved the efficiency of management of nursery systems.

In 2003 funding was approved (2003/203) to identify alternative algal species or nursery strategies that would ensure adequate supply of feed for the latter phase of nursery production (from 7mm to 12-15mm). This work highlighted the need to balance suitable algal feeds with the economics of culturing and delivering them on plates. Cost/benefit analysis of the economic performance of juveniles raised on nursery plate systems using diatoms compared to weaner systems using manufactured feeds suggests that animals be moved into a weaner tank system once they reach 7 mm. Indeed, farmers are now developing such techniques themselves, some even using smaller weaner tanks as a transitional phase before growout.

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Gordon, R. and Cook, P. 2001. World Abalone Supply, Markets And Pricing: Historical, Current and Future. J. Shellfish Research, 20(2): 567-570.

Appendix 1: Intellectual Property

None

Appendix 2: Staff

Dr Ann Fleming, Subprogram leader

Appendix 3: Communication and extension plan

Objectives

1. To distribute research outputs (technologies and knowledge) that has a net benefit for the Australian industry and to distribute that information in a timely manner to achieve rapid adoption by industry.
2. To disseminate information about the subprogram's role, activities and achievements to industry stakeholders.
3. To disseminate information to the general public when it contributes to a positive perception of the industry and/or the FRDC and contributes to the public good.
4. To disseminate information to international partners when there is a two-way flow of information

Target audiences

1. The Australian abalone aquaculture industry, abalone feed manufacturers and other industry stakeholders.
2. General public.

Key messages

1. Research outputs from the projects managed under the subprogram.
2. Role, activities and achievements of the subprogram.
3. Positive image of abalone aquaculture (clean and green, environmentally sustainable, economically beneficial for Australia, provides employment in regional Australia)

Communication/Extension methods

Annual workshop
The workshop's primary aim is to deliver information on research outputs to industry stakeholders as it becomes available. It also serves to raise the public perception of the industry in the host state as a body of local media is encourages to attend and report on the workshop and the development of the industry in that state. These media contacts then serve as a resource for the subprogram to deliver key messages to the public as they come to hand.
Action Plan: Annual

Workshop proceedings
The proceedings serve to delivery detailed research outputs. The collection of past proceedings serves as an extensive and valuable resource of knowledge and technologies that can be accessed by the industry on a needs basis. Sales of proceedings are restricted to Australia. However, the Steering Committee may allow overseas sales of past proceedings if it is decided their content no longer provides a competitive advantage to the Australian industry.
Action Plan: Annual

Website
The website serves to communicate current and past research outputs, subprogram activities, industry related events, information on the industry, advise to current researchers, advise to research applicants and publications available. As such, it serves industry stakeholders, potential farmers and investors, the general public, and research providers.
Action Plan: Continual

Newsletter
The newsletter communicates project status, current research outputs, subprogram activities and industry events.
Action Plan: Twice yearly.

Media releases
Media releases will be sent from the subprogram when key messages that contribute to public perception or public good arise. The annual workshop provides a key opportunity to achieve extensive media coverage of the industry, the subprogram and the FRDC.
Action Plan: Seek media coverage of the annual workshop. Send releases as newsworthy items become available.

Articles in magazines/newsletters
Articles on research activities and outputs are regularly submitted to various magazines and newsletters, including the FRDC R&D News.
Action Plan: Send articles as newsworthy items become available.

Evaluation

Communicating research outputs (technologies and knowledge):
- Attendance at annual workshop: 80-90% of industry attendance.
- Number of website visits: Number of website hits and downloads.
- Number of trade magazine articles: 5 per year.

Industry's perception of subprogram's value and contribution:
- Survey by independent reviewers: High level of understanding, high level of approval (80%)

The subprogram also has a Communications Policy to facilitate the orderly release of information produced by research providers managed under the subprogram. This policy covers the publication of final reports and scientific papers and the release of media articles, unsolicited media inquiries/interviews and films.

Appendix 4: R&D Strategic Plan

Via the subprogram leader and the Steering Committee, the subprogram has attempted to have an active role in all industry developments to date by providing planned research outcomes to support industry development.

The subprogram works towards its planned outcomes for industry development by seeking funding for R&D in accordance with the R&D priority-setting plan. The subprogram seeks to manage a balance portfolio of projects that encompass a broad scope of strategies. Consequently, priorities will fall into a range of the following strategies based on the needs of the developing industry, but not all at any given time.

Production and production systems

1. To improve the profitability of production (increased animal growth and survivorship, reduced capital costs, reduced ongoing operational costs, reduced ground area requirements) through the following sub-strategies:

    Technology and husbandry

    1a: To increase and apply knowledge of abalone aquaculture production systems and husbandry management.

    Genetics

    1b: To increase and apply knowledge of genetics to improve the performance of farmed stock.

    Environmental requirements

    1c: To increase and apply knowledge of the environmental requirements of abalone to ensure water quality parameters are met.

    Nutrition

    1d: To increase and apply knowledge of the nutritional requirements of abalone to improve animal performance.

    Feed development

    1e: To increase and apply knowledge of manufactured feeds to improve animal performance and reduce feed costs.

Health

2. To increase the health status of farmed abalone stocks through the following sub-strategies:

    Pests and diseases

    2a: To increase and apply knowledge of the pests and diseases that threaten abalone aquaculture and management strategies to control them.

Chemical use and registration

2b: To increase and apply knowledge of the use of chemicals in abalone aquaculture and seek registration for those used by the industry.

Health surveillance

2c: To increase and apply knowledge of programs to survey the health status of stock on farms.

Stress reduction

2d: To increase and apply knowledge of stress, its effect on production performance and strategies to minimise stress during production.

Quality and food safety

3. To increase and apply knowledge of quality and food safety systems on farms.

Value-adding

4. To increase and apply knowledge of product and process development that will add value to abalone and abalone product.

Market development

5. To increase and apply knowledge of markets for farmed abalone and abalone products.

Information and resource availability

6. To provide knowledge of abalone farming to people involved in abalone aquaculture.

Appendix 5: Publications from the subprogram

Publications from the subprogram included in the accompanying CD

AAS Annual Operational Plans

Fleming, A.E. 2003. Annual Operating Plan – 2003. Abalone Aquaculture Subprogram. December 2003, 20 pp.

Fleming, A.E. 2004. Annual Operating Plan – 2004. Abalone Aquaculture Subprogram. December 2004, 20 pp.

Fleming, A.E. 2005. Annual Operating Plan – 2005. Abalone Aquaculture Subprogram. December 2005, 24 pp.

Fleming, A.E. 2006. Annual Operating Plan – 2006. Abalone Aquaculture Subprogram. December 2006, 36 pp.

AAS Annual Workshop Proceedings

Fleming, A.E (Ed.), 2003. Proceedings of the 10th Annual Abalone Aquaculture Workshop, 19-21st November 2003, Port Lincoln, Australia. Abalone Aquaculture Subprogram, Fisheries Research and Development Corporation, Canberra, Australia, 155 pp.

Fleming, A.E (Ed.), 2004. Proceedings of the 11th Annual Abalone Aquaculture Workshop, 28-30th July 2004, Hobart, Australia. Abalone Aquaculture Subprogram, Fisheries Research and Development Corporation, Canberra, Australia, 44 pp.

Fleming, A.E (Ed.), 2005. Proceedings of the 12th Annual Abalone Aquaculture Workshop, 1st – 3rd August 2005, McLaren Vale, Australia. Abalone Aquaculture Subprogram, Fisheries Research and Development Corporation, Canberra, Australia., 142 pp.

AAS project milestone reports

Fleming, A.E., 2004. Milestone report of the Abalone Aquaculture Subprogram, FRDC. Jan. 2004, 3 pp.

Fleming, A.E., 2004. Milestone report of the Abalone Aquaculture Subprogram, FRDC. April 2004, 3 pp.

Fleming, A.E., 2004. Milestone report of the Abalone Aquaculture Subprogram, FRDC. July 2004, 3 pp.

Fleming, A.E., 2005. Milestone report of the Abalone Aquaculture Subprogram, FRDC. April 2005, 4 pp.

Fleming, A.E., 2005. Milestone report of the Abalone Aquaculture Subprogram, FRDC. July 2005, 4 pp.

Fleming, A.E., 2005. Milestone report of the Abalone Aquaculture Subprogram, FRDC. October 2005, 4 pp.

Fleming, A.E., 2006. Milestone report of the Abalone Aquaculture Subprogram, FRDC. January 2006, 4 pp.

Fleming, A.E., 2006. Milestone report of the Abalone Aquaculture Subprogram, FRDC. April 2006, 4 pp.