Final Report

AQUAFIN CRC - SOUTHERN BLUEFIN TUNA AQUACULTURE SUBPROGRAM: SERVICE DELIVERY AND INFRASTRUCTURE MANAGEMENT FOR PROJECTS REQUIRING PORT LINCOLN BASED R&D SUPPORT

Jeff Buchanan

June 2005

Aquafin CRC Project 1A.5
(FRDC Project No. 2002/249)

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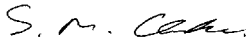
Signed:	
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(FRDC Project No. 2002/249)

SBT AQUACULTURE SUBPROGRAM

SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Australian Government
Fisheries Research and Development Corporation

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1. NON-TECHNICAL SUMMARY

2002/249 Aquafin CRC - Southern Bluefin Tuna Aquaculture Subprogram: service delivery and infrastructure management for projects requiring Port Lincoln based R&D support

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OBJECTIVES:

1. Provide and maintain a managed (staff and budgets) scientific and technical service as required by other project principal investigators (PIs) undertaking southern bluefin tuna (SBT) research and development (R&D) activities in Port Lincoln. These services are provided for experiments conducted in a range of situations: on commercial tuna farms, in the waters adjacent to commercial tuna farms, in the controlled environment of the Tuna Research Farm and in the shore based facilities at the Lincoln Marine Science Centre (LMSC).
2. Ensure, to the level of resources available, that the research facility and procedures are world best practice.
3. Coordinate and therefore optimise the use of the limited resources available for research and development requiring live SBT in a managed research environment, through the development of an agreed project Annual Operating Plan.
4. Complete, in consultation with other project PIs, the planned research and development activities designated in the project Annual Operating Plan, providing the agreed outputs (generally data) in an orderly and timely manner.
5. Support improved communication between project PIs and industry partners.

OUTCOMES ACHIEVED TO DATE

The direct outcomes of this project were:

1. The delivery of a successful experimental service to PIs utilising live SBT in a controlled and managed experimental environment.
2. The provision of appropriate samples and/or data to PIs reliant on this service.
3. Improved understanding of the behaviour of SBT associated with advances in feed development and farm husbandry practices affecting product quality.
4. Improved understanding of great white shark interaction with SBT pontoons.

The long-term outcomes of the SBT Nutrition and SBT Product Quality projects, which relied in large part on the services of this project, include:

1. A more sustainable tuna farming industry through reduced reliance on baitfish as a single nutrient source for production.
2. An enhanced understanding of SBT responses to nutritional inputs and feeding behaviour.
3. A suitable manufactured feed that meets the criteria of "easy to handle, easy to store, highly acceptable and efficiently utilised".
4. Improved understanding of SBT product quality leading to better farm management practices resulting in enhanced product quality and higher market prices.

The project provided scientific and technical support to southern bluefin tuna (SBT) research involving live fish, conducted by the Aquafin CRC as part of the SBT Aquaculture Subprogram. Experiments were undertaken in relation to:

- SBT product quality (Aquafin CRC No. 2.2, FRDC No. 2001-248),
- metabolism in live-held SBT *(*Aquafin CRC No. 1A.7, FRDC No. 2003/228),
- SBT nutrition (Aquafin CRC No. 1A.4, FRDC No. 2001-249).

Support was also given to a range of other projects, including:

- baitfish composition (Aquafin CRC No. 1A.2, FRDC No. 2000-221),
- farm waste characterisation (Aquafin CRC No. 4.3.2, FRDC No. 2001-103),
- environmental monitoring (Aquafin CRC No. 4.3.1, FRDC No 2001-102).

Despite initial quality issues with diets and the intrusion of a 4.5m Great White Shark into a pontoon, experiments were completed successfully in line with the annual operating plan finalised with the SBT Aquaculture Subprogram Steering Committee. The support to the other projects was gratefully approved by project PIs. Results and outcomes from these experiments are

presented in the final report associated with each of the projects that used the specified services provided by this project.

In the conduct of the above-specified experiments, this project utilised 292 live SBT in two 32m diameter experimental pontoons and one 12m diameter holding pontoon on the Tuna Research Farm site offshore of Pt Lincoln, South Australia. At the commencement of this project, the Tuna Research Farm was relocated from its previous site inside Boston Bay to a site 500m North East of Hayden Point with the aim to minimise health issues, enhance production and better represent commercial farm conditions, an important element in facilitating the acceptance of research results by commercial SBT farmers.

The manufactured feed used at the start of the experiments was readily accepted by the SBT, however, significant mortalities occurred early in the season mainly due to dietary problems. To overcome these issues SBT were switched from the pelleted diet to a baitfish diet and the product quality project experiment was redesigned to achieve its objectives using baitfish as the base feed. While SBT harvested mid season had not reached market size and prices were poor, those tuna harvested later in the season had reached industry-standard condition and achieved much higher prices. The dietary problems encountered prevents the anticipated benefits from new site in better health and growth rate being fully realised.

In October 2003 the SBT Aquaculture Subprogram resolved to discontinue the Tuna Research Farm in its present form and move to a commercial farm as a research platform.

KEYWORDS: **Southern Bluefin Tuna, Aquaculture, Subprogram, Aquafin CRC, Research and Development, R&D, South Australia, Aquafin CRC, FRDC.**

2. ACKNOWLEDGEMENTS

This work was a project of the Aquafin CRC and received funds from the Australian Government's CRCs program, the Fisheries Research & Development Corporation and the CRC participants. The staff of this project, Brenton Ebert, Richard Morrison, Michael Bartsch, Chris Leech, Troy Desfontaine and Beverly Stephens played a vital role in completing this project. I wish to thank Mr David Ellis, Tuna Boat Owners Association of South Australia (TBOASA) for his support and advice as well as Mr Steven Clarke, South Australian Research and Development Institute (SARDI) for his project involvement and editorial comments in the preparation of this report. Ian Gordon and Kate Rodda provided invaluable help in removing the Great White Shark.

3. BACKGROUND

The SBT aquaculture industry has grown to be worth $267 million in 2002/03 since its inception in 1990 (Knight *et al*, 2004). It is now a major regional employer in South Australia (Econsearch, 2003). As nearly 100% of the available SBT quota is now being utilised for aquaculture, further growth opportunities for the industry will depend in the short to medium term on longer holding of tuna, improving growth rate, improving survival rates and value adding of product. The Aquafin CRC, FRDC and the SBT Aquaculture Subprogram address these industry research priorities with a range of research projects.

This project provided the infrastructure, expertise and scientific support to conduct the research within the other projects that involve live, or recently slaughtered, SBT. In doing this, this project co-ordinated field activities, minimised duplication of infrastructure and enabled researchers with specific expertise in particular scientific disciplines but not located in Port Lincoln, to actively participate. Experimental data from each of the supported projects is analysed and reported by the principal investigator of the relevant project.

4. NEED

This project was essential for cost effective and cohesive R&D aimed at meeting the priority needs of the highly successful SBT aquaculture industry. While the industry has developed rapidly since its initiation in 1990, R&D is a pivotal requirement to underpin its development and assure the long-term sustainability of the industry. This project was focused on maintaining an offshore SBT R&D capability.

This project involved providing services to:

1. Support research activities undertaken on and around offshore commercial tuna farms;
2. Manage and coordinate the infrastructure for small scale, experimental, high risk and/or novel research and development activities utilising live SBT; and
3. Provide the SARDI-managed onshore facilities at the Lincoln Marine Science Centre (LMSC) and SARDI Tuna Depot at Port Lincoln.

5. OBJECTIVES

- Provide and maintain a managed (staff and budgets) facility as required by other project PI's undertaking small scale, experimental, high risk and/or novel research and development activities requiring live SBT.

- Ensure, to the level of resources available, that the research facility and procedures are world best practice scientifically as well as from an industry perspective.
- Coordinate and therefore optimise the use of the limited resources available for research and development requiring live SBT in a managed research environment, through the development of an agreed project Annual Operating Plan.
- Complete, in consultation with other project PI's, the planned research and development activities designated in the project Annual Operating Plan, providing the agreed outputs (generally data) in an orderly and timely manner.
- Support improved communication between project PIs and industry partners.

6. METHODS/RESULTS/DISCUSSION

6.1 Tuna Research Farm Operation

An overview of farm operations is given here, whereas details of individual experiments are presented in the final reports for the relevant projects.

This project supported the SBT Aquaculture Subprogram by maintaining and conducting, in association with other project PIs, controlled small-scale experiments with live SBT. The yearly research cycle involved three parts: preparing and setting up the research farm for the season; conducting the agreed experiments documented in the Annual Operating Plan whilst maintaining the SBT and infrastructure, as well as marketing the SBT harvested; and finally documenting and disseminating the outcomes of the designated research.

Setting-up for experiments was conducted in October 2002 to January 2003 with preparation and deployment of infrastructure. This involved cleaning nets and pontoons, and preparing feeding equipment and vessels. Due to the decision to relocate the Tuna Research Farm to a more exposed site east of Boston Island (Figure 1), extensive upgrading of equipment and vessels was required at the beginning of 2003. Larger anchors were purchased and two heavy-duty 32m pontoons were assembled. To operate SBT research in more exposed conditions, SARDI purchased the Breakwater Bay, a 14.5m steel vessel. This vessel commenced service in January 2003. At the start of the season two 32m pontoons and two 12m pontoons were deployed for experiments.

Approximately 5.5 tonnes of SBT quota, provided by the TBOASA, were collected from a commercial tuna farm and towed by the Breakwater Bay back to the Tuna Research Farm site in early March.

These tuna were then maintained on the Tuna Research Farm until no longer needed for experimental purposes.

SBT were maintained according to the protocols of the individual experiments. Feeding involved the delivery, defrosting and weighing of feeds onshore, and feeding the SBT twice daily, with the amount of feed fed, measured and documented. During experiments divers inspected nets and recovered any SBT mortalities. At the end of most experiments SBT were harvested and weighed, and sampled inconspicuously for muscle cores. Blood, digesta from the intestine and liver samples were also taken when required. SBT were then processed at Southern Waters Ltd and exported to Japan where they were marketed through fish agent Sirius Oceans Inc. Funds from the marketing offset the costs of research and form part of the annual Tuna Research Farm budget.

During the SBT season the project staff and the research vessel Breakwater Bay also took extensive sediment and water samples from around commercial tuna farms as well as control sites for Aquafin CRC SBT environment project (Aquafin CRC No. 4.3.2, FRDC No. 2001-103).

The post-experimental period involved the collation, reporting and dissemination of data and outcomes to the PI's of other associated projects and industry.

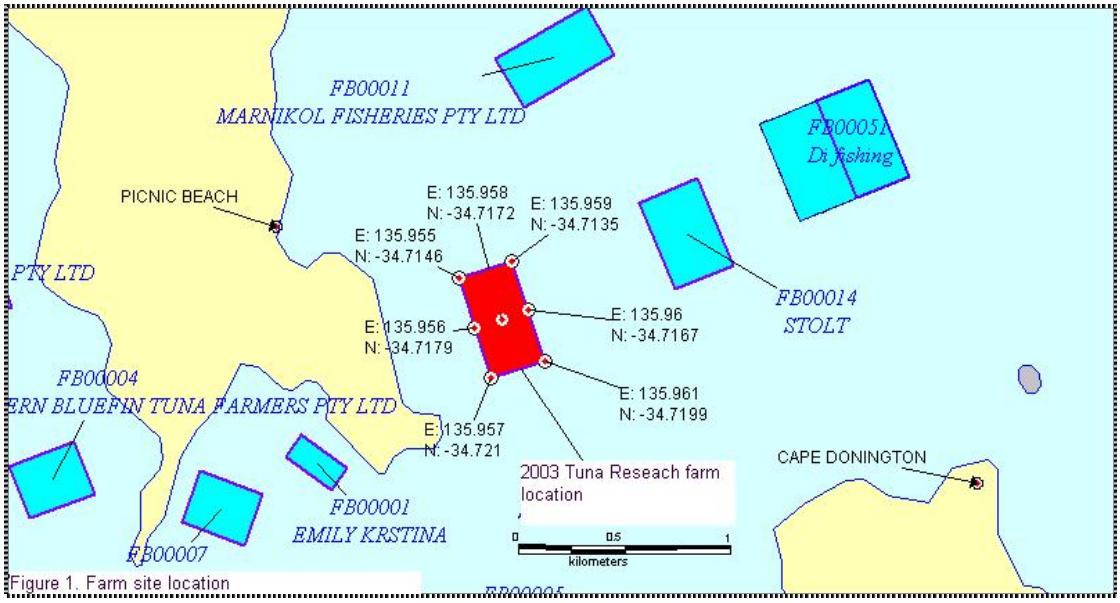

Figure 1. Location of Tuna Research Farm 2003.

6.2 Overview Of Experiments Completed

a) Development Of Manufactured Diets

(Aquafin CRC Project No. 1A.4, FRDC Project No. 2001-249) Aquafin CRC – SBT Aquaculture Subprogram: development and commercial evaluation of manufactured diets.

New manufactured SBT diets were produced by Dr Robert van Barneveld, Barneveld Nutrition, from the Australasian Experimental Stockfeed Extrusion Centre at Roseworthy as part of the Aquafin CRC "nutrition' project. These diets were also planned to be used in both the product quality project's vitamin dose experiment and the environment project looking at waste dispersal using stable isotope enriched diets.

SBT were successfully weaned on to this diet with good initial intakes (Figure 2). However, after four weeks intakes rapidly declined and high mortalities of SBT were experienced. A decision was made to discontinue the use of the manufactured feed and revert to a baitfish diet.

Subsequent investigation found that the SBT were exhibiting pathology "consistent with gross vitamin deficiency" (Dr Colin Johnston, Manager, Fish Health Unit, Primary Industries and Resources South Australia - PIRSA). It was identified that the vitamin premix used in the manufactured feed was deficient and did not provide the specified vitamin levels.

Planned digestibility measurements on diets were consequently deferred until 2004.

b) Vitamin Dose Experiment

(*Aquafin CRC Project No. 2.2, FRDC Project No. 2001-248) Aquafin CRC - Southern Bluefin Tuna Aquaculture Subprogram: maximising the control of quality in farmed SBT.*

The Aquafin CRC "vitamin dose experiment" pre-schedule was provided by Dr Philip Thomas, Flinders University and Dr Jeff Buchanan, SARDI with commencement in June and completion in late August. 292 SBT were held in one of two 32m-diameter pontoons and maintained on a commercial baitfish diet with (high vitamin) or without (control) a vitamin coating.

Diets were fed twice daily, seven days per week. A small sub-sample of 40 SBT were hooked, weighed and tagged at the start of the experiment to provide an indication of growth rates. The SBT were transferred into the treatment pontoons by connecting up the two pontoons and swimming the tuna into the pontoons while observed by a camera system. Swimming tuna into

pontoons is a lot less stressful than using hooking to transfer SBT but doesn't allow SBT to be tagged and weighed removing the ability to measure individual growth rates.

Five sequential harvests of SBT (Table 1) from each treatment were successfully completed within the period of the experiment with flesh samples collected from SBT at each harvest. The data were collated, analysed and reported by Dr Philip Thomas (Project 2001/248 milestone).

c) Tuna Metabolism Project

(Aquafin CRC Project No. 1A.7, FRDC Project No. 2003/228)
Aquafin CRC - SBT Aquaculture Subprogram: activity metabolism in live-held southern bluefin tuna.

The Aquafin CRC "metabolism project" commenced on the Tuna Research Farm in August. Project staff prepared and deployed the flexible oxygen chamber ("mesocosm") and supporting recording equipment into a 12m-research pontoon on the Tuna Research Farm. The system performed well, but rough weather delayed the introduction of live SBT to the system. During gale force weather conditions the chamber lining tore. The chamber was retrieved for repairs and trials in a more protected location were planned for 2004.

d) Tuna Environmental Projects

(Aquafin CRC Project No. 4.3.2, FRDC Project No. 2001-103)
Aquafin CRC - Southern Bluefin Tuna Aquaculture Subprogram: tuna environment subproject - evaluation of waste composition and waste mitigation.
(Aquafin CRC Project No. 4.3.3, FRDC Project No. 2001-104)
Aquafin CRC - Southern Bluefin Tuna Aquaculture Subprogram: tuna environment - development of regional environmental sustainability.

Vessels and staff were provided for the collection of environmental samples for Aquafin CRC "environment projects". This involved deployment and collection of sediment traps, collection of benthic samples using the HAPS corer and collection of water samples. During this process 32 water samples and 384 sediment samples were collected across 16 sites, (Figure 2), during a two week period.

Project staff also provided support for the design, installation and maintenance of a water quality monitoring telemetry system.

The planned waste dispersal experiment using N^{15} labelled feed had to be postponed to 2004 after diets were changed from pellets to baitfish.

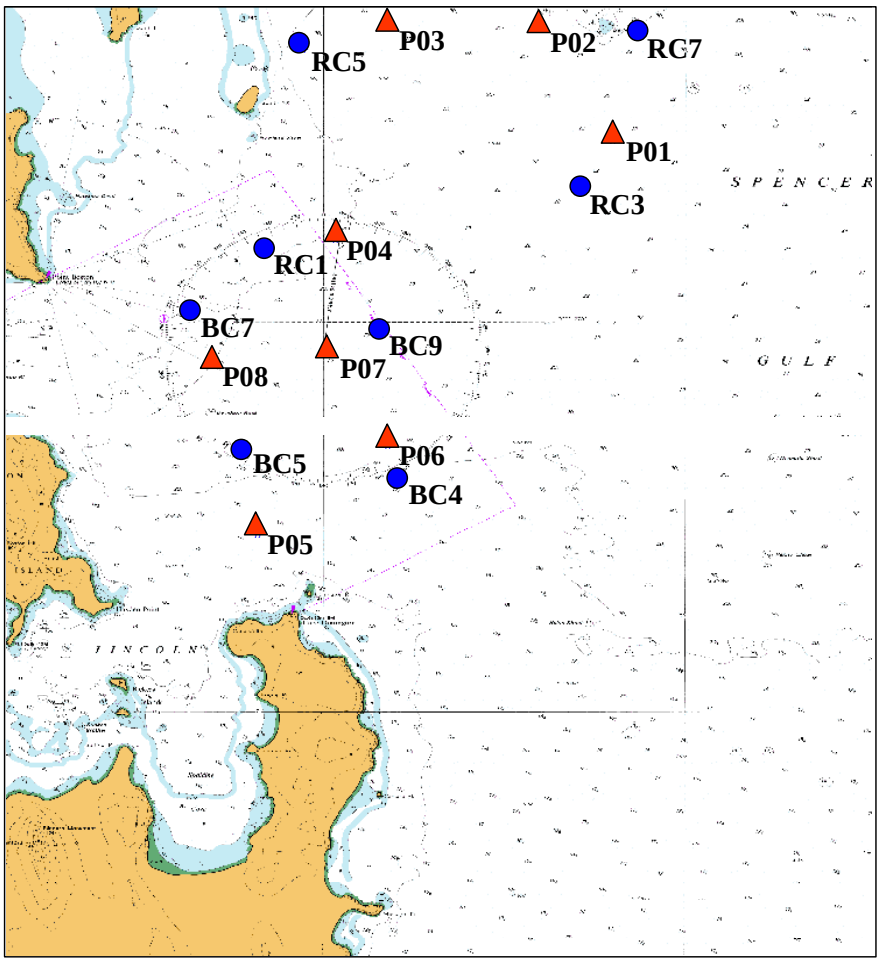

Figure 2. Locations for environmental sampling undertaken by Breakwater Bay. Eight control site (circle) and eight farm sites (triangle) were sampled.

6.3 Overview Of SBT Performance On The Tuna Research Farm During 2003

a) Tuna Harvest Data

SBT were harvested from the Tuna Research Farm from June to August. Only 15 tagged SBT were retrieved and growth was highly variable (Figure 3). As most SBT were not tagged, growth of individual fish could not be determined. Only harvest weights, lengths and conditions could be measured for most tuna. The SBT from the first two harvests were in poor to moderate condition, probably due to the initial dietary problems.

By mid July, SBT had recovered and they then maintained condition comparable to industry standards, with condition indexes of above 25 (Table 1).

Table 1. Performance of SBT harvest on the Tuna Research Farm during 2003.

Harvest Date	Number of SBT Harvested	Live weight# Average (kg)#	Live weight Range (kg)#	Condition index*±SD
2/6/03	10	33.9	23.5-45.0	21.2±1.56
30/6/03	23	39.1	16.5-73.3	22.7±1.90
15/7/03	20	42.0	15.2-86.4	24.7±1.88
27/7/03	26	44.0	15.3-81.5	25.1±1.96
18/8/03	32	41.2	18.9-96.6	25.7±2.14
25/8/03	32	43.1	18.7-80.0	25.3±1.87
26/8/03	17	33.8	20.5-59.5	25.0±1.99

Calculated from gilled and gutted weight divided by 0.875 on occasion where direct measurements of live weight were not possible due to rough weather during harvesting.

*Condition Index (CI) was calculated using the formula CI = (GG/K)/L^3
Where L is tuna length in metres, GG is gilled and gutted weight in kilograms
And K is 0.875 (the conversion factor to live weight)

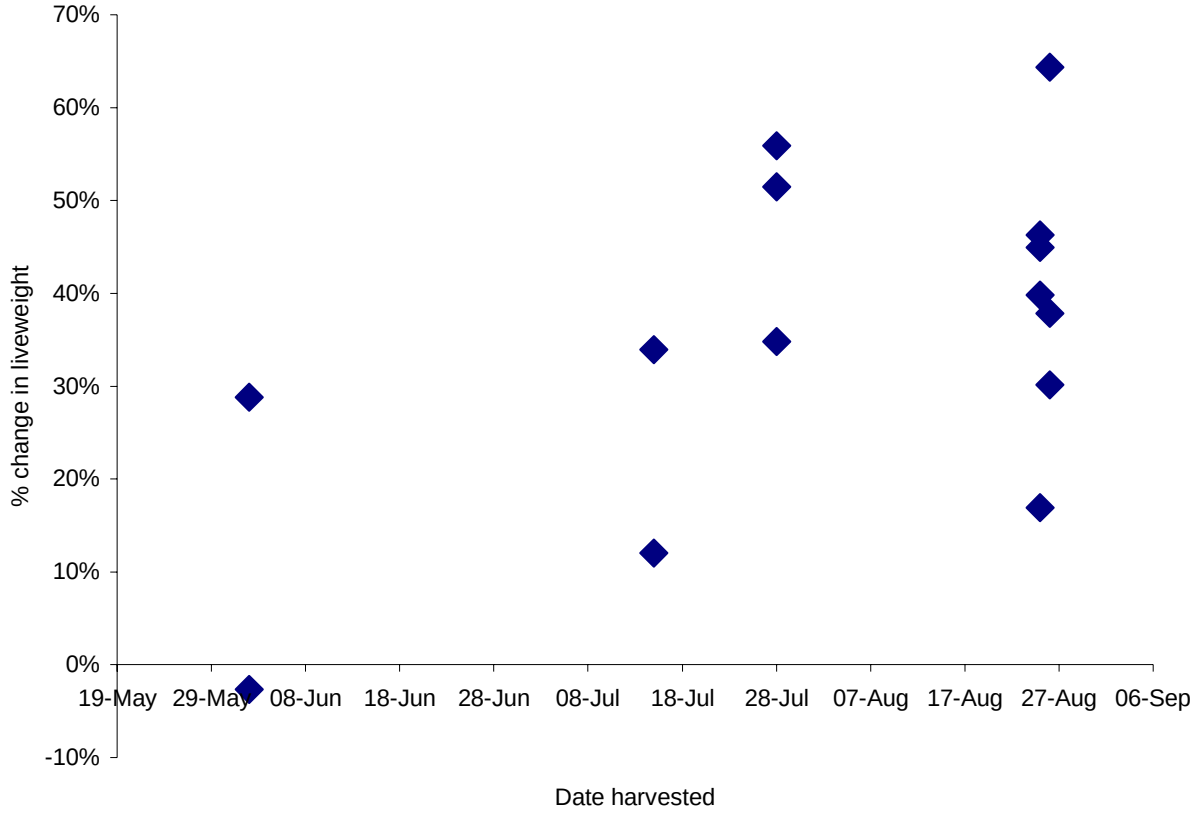

Figure 3. Weight gain of SBT tagged in TRF in 2003. SBT were tagged on 28/3/03.

b) Feed Intake

Feed intakes (Figure 4) increased rapidly over the first two weeks and reached a plateau of 1.6kg/tuna/day at the beginning of March. Intakes then dropped substantially in April as the issues with vitamin deficiency emerged. By April 26th the decision was made to switch the SBT onto baitfish diets. Intakes increased again after the diets were changed (Figure 5). The intake of baitfish slowly declined with declining water temperature.

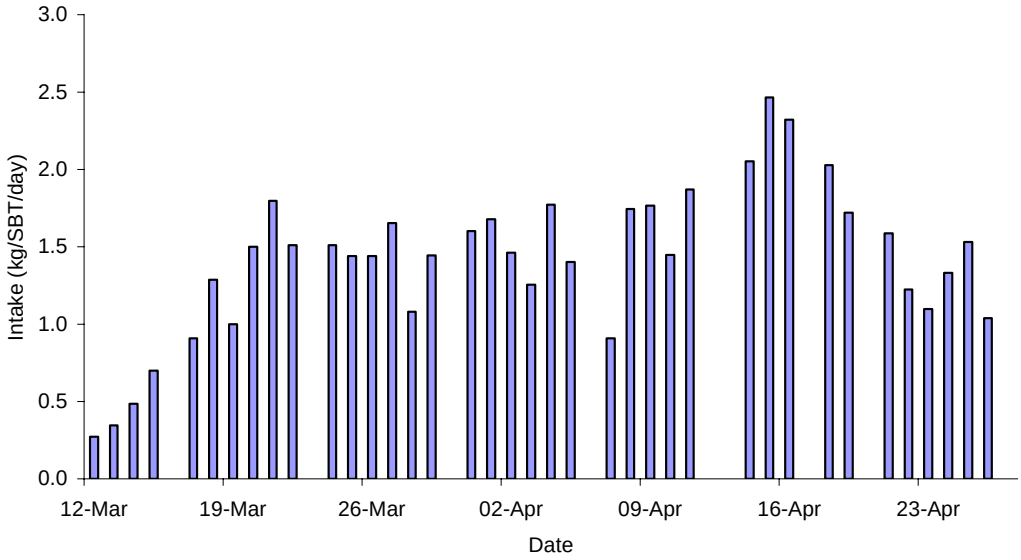

Figure 4. Apparent intake of pellets for SBT on the Tuna Research Farm in 2003. Note values for the last seven days over-estimate of intakes as excess feed was offered trying to stimulate feeding behaviour and maintain intakes.

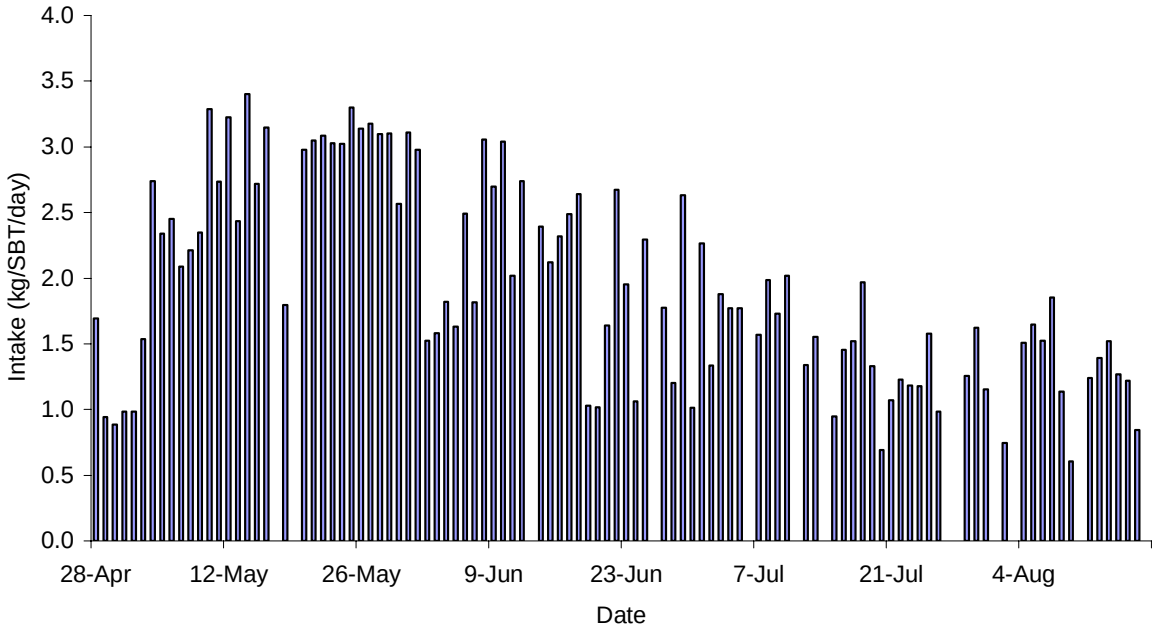

Figure 5. Apparent intake of baitfish by SBT on the Tuna Research Farm in 2003. Gaps in feeding are caused by rough weather or harvests preventing feeding.

c) Fish Health

The primary cause of SBT mortality in 2003 was concluded to be dietary induced vitamin deficiency and oxidative stress. Figure 6 gives the cumulative mortality for the season. In mid April mortalities increased rapidly and food intake fell sharply. As there had been no predator attacks, water quality parameters (dissolved oxygen, temperature) were in normal ranges, there were no unusual levels of toxic algae detected and feed intakes were falling, the problem was suspected to be dietary. To address the alarming death rate the decision was made, after consultation within the SBT Aquaculture Subprogram, to switch diets to baitfish. To more definitely identify the sources of the problem, two SBT were slaughtered and tissues sent to Dr Colin Johnston, Manager, Fish Health Unit, PIRSA for examination. Dr Johnston identified pathological tissue changes consistent with vitamin E deficiency similar to "salmon fed rancid feed low in vitamin E". Analysis of the samples of the manufactured feed found vitamin E levels of 5mg/kg (<8 IU/kg), which were less than one-twentieth of the formulated level. This corresponds to about one-fifth the vitamin intake of SBT consuming fresh local pilchards, which typically have 8-12mg/kg vitamin E. The problem was eventually traced back to a faulty vitamin premix from a commercial supplier. We were advised all vitamins in the premix were at abnormally low levels (this was not directly measured in the feed). It is likely that the SBT were suffering from multiple vitamin deficiencies not just vitamin E deficiency.

Mortality rate rapidly decreased with the change of diets and was very low in the period July to August. The intrusion of a Great White Shark into the control pontoon for six days in late June had a surprisingly small effect on mortalities.

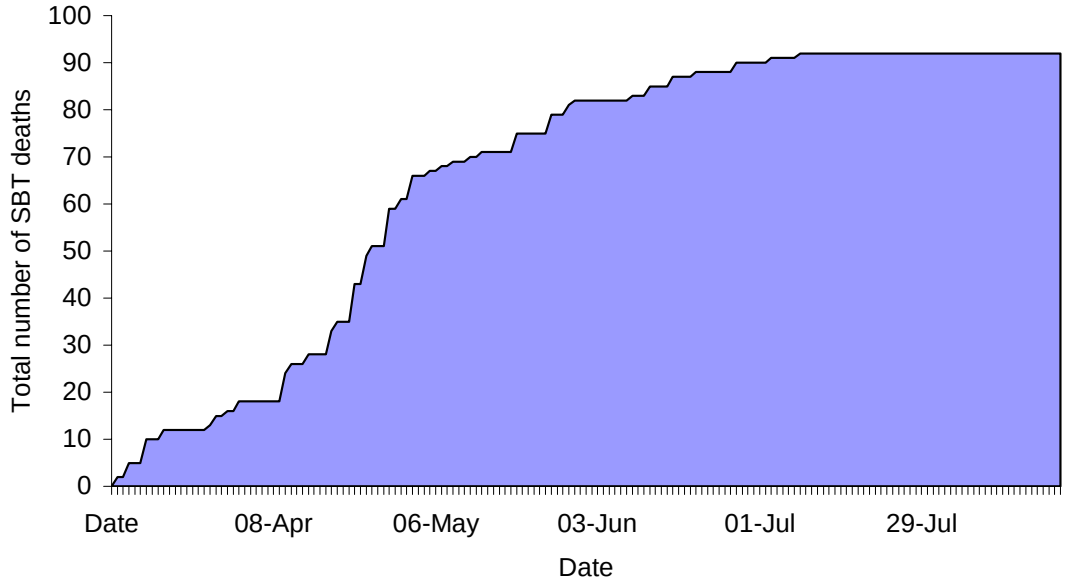

Figure 6. Cumulative mortality numbers for SBT on the Tuna Reseach Farm in 2003.

6.4 Great White Shark Intrusion

On 19th June 2003 a 4.5m long Great White Shark entered one of the 32m research pontoons after breaching the net. This large shark species is totally protected in South Australia and the entrapped animal was therefore not permitted to be destroyed unless human life was in immediate danger. As such, it was necessary to develop a method of removing the animal unharmed without risking staff safety or releasing the SBT (and thereby terminating the vitamin dose experiment). The removal of a Great White Shark from an aquaculture pontoon had never been successfully undertaken anywhere in the world previously. Advice was sought from Dr Barry Bruce (CSIRO Marine division) and Mr Ian Gordon (independent shark researcher recommended by Barry Bruce) to develop a way to safely remove the shark.

It took six days to remove the shark. A detailed description of the process used is found in Appendix 3. Briefly, when the shark was circling at the surface a large net opening was cut by divers and one edge was pulled towards the centre of the pontoon for about 3m to direct the shark towards the opening. The shark eventually found the opening and swam out unharmed. To minimise SBT escapees, the tuna were fed baitfish on the other side of the pontoon from the opening. While this was largely successful, with only two of the 100 SBT seen to escape, 23 tuna were calculated to be missing at the time of the final harvest and may well have escaped.

The SBT adapted surprisingly quickly to the presence of this large predator in the pontoon and resumed feeding one day after the shark entered the cage. Because the shark was able to be removed while

most of the SBT were retained, the vitamin dose experiment was able to be continued and completed successfully.

7. BENEFITS

The Tuna Research Farm provided a high quality, flexible platform, which responded rapidly to changing needs and circumstances to achieve project objectives for SBT researchers. It avoided duplication of services and infrastructure, and maintained a pool of scientific and technical experience with SBT. This service allowed the Subprogram to utilise the expertise of project Principal Investigators who are leaders in their disciplines, but not located in Port Lincoln, or do not have direct field experience in handling live tuna.

Results from experiments conducted on the Tuna Research Farm have directly benefited the tuna industry:

- Developments in nutrition have supported the development of a commercial pelleted feed, which may provide a more secure and efficient feed source in the long term and in the short term could provide a more costly alternative to baitfish if supplies were ever disrupted.
- Research into product quality will benefit the industry by providing a competitive advantage in the market against overseas-farmed tuna.
- The data from the environmental research have supported industry applications to the State Government for lease sites and is vital for ongoing support by state regulatory authorities.
- The ability to safely remove a Great White Shark from an aquaculture pontoon is an important advance for this industry and supports the environmental sustainability of the industry.

8. FURTHER DEVELOPMENT

After a review in October 2003 the SBT Aquaculture Subprogram Steering Committee decided not to continue the project in its present form. The Tuna Research Farm was closed and the holding of live SBT was contracted to a commercial tuna company through the Tuna Boat Owners Association of South Australia. A new Aquafin CRC project (2004-205) was approved to achieve this change, while high level technical support and the scientific involvement of Dr Jeff Buchanan was allocated to several research projects. A draft annual operating plan was prepared for 2004. The new project (2004-205) was designed to maximise the relevance of research results to industry and encourage uptake of research findings by increasing interaction with industry.

9. PLANNED OUTCOMES

The project program was successfully completed as outlined in the annual operating plan. Six Tuna-briefs (short industry targeted newsletters) were distributed by the project in collaboration with the relevant project Principal Investigators to inform the tuna industry of research being undertaken. More detailed outcomes of the experiments conducted on the Tuna Research Farm are presented in the individual project final reports for the projects serviced (Table 2).

Table 2. Reporting details for projects support by this project.

Project title	Project leader	Aquafin CRC No.	FRDC No.	Expect reporting date
Aquafin CRC – SBT Aquaculture Subprogram: development and commercial evaluation of manufactured diets.	Dr Robert van Barneveld	1A.4	2001/249	30th June 2005
Aquafin CRC – FRDC Southern Bluefin Tuna Aquaculture Subprogram: quality and nutritional evaluation of baitfish used for tuna farming	Mr David Ellis	1A.2	2000/221	30th June 2002
Aquafin CRC - Southern Bluefin Tuna Aquaculture Subprogram: maximising the control of quality in farmed SBT	Dr Philip Thomas	2.2	2001/248	31st March 2008
Aquafin CRC - SBT Aquaculture Subprogram: activity metabolism in live-held southern bluefin tuna	Dr Richard Musgrove	1A.7	2003/228	30th December 2004
Aquafin CRC - Southern Bluefin Tuna Aquaculture Subprogram: tuna environment subproject - evaluation of waste composition and waste mitigation	Professor Anthony Cheshire and Dr Milena Fernandes	4.3.2	2001/103	30th September 2005
Aquafin CRC - Southern Bluefin Tuna Aquaculture Subprogram: tuna environment - development of regional environmental sustainability	Professor Anthony Cheshire and Dr Jason Tanner	4.3.3	2001/104	30th September 2005

Project title	Project leader	Aquafin CRC No.	FRDC No.	Expect reporting date
Aquafin CRC - Southern Bluefin Tuna Aquaculture Subprogram: tuna environment - development of novel methodologies for cost effective assessment of the environmental impact of aquaculture	Professor Anthony Cheshire and Dr Maylene Loo	4.3.1	2001/102	31st October 2004

10. CONCLUSION

This project provided valuable research support to the tuna industry in an efficient and cost-effective manner. Increased industry involvement in the project as described in the "Further Development" section is likely to lead to increased industry support and improved outcomes. Closer industry interaction will also facilitate faster uptake of research findings.

11. REFERENCES

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12. APPENDIX 1: Intellectual Property

There was no intellectual property generated as a result of this project.

13. APPENDIX 2: Project Staff

Name	**Organisation**
Dr Jeff Buchanan	SARDI, Port Lincoln 5606
Mr Brenton Ebert	SARDI, Port Lincoln 5606
Mr Richard Morrison	SARDI, Port Lincoln 5606
Mr Michael Bartch	SARDI, Port Lincoln 5606
Mr Troy Desfontane	SARDI, Port Lincoln 5606
Mr Christopher Leech	SARDI, Port Lincoln 5606
Mr David Ellis	Fishing Industry Services Port Lincoln 5606

14. APPENDIX 3: Removal of White Shark

Removal Of White Shark Trapped In Tuna Pen

By Kate Rodda and Jeff Buchanan, SARDI Aquatic Sciences

Thursday 19th June 2003

0900 - the feed boat crew for the SARDI tuna research program noticed that the tuna in experimental farm A1 were not feeding as normal, that is, not coming to the surface. They saw a tail fin of a white shark and soon after a New Zealand fur seal inside the cage. They notified Jeff Buchanan who then notified SARDI (Kate Rodda, Steven Clarke), PIRSA compliance (Mel Snart), PIRSA Aquaculture (Michael Deering – couldn't contact Ian Nightingale). Also notified were DEHAA (Sheriden Martin) and Will Zacharin (Director of Fisheries). Local Fisheries compliance officers (Brett Willis and Brett Chalmers) and DEHAA came out later that morning to observe both the shark and the seal. Early in the day, the shark (later identified as a 4.4m long female white shark, *Carcharodon carcharias*) was observed (Figure 1) with a remote camera to be swimming mid water within 2 meters of the inside edge of the cage in a clockwise direction. The female shark appeared relaxed and was taking about 3 minutes to complete a lap of the 32m diameter cage (~2 km/h). Later it swam close to the surface, thrashed near the pontoon on four separate occasions before diving below visible range. The crew opened up slits in the seal net to see if the seal would escape, but it did not at this stage. The seal was observed with the camera to be swimming behind the shark at depths below 6 meters. According to the crew, the seal seemed stressed early in the day but later appeared more relaxed.

There was evidence that at least one tuna had been attacked with a 20cm diameter chunk of muscle removed with long serrations either side of the missing chunk, however, there was much discussion as to whether this injury was caused by the shark or the seal. This tuna was swimming around on the surface on Friday but was not seen on Saturday.

Jeff Buchanan was instructed by PIRSA that the shark would not be destroyed and every attempt was to be made to aid its release. The farm in question contained between 80-100 tuna that were control fish in a long-term Aquafin CRC – FRDC experiment.

Figure 1. The 4.4m female white shark swimming near the surface inside the SARDI research tuna farm (photo curtesy Stan Gordon, Port Lincoln Times).

Friday 20th June

0800 - the shark was still alive and swimming normally at a depth below 5 meters at about one minute per lap (~6 km/h) and the seal appeared to have escaped overnight. Present were PIRSA (B.Whillas), SARDI (tuna crew plus K. Rodda) and the Euphotics dive team (contract divers for the SARDI tuna research program). The shark was not seen on or near the surface for the first hour. A hookah dive hose was thrown into the bottom of the cage in order to stir the shark to the surface. No air was pumped. The shark did surface

temporarily (about 10 minutes) and then stayed between 4-15 meters for the remainder of the day. Air was pumped through the hose on two occasions but this appeared to have no effect in bringing the shark closer to the surface.

A diver from Euphotics entered the water on the outside of the cage and cut open the gate (Figure 2) through which tuna are normally transferred. The gate was approximately 4 by 5 meters and located one meter below the surface. We attempted to entice the shark through the gate with half a frozen tuna attached to a rope as a bait, and also with the gut and gills of a freshly caught tuna placed at the entrance to the gate. The captured shark did not react to these baits at all, however they were successful in bringing in another shark outside the cage (approximately 4.5m female) that took both baits (Figure 3). The gate was quickly closed to prevent this second shark from entering the cage and it subsequently left the area.

While the gate was open, tuna were offered small amounts of feed (pilchards) on the opposite side of the cage to lure the tuna away from the gate and minimise the chance of tuna escaping. The shark appears unaffected by this feeding and the practice was repeated on subsequent occasions when the gate was opened.

Figure 2. Euphotic's diver Paul cuts the net to deepen the gate.

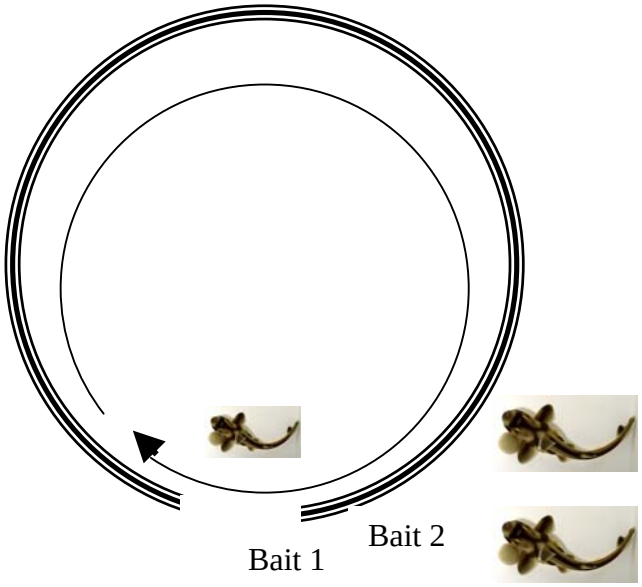

Figure 3. A diagrammatic view of the tuna farm from above indicating the position of the gate, baits and sharks.

The gate was reopened later and an attempt to encourage the shark out through the gate was made by placing an operational shark shield at the opposite side of the cage. The shark reacted to it on one occasion but not on subsequent laps. This was not intended to scientifically test the ability of shark shields to repel sharks, but an attempt to move it towards the side of the cage containing the gate. An 'electronic wall' of 5 of these shields, approximately 8 meters apart, strung along a rope was placed in the water. This wall was towed towards the gate to force the shark this way but the video showed that the shark remained swimming on the bottom of the cage. It should be noted that the recommended distance between shield and antenna and the electronic overlap between shields may not have been optimal in this case, thus not producing the desired effect. Given that we know little of the effects of prolonged exposure to concentrated electronic signals on captured sharks, we ceased operation of the electronic wall after 10 minutes.

The shark did not surface so we closed the gate and left at 1300.

Saturday 21st June

1200 - the weather was too sloppy to attempt a release but the feed boat went out. A remote operated vehicle (ROV) was deployed (donated by STOLT Fisheries). It observed (bumped into) the shark at 5 meters depth. The shark seemed to swim higher when the ROV went in. The shark did not surface all morning. The ROV recorded 3 tuna mortalities on the bottom of the cage, all appeared to have heavy damage but the cause of the damage could not be verified as they were not able to be removed and examined for a further 3 days.

At this time it was decided that we should enlist the help of Ian Gordon (independent shark researcher from NSW) who has had 23 years of experience with sharks in captured and free-swimming situations.

Sunday 22nd June

0900 - left for farm. The weather was calm, and sunny with an occasional rain shower. The shark was alive and well, swimming around the inside edge of the cage at 1 minute per lap (~6 km/h) and at between 1-4 meters below the surface. We opened the gate since it was close to the surface but it did not leave. An object (secchi disc) was placed in the water as the shark went past to test its responses and it reacted to the object by veering away from it. Then the shark was prodded gently on the right hand side with a pole as it was near the gate but this only made it veer inwards and dive deep where it remained for the remainder of our time there (1330). At this time the gate was closed.

Monday 23rd June

0800 - picked up Ian Gordon from the airport and immediately went to the farm to assess the situation. The shark was still alive and swimming at about 6 km/h. While it was at the surface and close to the edge, we attempted to measure it by marking the outer ring at a point where its tail passed when its nose was at a set point (spider rope). This was repeated at least 6 times to get an accurate estimate of length. The shark was estimated to be 4.4m long. It was swimming at about 0.5-1 meter below the surface. As it touched the ropes of the spider (holding structure of ring in a circle) it dipped below the

surface and came back up again. After consultation, Ian and Kate recommended the spider be removed to encourage the shark to stay at the surface. A half tuna (fresh mortality) was placed on the inside to see if the shark would take a bait but several boats arrived and this “spooked” the shark causing it to thrash at the surface briefly before diving deep where it remained. There was evidence of new damage to the lower part of the bottom caudal lobe of the shark, presumably from rubbing against the bottom of the cage, but otherwise it appeared relaxed, responsive and healthy. The skin was shiny and there were no other injuries. The head was virtually clean of marks with only a few small lines on the dorsal surface between the eyes. Three copepods were attached near the caudal pit and one near the head. We left the bait in overnight to see if the shark would take it. During the afternoon a release plan was formulated based on Ian’s behavioural observations coupled with ideas and input from Kate, Jeff & Paul (Euphotic dive team member). It was decided a release attempt should be implemented early the next day.

Tuesday 24th June

0730 - the weather was choppy and cloudy. The shark was still alive but not visible from the surface. The bait was not touched. The in-water video located the shark at about 12 meters where it stayed for about 2 hours. Ian & Paul entered the water on the outside of the cage and cut the gate opening such that it was now nine meters deep. This process was filmed with an underwater video. Ropes were attached to the following edge at the top and bottom such that when it was pulled, it drew the gate open inwards and formed a V-shaped tunnel, (see diagram) expanding the opening so that the shark would have an increased chance of seeing it. In addition, it would run into or sense the net wall (about 3m long) and turn away from it, through the opening.

A diver in the shark cage (owned by Ian Gordon and placed at the outer end of the gate and on the outside of the cage) observed that at least two tuna escaped. Weather was getting worse and the shark was circling below the depth of the opening so we closed the gate to wait for it to surface. The shark

surfaced at about 1100 and the gate was reopened and the funnel formed with net extending 3 meters in towards the centre of the cage. The shark swam towards the net wall, veered around it on two laps, however it was seen to be observing the hole on each pass. On the third lap, the shark turned towards the opening and swam out (Figure 4). It was not tagged and not seen again. The gate was closed and the net repaired by divers. A hole approximately 1.1 by 1 m^2 was found 6.4 meters below the surface. Previous morphometric research on white sharks has shown that a 4.4 m shark has a maximum girth of 2.8 m. In addition, 4 meter white sharks that Kate Rodda has dissected have had a body height of approximately 1 meter. Therefore the hole would have been more than adequate in size for the shark to enter through.

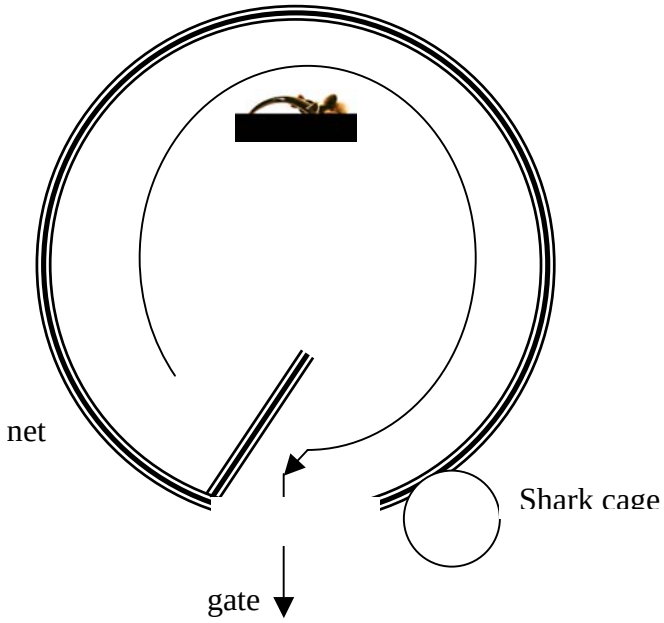

Figure 4. A diagrammatic view of the tuna farm from above indicating the position of the gate and shark.

Individual sharks can behave differently and therefore could react in different ways in the same situation. The outcome of this event showed that a captive white shark is unlikely to either kill or enormously stress the tuna in pens. Also, that it is possible to assess each situation and probably, in many cases, release the shark without destroying it (a desired issue as it is a protected

species). There is also potential to design new tuna pens with shark escape hatches built in.

Total losses of tuna could not be confirmed until the final harvest but visible losses appeared low. While the tuna exhibited some signs of stressed behaviour, throughout the period of exposure the tuna continued to feed and within 2 days of the shark's removal the tuna were observed to return to normal feeding rates.