SARDI

SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Government of South Australia

Optimising at-sea post-harvest handling procedures for the Australian sardine (*Sardinops sagax*)

Edited by

R.J. Musgrove and J.F. Carragher

Project No. 2002/236

Australian Government

Fisheries Research and Development Corporation

Queensland Government

Department of Primary Industries and Fisheries

This report may be cited as: Musgrove, R.J., Carragher, J.F. (2006) Optimising at-sea post-harvest handling procedures for the Australian sardine (*Sardinops sagax*). Final report to the Fisheries Research and Development Corporation. Project 2002/236. 202pp

The Fisheries Research and Development Corporation plans, invests in and manages fisheries research and development throughout Australia. It is a statutory authority within the portfolio of the federal Minister for Agriculture, Fisheries and Forestry, jointly funded by the Australian Government and the fishing industry.

Printed in Adelaide July, 2006.

SARDI Aquatic Sciences Publication No. RD02/0051-2

SARDI Research Report Series No. 146
ISBN: 0 7308 5348 9

Editors:	R.J. Musgrove, J.F. Carragher
Reviewers:	Dr A. Linnane and Mr P.J. Rogers
Approved by:	Dr Anthony Fowler

Signed:

Date:	Monday 31st August 2006
Distribution:	Sardine Industry participants, Fisheries Research Advisory Boards in South Australia, Victoria and Tasmania, SARDI Aquatic Sciences Library
Circulation:	Public Domain

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

2002/236	**Optimising at-sea post-harvest handling procedures for the Australian sardine (*Sardinops sagax*)**

PRINCIPAL INVESTIGATOR: J.F. Carragher

ADDRESS: Product Quality And Value-Adding Program

SARDI Aquatic Sciences,

PO Box 120,

Henley Beach,

SA 5022

AUSTRALIA

Phone (61 8) 8207 5440

Fax: (618) 8207 5481

OBJECTIVES:

1. To assess current on-board and on-shore processing practices and equipment used by the SA sardine fleet and to determine the capacity for improvement.
2. To assess marketing issues as they relate to the capacity of the industry to develop new processes/products.
3. To investigate biological and ecological factors that affect rates of deterioration in sardine quality in the immediate post-harvest period.
4. To examine and compare the effects of at-sea post-harvest handling procedures on the rates of deterioration in sardine quality.
5. To develop options for alternative handling procedures that optimise sardine

quality and economic return

6. To undertake a cost-benefit analysis of the various processing options including any changes in gear requirements and fisheries management requirements.

OUTCOMES ACHIEVED

The research documented in this report has contributed to the development of the value-adding component of the South Australian sardine (*Sardinops sagax*) fishery by providing information on the key factors affecting sardine quality from harvest through to the factory. The research showed that although there were differences in the rate at which sardine quality deteriorated between different times of year, different fishing boats, different on-board holding tanks, and the start and end of each net haul, the main effect was the detrimental consequence of not chilling the fish as quickly as possible after capture. Emphasis was placed on the ability to chill fish rapidly to maximize sardine quality via an appropriate low fish load, hold water:volume ratio, more effective circulation of chilling water and/or the opportunities for new flo-ice technologies. This information, together with an audit of vessel hygiene and operating practices, has been used by industry to improve processes and practices to maintain sardine quality such that several more vessels and value-adding ventures are now operating in Port Lincoln than when the project started. Indications are that these ventures are supplying value-added sardines to the substantial domestic commercial and recreational fishing bait markets and thereby replacing some imported baitfish. The option of being able to value-add to a percentage of the sardine catch is of economic and social benefit to the fishers and factory owners in Port Lincoln.

NON-TECHNICAL SUMMARY

The sardine (*Sardinops sagax*) fishery based in Port Lincoln, South Australia expanded to ~26,000 tonnes in 2006. Most of the catch is used as feed for the established tuna farming operations that are co-located at Port Lincoln. The tuna aquaculture industry is willing and able to absorb the total output from the sardine fishery but at a low price per kg. Some of the sardine fishers have sought to increase their earnings by supplying value-added sardine products –

recreational and commercial fishing bait, and/or sardines for human consumption. The main issue these fishers face in striving to supply these markets is deterioration in the physical integrity of the sardines. This deterioration shortens the window during which fish are suitable for value-adding, this is further compounded by the limited capacity of the on-land freezing infrastructure to process a significant proportion of the catch. The aims of this project were to (a) understand the pre-harvest, harvest and post-harvest factors that are responsible for the rapid rate of deterioration in the physical integrity of sardines, (b) identify the domestic market status and opportunities for value-added sardines, and (c) undertake a cost-benefit analysis of implementing the recommended changes that would improve sardine quality.

An audit of harvest practices on several boats interested in undertaking value-adding revealed a number of shortcomings that were likely to contribute to deterioration in product quality. The main issues were related to holding tank hygiene and the effective circulation of refrigerated water in fish filled holds. This information was used by some of the boats to make modifications to holding tank cooling functionality and improvements to holding tank hygiene practices.

A desktop and survey approach was used to identify the nature of the current domestic markets for frozen bait sardines and fresh, frozen and processed sardines for human consumption. Following this status report there was an assessment of where Port Lincoln sardine products could capture some of this market. The short-medium term opportunities were assessed as being in the bait markets and the fresh fish markets in Sydney and Melbourne. The marketing advantages of Port Lincoln sardines as bait would include the ‘clean and green’ perception of the fishery, as well as the perception that this is a ‘natural food’ for the main target species. These advantages, however, will not overcome an inferior quality product or a significant price premium. For the human-consumption market the price premium is guaranteed for fresh product providing the quality is high; however, any further processing to butterfly fillets and/or canned product would require substantial investment in processing technology, and the financial returns may not be justified in the short-medium term.

An investigation was carried out on the biological and ecological factors affecting rates of deterioration in sardine quality in the immediate post-harvest period (i.e. net to processing factory) using a quality index (QI) and physico-chemical measurements. One of the major issues to be addressed in the study was post mortem belly burst, thought to result from visceral autolysis accentuated by consumption of particular prey species (i.e. copepods). However, although a degree of visceral post-mortem autolysis was detected, very few fish were found with burst bellies therefore it is suggested that this issue is not a major constraint on the progress of value-adding in the fishery. There was only one significant instance of burst stomachs/bellies within the field sample. There may be a relationship between spawning fish and susceptibility to stomach/belly burst as this was also the only time ripe gonads were observed during the fieldwork. Postmortem autolysis was more commonly recorded and is likely to have been caused by digestive enzyme activity, significantly contributing to the observed increase in sardine QI with time.

The QI method proved useful in sardine quality assessment, with inclusion of ten of the seventeen parameters suggested in the literature. Four of these (i.e. gill colour, eye clarity, body appearance and body stiffness) accounted for 76% of the overall QI. It was evident that the QI would provide a framework for standardisation of the quality of fish going to market, a necessity in the process of value adding. The setting of the QI acceptability threshold would involve market acceptability trials including taste testing, microbiological studies to determine safe levels of bacteria on/in the product, and work to determine safe rancidity levels and should be included as a essential element of any further value adding work on this species.

Methods are suggested for maintaining sardine quality through the onboard storage process to allow entry of the product into premium markets. These include more rapid water temperature reduction using more efficient, dedicated, on-board value-adding tanks, and reduction in the quantity of fish loaded into tanks to maintain water circulation and facilitate cooling. The practice of topping up nearly-full, cold tanks with the later shots containing relatively warm fish should be limited as this practice causes a temperature spike and probably accelerates deterioration of fish already in the tank. Fish should also be iced between unloading at the jetty and arrival at the processing factory, and jetty-to-factory transport bins chilled using an efficient cooling medium such as flow ice.

A cost-benefit analysis was undertaken of various options including investment in small scale (processing 50 to 100 t.p.a.) and large scale (processing 200 to 400 t.p.a) equipment for improved post-harvest handling and processing of sardines. The analysis was conducted from an individual licence holder (single boat) perspective using a model based on financial data provided by all active licence holders.

The results of the analysis showed that investment in post harvest handling equipment can generate positive returns to the fishery. However, the outcomes are sensitive to the premiums available for human consumption sardines, the quantity processed (which will be determined by the volume that the licence holder can market) and the initial cost of the equipment and its installation. For small scale equipment, for example, the prices (landed beach price equivalent) at which the investment would yield a breakeven return ranged from $1.46/kg for 50 tpa throughput down to $1.15/kg for 100 tpa throughput. For large scale investment, the breakeven prices ranged from $1.26/kg for 200 tpa throughput down to $1.06/kg for 400 tpa throughput.

While the analysis demonstrates the potential returns that can be generated by investment in post harvest handing of sardines, it also highlights the critical role that marketing will play in securing those returns. Successful marketing of the product will be essential to achieve both the price and the volume necessary to generate positive returns to licence holder investment.

KEYWORDS: sardine, pilchard, *Sardinops sagax,* post harvest handling, value-adding.

ACKNOWLEDGEMENTS

We would like to thank the members of the South Australian Sardine Fishing Industry who contributed so much to this project in ideas, fish and time.

This report is dedicated to the late Norm Craig, whose vision got it all off the ground.

CHAPTER 1 GENERAL INTRODUCTION

1.1 Background

South Australian waters support the most valuable sardine (*Sardinops sagax*) resource in Australia. The fishery is South Australia's largest by weight for a marine scale-fish. The total annual catch increased from 3,836 tonnes in 1999/2000 to 33,160 tonnes in 2003/2004. The Total Allowable Commercial Catch (TACC) for 2006 was set at 25,463 tonnes. Since 1998, the exploitation capacity of the fleet has increased in line with the increases in TACC. For example, a number of sardine license-holders currently operate state-of-the-art purse seine vessels capable of handling more than 100 tonnes/night.

The South Australian sardine fishery was initiated to provide fresh fodder for the tuna mariculture industry and most of the catch is still used for this purpose. As the fishery has expanded there has been changes in sardine quota ownership, with most of the new quota owners being directly connected to particular tuna farming companies. The development of ‘vertically integrated’ operations (i.e. sardine boat, processing factory and tuna pens all within the same company) reduces the uncertainties that exist over quantity, quality and price when supplies of baitfish are controlled by others, or a dependence upon imports of large volumes of baitfish sourced from around the world.

Significant declines in the Western Australian sardine stocks and fisheries between 1998 and 2000 resulted in shortages of sardines on Australian markets for recreational fishing bait and human consumption. The wholesale price for sardines sold in Australia, for bait ($2.20-2.50 per kg) or human consumption ($3.00-$6.00) per kg), is substantially higher than the price paid for sardines used as tuna fodder ($0.65 - $0.85).

In view of the potential opportunity to add value to a proportion of the Port Lincoln sardine catch, some industry representatives approached the Eyre Regional Development Board (ERDB) and the Department of Industry and

Trade, for funding to commission an independent feasibility study into value-adding opportunities for the SA sardine industry. The preliminary report indicated that such processing is financially feasible and that the quantity of sardines sold for bait and human consumption could reach 4000 tonnes per annum within four years (Davidson et al. 2000). In 2005 there are four factories supplying sardines for human consumption and/or bait (South Australian Premium Pilchards, South Australian Seafood Exporters, Sardine Temptations, Temptation Sardines). These factories currently sell approximately 2000 tonnes of sardines per annum to bait vendors across Australia, but especially the east coast (northern NSW and Southern Queensland).

The ERDB also provided financial assistance to South Australian sardine industry players interested in exploring value-adding opportunities. In August 2000, the ERDB and sardine industry co-funded a research trip to Norway by Mr Alex Jelinek (SA Premium Pilchards), Mr Gary Feuerherdt (SA Premium Pilchards and Taylor Island Fisheries), Mr Norm Craig and Mr Branko Sarunic (Sardine Temptations and Velvet Fisheries). The funding also included expenses for an independent scientific observer, and Dr Tim Ward (SARDI Aquatic Sciences) was asked by industry to fill this position. During the trip, the research team investigated contemporary fishing and processing technologies displayed at NORFISHING 2000 and observed procedures used in Norway's lucrative pelagic fishing industry. The findings were documented in a report to the ERDB (Ward et al. 2000).

Ward et al. (2000) describes how weaknesses in the at-sea post-harvest handling procedures previously impeded the development of the Norwegian sprat fishery. The main issue was that sprat quality often deteriorated very quickly (within a few hours) of fish being landed. Research identified that the critical factor affecting sprat quality was the presence or absence of a plankton (veliger) in the gut which caused the sprat’s abdomen wall to burst (Norwegian Fisheries Research Institute). Armed with this knowledge, fishers: (i) learnt to determine the presence/absence of this plankton in the gut of sprat; and (ii) began keeping catches of sprats that contained these plankton in holding cages for 24-48 hours prior to landing so that the plankton could be purged from the gut, and consequently the quantity and quality of Norwegian sprats supplied to processing factories increased and a viable industry was created.

Ward et al. (2000) and Davidson et al. (2000) both suggested that deficiencies in at-sea post-harvest handling procedures on the Port Lincoln based sardine fleet limited the quality and quantity of product that could be sold on the bait and human consumption markets. And, much as in the Norwegian example, these deficiencies are major impediments to any future development of this value-adding sector of the South Australian sardine industry. Deficiencies that were identified as being particularly significant included:

(i) the lack of understanding of factors that affect the rates of deterioration in sardine quality; and

(v) inadequacies in the techniques currently employed to prevent the rapid deterioration of sardine quality in the immediate post-harvest period (Ward et al. 2000).

In response to these two reports, the South Australian sardine industry supported an FRDC project application to address the issues raised by Ward et al. (2000). The project was funded. The principal investigator was Dr Tim Ward (2003-2004) replaced by Dr John Carragher in (2004-2005), with Dr Richard Musgrove as Co-Investigator.

1.2 Need

Future development of the South Australian sardine industry must involve increased utilisation of inter-state and international markets for recreational bait and human consumption (Ward et al. 2000; Davidson et al. 2000). As South Australian sardine fishing grounds are often located 12-24 hours steaming away from local ports (cf 2-3 hours in WA), the quantity and quality of product supplied to processing factories and markets for bait and human consumption will be largely determined by nature and quality of the at-sea post-harvest handling procedures (Ward et al. 2000; Davidson et al. 2000).

In addition, it is possible that changes in the operational circumstances (eg regulatory, financial, alternative feeds) of the Port Lincoln tuna farming industry could reduce the need, demand or use of the local sardine. This project was initiated to assist the sardine industry to identify methods to deliver products into alternative markets.

The project had three phases:

Phase 1

(a) An audit of the SA sardine fleet to assess current practices, quantify on-board processing gear, determine the capacity for improving the latter and assess onshore facilities capacity to process sardines.

(b) An assessment of the marketing issues as they relate to the capacity of the Industry to develop new processes/products.

Phase 2

(a) An investigation of the biological and ecological factors that affect the rates of deterioration in sardine quality in the immediate post-harvest period (i.e. net to processing factory); and

(b) Development of options for alternative handling procedures that optimise sardine quality and economic return.

To achieve these objectives, information is needed on spatial and temporal variation in the biochemical composition of South Australian sardines, especially with regard to the lipid content. Lipid content would be expected to vary seasonal depending on the sardines reproductive condition, and the quantity and quality of it’s diet. Lipid content and lipid quality are useful indicators of fish condition and the deterioration rate in fish quality during post-harvest handling (Fitz-Gerald and Bremner, 1994, NSC project 6), and the health benefit of fish oil is an important factor to consider when marketing the product for human consumption. Knowledge of the taxonomic composition and biochemical characteristics of the gut contents of the South Australian sardine is needed as these factors have been shown to affect the rates of deterioration of planktivorous pelagic fishes in the immediate post-harvest period (Stenstrom, 1965; Goldberg and Raa, 1980; Dr Bjordal Asmund, Norwegian Institute of Marine Research, pers. comm.; Mr Ian Wells, Seafood Services Australia, unpub. data).

Phase 3

A cost-benefit analysis of the various processing options will have to be undertaken to assess the potential benefit of any changes in gear/practices. In order to do this a financial survey of licence holders, including measures of financial performance for the “average licence holder” will be carried out, and measures of economic performance of the fishery derived (i.e. gross value of production (GVP), economic rent, etc). This will be used to develop a model of the fishery linking biological and management parameters (catch prer unit effort, days fished, etc.) with the economic characteristics of the fishery. The model will be used to derive a baseline scenario, reflecting existing operator and fisheries management practices which will then be compared with scenarios reflecting the various processing options developed during the study.

1.3 Objectives

1. To assess current on-board and on-shore processing practices and equipment used by the SA sardine fleet and to determine the capacity for improvement
2. To assess marketing issues as they relate to the capacity of the industry to develop new processes/products
3. To investigate biological and ecological factors that affect rates of deterioration in sardine quality in the immediate post-harvest period.
4. To examine and compare the effects of at-sea post-harvest handling procedures on the rates of deterioration in sardine quality.
5. To develop options for alternative handling procedures that optimise sardine quality and economic return
6. To undertake a cost-benefit analysis of the various processing options including any changes in gear requirements and fisheries management requirements.

CHAPTER 2 AUDIT OF THE FOOD GRADE SARDINE INDUSTRY IN PORT LINCOLN

Steven Slattery
Centre for Food Technology
Queensland Department Of Primary Industries

2.1 Introduction

The expansion of the Port Lincoln Sardine fishery into production of sardines for human consumption is relatively new. Three factories and four vessels, either already participating, or considering participating, in sardine value-adding were audited over the course of this project. Another factory in Port Lincoln also produces sardines for human consumption, but the management was reluctant to participate in this project. They stated that they have already researched their process and have identified limited local markets for food grade sardines. They felt that these markets could be jeopardised by oversupply from new industry participants.

2.2 Methods

Initial discussions with project participants revealed that none of the vessels or factories had QA or HACCP manuals for catching and processing sardines for human consumption or bait. This made it difficult to conduct a formal Systems Audit; hence, it was more appropriate to conduct a Good Manufacturing Practices (GMP) Audit on each boat and factory. Whilst preliminary, this GMP information will not only identify the process that fishers and processors use and how they can be improved but will also provide the foundation for them to start their QA or HACCP manuals.

The project participants were also concerned about the loss of confidential information regarding their own catching and processing procedures; so much of the information reported here will be generic. However, specific information (documented procedures and process flow charts) was communicated back to each vessel and factory audited to encourage them to adopt quality management systems. In addition, recommendations for sardine storage, handling and processing conditions and draft QA and HACCP plans were forwarded to each participant along with their audit reports.

Note: As most of the boats and factories were refitted to greater or lesser degrees during the course of the project the information presented here may not reflect current operating practices or procedures.

2.3 Results

2.3.1 Catching and handling

All vessels use a purse seine net to capture sardines at night. As there are peak feeding times toward dusk and after dawn, the fishers try to avoid catching fish that have been actively feeding. The fishers believe that digestive enzymes present in the gut of the fish (and perhaps also their prey) can be very destructive when the fish die, possibly causing belly bursting and other quality changes (see Chapter 4). At this time, it is unknown how long it takes for a sardine to digest its food.

Each boat has a different handling and processing capacity. For example, the method of removing the catch from the net varies with most boats using fish pumps while others, concerned about the impact of the pumps on the quality of the sardine (blamed for causing excessive damage, including bleeding from the gills), brail the catch from the net. Although the brail can lift almost a ton of sardines, it can take up to 1.5 hours to empty a net. This additional time could impact on the quality of sardines delivered for processing.

Most of the vessels chill sardines in refrigerated seawater (RSW) then land the catch for further processing in their factory including IQF (individual quick frozen) and blast freezing. Some of the vessels also use an ice-slurry in one or more tanks to chill fish. One of the vessels had the capacity to freeze (IQF) some of the catch on board, and chill (RSW) the remainder until delivery to the factory (not participating in this project), for freezing. However, limitations to the processing rate of this factory (1.5 tonnes of sardines per hour) have convinced the vessel owner to build his own factory to cater for the more than 100 tonnes per night that his vessel can catch.

2.3.2 Vessel IQF

The rate of freezing in the IQF system depends on the initial temperature and quantity of product introduced to the brine, and the rate of heat removed from the fish. This, in turn, is linked to capacity of the compressor and heat exchange system, and the salt content of the brine. On one vessel is was anticipated that it would take 6 minutes for fish to drop from RSW temperature (0 to -1°C) to -16°C and that the processing rate will be 2 to 3 tonnes per hour for the vessel IQF. Once the sardines have been frozen in the IQF they will then be stored in the blast freezer. The owner stated that the blast freezer temperature would be only -18°C but he was encouraged to attempt to achieve an operating temperature of -30°C. As it turned out, in the course of this project the amount of vessel IQF product produced was minimal, thus, the vast majority of value-added catch was processed onshore.

2.3.3 RSW tanks

Where the catch is to be landed for processing, the RSW tanks are intended to reduce the temperature of the sardines (perhaps to -1°C or lower, depending on the amount of extra salt added to the seawater, however most boats did not add extra salt). The different vessels audited (n=3) had different numbers, volumes and shapes of RSW tanks. RSW tanks with narrow loading/unloading hatches that open out to larger, deep spaces were considered to be particularly difficult to assess and/or monitor. The vessels fill their RSW tanks on their way out to the fishing grounds. Few of the vessels had gradations or marks on the tank walls to indicate the volume of water that had been pumped in. The order in which the tanks were filled with water and fish was consistent within each vessel, and usually related to improving stability, rather than the most effective chilling rate of the fish. The quality of the water pumped into the tanks will vary depending on where pumping occurs, sometimes when the fishing ground was close to Port Lincoln the tanks would begin being filled before the vessel had left the berth to maximise the time of pre-harvest chilling. The high potential for contaminants to enter the tanks under such circumstances was pointed out. Few of the boats used any type of pre-filling hygiene protocol before tanks were filled, where it did occur it consisted of hosing the tanks with water from the berth.

When fish were pumped from the purse-seine net into the holding tanks they are placed loose in the RSW. Without exception, the quantity of fish loaded into a particular tank was estimated with varying levels of accuracy – as determined by how many fish bins were filled at unloading. In most cases, pumps (submersible or fixed) are introduced or switched on after the tank has been filled to try to ensure good water circulation to maximise chilling. Water temperature in the holding tanks was sometimes measured using a thermometer on a weighted string, other times it was from digital temperature probes installed in each tank that showed the readout in the wheelhouse. Few records of water temperatures were actually written down during a fishing trip.

The efficiency of the cooling system associated with a particular tank varied tremendously both within and between boats. The compressors on the refrigeration systems were often over- or under-powered to chill the volume of seawater and/or fish caught. Similarly, in some larger tanks the surface area of the cooling coils was insufficient to drop the temperature quickly enough, in other cases the positioning of the coils and the poor circulation of water, particularly when the tank was full of fish, would limit effective cooling. In other situations the cooling coils inside the RSW tank come in contact with the sardines and, because they are so much colder the the sardines, several layers of sardines will stick to the coils. This insulates the water and fish from the refridgerant and inhibits cooling. In some cases the compressors and heat exchangers became ice-bound and needed to be switched off until they were clear of ice and then they were switched on again. In most boats the control of the compressors and refrigeration was done by the engineer who was not monitoring what was happening inside the RSW tanks.

2.3.4 Unloading

When the vessels are unloaded the brail or fish pump move the sardines from the RSW to the transport bins on trucks parked alongside on the jetty. Again, brailing was slower than pumping, and this delayed time to processing. Fish pumps were often operated in a different configuration compared to when they extracted fish from the net, and the unloading configuration was often perceived as more damaging to the fish (eg a longer vertical drop into the bin, the bin does not contain water). Depending on the size of the truck, number and size (most hold ~1 tonne) of bins, pumping rate and congestion on the jetty, the unloading process could take from one to three hours. The bins are then driven a short distance to the factories for processing.

2.3.5 Factory

Brine immersion is used to produce individual quick frozen (IQF) sardines. This is done by adding salt to the water to depress its freezing point, then chilling the water to a temperature of -16°C. This freezes the water inside the sardine but not the brine. The frozen fish are then removed from the brine and either bagged, or put into a block mould, and stored in a blast freezer. Two sizes of block are produced, 18kg for tuna feed or bait and 2.5kg for bait or human consumption. The number of bins and the refrigerating capacity of the brining tanks could often mean that the bins were sitting for a day or more between arriving at the factory and when they were frozen. At some point the factory manager decides that the fish in a bin are no longer suitable for value-adding as bait, and they are frozen for tuna feed.

2.4 Recommendations For Storing And Processing Sardines

As a result of the GMP audits carried out in this project, the following points and suggestions are made to improve the processes and practices related to value-adding of sardines. None of the points are directed towards any of the vessels participating in this survey, and they should not be interpreted as such.

Recommendations:

- Holding tanks and bins should be scrubbed down with a 2% chlorine solution or steam cleaned to remove fish residue immediately after unloading or emptying.
- All cleaning solutions should be made in town water, not seawater taken from the marina or jetty environments. When the boat is en-route to the fishing grounds the tanks should again cleaned, by hosing with seawater.
- Non-marina seawater should be used to fill the RSW tanks to a line marked in each tank indicating a known volume.
- It is suggested that RSW tanks being used to hold fish for human consumption should have no more than an equal weight of fish: volume of water (ie 1:1). In addition, the water/fish mixture should not fill the tank competely. These two suggestions should ensure that there is a sufficient circulation of water in the RSW tank to chill fish adequately, and that it will be possible to monitor the tank during the post-harvest period.
- Monitoring of holding tank temperature should be done using probes permanently installed at some distance from the cooling coils, with a display readout in the wheelhouse. This will allow the skipper to switch on and off compressors without having to access the tanks.
- Fishing nets should have any unsanitary material (eg adhering dead fish from the previous trip, seabird faeces etc) removed by hosing (this should also have been carried out after the previous trip) to reduce bacterial load. Cleaning with a chlorine solution is also advised, but can be impractical.

- Fish destined for human consumption or other value-adding activity are probably best caught around dawn. This is to minimise the time between catching and time to unloading.
- Fish destined for human consumption should be kept separate from those used for other purposes throughout the post-harvest period. Thus, a specific "destined for human consumption" RSW tank should be configured, and only used for this purpose.
- It would be advisable to pump or brail *live* sardines into the "destined for human consumption" RSW tank.

The information present below has been collated from scientific papers on sardines, pilchards and other closely related species by Garcia & Careche (2002), Careche & others (2002), Roach & others (1961), Kolakowska & others (1992), Neilson & Hyldig (2004), Ozogul & others (2000), Smith & others (1980). Many of these aspects are already being catered for by current practices in the Port Lincoln fleet but some do need improvement.

1. Sardines should be chilled as soon as practicable after capture. The faster sardine body temperature can be reduced to 0^oC, the less likely it is there will be softening or deterioration due to muscle or gut enzyme activity.
2. Sardines can deteriorate rapidly under chilled storage because of the exposure to oxygen. After four days peroxide values (a measure of fat breakdown) rise substantially and oxidised odours and flavours develop.
3. Immersion in RSW is more effective than under ice because of the lower temperature that can be achieved and the exclusion of excess oxygen. Spoilage during transport is reduced if water and ice is used rather than ice alone.
4. A rapid distribution chain with strict temperature control would be required for marketing fresh sardines.

5. Oxidation can occur after only one month frozen storage at -20°C.

6. Fat (lipid) breakdown due to endogenous (the fish's own) enzymes occurs during storage down to at least -35°C. Just freezing in an IQF system (-16°C) is not adequate.

7. This breakdown could be delayed if the fish were glazed with water or frozen as an ice block.

8. Vacuum packing (which removes oxygen) is less effective than glazing.

9. Where oxidation has already commenced before freezing, it will continue regardless of glazing or vacuum packing.

10. Blast freezing after IQF should always be carried out until the core temperature of blocks is below -30°C. This should ensure an acceptable product after 6 months.

11. Frozen sardines for tuna feed should not be stored longer than 3 months at a temperature of -20°C.

12. A frozen iced block would be more appropriate for preserving sardines for human consumption than just IQF.

13. Plate freezing is much more rapid than blast freezing with a glaze present.

CHAPTER 3 NEW PROCESSES AND PRODUCTS FOR THE SARDINE INDUSTRY AND THE MARKETING ISSUES INVOLVED.

Tony Onley

Trade, Markets and Investment

Queensland Department of Primary Industries and Fisheries

Note: This report was prepared in 2002 and the industry circumstances, quantities and prices reflect the 2002 situation.

3.1 Background

The South Australian sardine industry was initiated to provide feed-stock for the tuna mariculture industry and most of the catch is still used for this purpose. The price paid for fish destined to this market is between $0.65–$0.85/kg. This is substantially lower than the wholesale price for sardines sold in Australia as bait ($2.20–$2.50/kg) or human consumption ($3.00–$6.00). However, the tuna feed market remains attractive to the majority of the 14 sardine licence holders for the following reasons:

- Proximity to tuna farms—all tuna farms are near Port Lincoln where the entire sardine fleet is based
- Tuna farms holding sardine licences—approximately nine (9) sardine licence holders supply tuna farms directly and most of these are tuna farm operators using sardines to supplement imported feed
- Minimal quality requirements—sardines are sold to tuna farms fresh, in ice slurry or brine or in frozen form. Appearance is not a major issue and generally quality requirements are minimal
- Minimal processing required—where freezing is required, sardines are frozen in batches in a simple blast freezer and stacked on pallets

This project aimed to facilitate the adoption of post-harvest handling techniques that would improve the quality of sardines. However, a number of markets do not pay a premium for quality since the end use of the sardines does not require it. In recognising this fact, this report examines the issues relating to the marketing of sardines in existing market segments, and, promising new market segments, with a view to identifying marketing options that are congruent with the production of high quality sardines from South Australia. The work forms part of Phase 1 of the project 'Optimising at-sea post-harvest handling procedures for the sardine (Sardinops sagax)'. The marketing study reflects a determination by industry stakeholders to adopt a more strategic approach to the marketing of the very significant and expanding sardine harvest, in order to add value to the industry.

3.1.1 Objectives

- Identify existing and potential market segments for sardines
- Identify the quality requirements in each market segment
- Identify price potentials for each market segment
- Identify supply chain issues and implications for fishers and processors looking to target a particular market segment.

3.1.2 Scope

A considerable amount of research has focused on the Australian sardine industry, particularly since the fishery first showed strong signs of recovery in 2000/2001. This report aims to present new information and has avoided repeating many industry statistics, unless of direct relevance to the objectives of this document. This particularly refers to many of the statistics presented in the very comprehensive report, 'SA Sardine Industry Feasibility Study—Final Report, November 2000'.

The report does not investigate in detail the following:

- Demand for sardines from tuna farms and the pet food industry

- The feasibility of establishing a cannery for sardines

An investigation of the marketing of sardines to tuna farms and the pet food industry was not considered necessary for this report for reasons explained in Appendix 3.1.

The potential for a canning operation is discussed in very broad terms. However, to investigate this option in detail would require a very comprehensive feasibility analysis, which was beyond the scope of this report. Mention is made of collaboration opportunities with existing canneries, however, interviews were not carried out with representatives since this was considered premature in the context of the industry's current phase of development.

Determining the size of the commercial and recreational bait markets for the report was difficult due to the lack of comprehensive data on sardine consumption by these sectors. Imports are recorded by ABARE (Australian Bureau of Resource Economics) under the term 'non-edible marine finfish', a term that encompasses a number of different species. Furthermore, various confidentiality clauses in the import agreements of certain importers further complicates the task of determining the exact quantities and end uses of frozen sardines imported into Australia for non-edible purposes. Quantities presented in the report are based on industry estimates and sample surveys and should be used with caution.

Primary research carried out was mainly qualitative in nature.

3.1.3 Methodology

Research for the report followed a 3-stage process:

Stage 1—Desktop research

Desktop research consisted of the following activities:

- Internet searches;
- Review of publications relating to the sardine industry prepared by:
  - consultants;
  - state fisheries departments;
  - AQIS (Australian Quarantine and Inspection Service)
  - Biosecurity of Australia;
  - Fisheries Research and Development Corporation;
- Collation of statistics from ABARE, Department of Agriculture, Fisheries and Forestry Australia, Sydney and Melbourne Fish Markets and state fisheries departments.

Stage 2—Primary research

Visits were made to Port Lincoln, Melbourne and Sydney and discussions held with the following industry stakeholders (Table 3.1).

Table 3.1: Interviewees

Interviewee	No of interviews
Sardine fishers	3
Sardine processors	4
Sardine importers	6
Seafood wholesalers	7
Seafood retailers	15
Bait wholesalers and retailers	6
Seafood consultants	4
Other: State fishery representatives, Fish Market representatives, Coles supermarkets, spanner and mud crab fishers	15

Interviews were carried out face to face and by telephone to gain a better understanding of the dynamics of the Australian sardine industry and to identify marketing issues that relate to the South Australian situation.

3.2 Bait Market

The Australian bait market is characterised by a large number of importers and a small number of domestic suppliers competing for a share of a very price sensitive market. This is particularly the case in areas above the latitude of 30° (north of Coffs Harbour) where imported product is permitted by AQIS for use as recreational bait with few restrictions (see Appendix 3.2).

Bait distributors and wholesalers contacted during the research were generally very negative about the current marketing environment for recreational and commercial bait. A common view expressed was that the industry operated more effectively when Australian sardines dominated the market, prior to the collapse of the domestic fishery. At this time the quality of Australian sardine bait (mostly sourced from Western Australia) was perceived to be very high and the relationships that existed between the various stakeholders along the supply chain more stable.

3.2.1 Recreational and commercial bait segments

The main bait markets and their bait preferences are as follows (Table3.2).

Table 3.2: Bait market segments and product preferences.
IQF - Individually quick-frozen

Market segment	Bait preference	Target species
Recreational anglers and sports fishermen	Block frozen and IQF	Numerous incl. tailor, snapper, bream, flathead
Dropline fisheries (deep and shallow water)	Block frozen	Reef fish and deep water species eg coral trout, tailor, snapper, Spanish mackerel
Commercial trap fishing (sardines usually in combination with other baits)	Block frozen	Predominantly spanner crabs, some fish species such as leather jacket

3.2.1.1 Size of market

Anecdotal evidence based on estimates by a significant bait supplier in Queensland and Davidson et al, 2000 in the publication, *SA Sardine Industry Feasibility Study*, suggests that the total recreational and commercial bait market in Australia for sardines is approximately 3,800 tonnes.

Recreational bait

Calculations based on a study conducted by Kewagama Research in 2002 indicate that the recreational bait market consumes 2500–2880 tonnes/year of sardines (see Table 3.3). This estimate is derived from the responses to questions relating to the quantities of saltwater fish used for bait and bait preference. The key findings of the Kewagama survey were:

- A total of 3,841 tonnes of saltwater fish are used for bait and berley Australia wide
- 73% of respondents used sardines as bait
- After sardines the next most common bait used by respondents was mullet at 28%
- A variety of other saltwater fish species were used as bait/berley by 10% or less of respondents.

The figure of 2,500–2,880 tonnes/year is based on the assumption that 65–75% of the saltwater bait used by recreational fishers (3,841 tonnes) consists of sardines.

Table 3.3: Purchase sources of saltwater fish used for bait/berley – Annual quantities used by State/Territory of residence.

***** Grand mean

Purchase source	**NSW/ACT**	**VIC**	**QLD**	**SA**	**WA**	**TAS**	**NT**	**TOTAL**
Total (tonnes)	**990.3**	**332.3**	**1,471.7**	**137.6**	**860.6**	**39.2**	**9.6**	**3,841**
Mean kg/purchaser	3	1.2	4.3	1.8	4.41	1.1	0.42	3*****

(Kewagama Research, 2002)

The Kewagama Research survey indicated that Queensland is the largest user of recreational bait. This is most likely due to Queensland's year round climate suitable for fishing, prevalence of fish species for which sardines are very effective bait (eg tailor, Spanish mackerel, reef fish) and large numbers of tourists. In comparison, other states experience more seasonal demand such as sharp peaks during summer months (particularly school holidays) and to a lesser extent holiday periods during the winter months (Bait wholesaler 2003).

Commercial bait

Based on the previously quoted estimates of 3800 tonnes for the total size of the bait market and 2500–2880 tonnes for the size of the recreational market, the estimated size of the commercial bait market is between 920 and 1300 tonnes. However, these estimates should be viewed within the context of a volatile commercial sector and are very much indicative figures rather than substantiated tonnages.

The volume of commercial bait sold is likely to display more volatility year to year than the recreational bait market due to uncertainties in the industry such as:

- access to commercial fisheries;
- catch limits and size limits;
- availability of substitute products; and
- demand factors (eg SARS has significantly reduced demand for Australian reef fish).

Queensland is a large user of commercial bait due to strong demand from:

- the live fish export industry operating off northern Queensland;
- other drop-line fisheries in both shallow and deeper waters for the fresh and live fish markets;
- commercial trap fishing, particularly the spanner crab fishery where sardines are used in combination with other baits (Gosbell 2003).

In Western Australia, the large rocklobster industry creates a significant market for sardines although numerous products compete for this market, including jack mackerel, scaley and blue mackerel, mullet, tuna heads and Australian salmon. The industry also has a voluntary ban on the use of imported sardines due to disease concerns. This benefits the local sardine industry and reduces the quantity of sardines on interstate markets.

3.2.1.2 Market growth

Recreational bait

Evidence from surveys conducted in Queensland indicates any growth in demand for sardines as recreational bait, will be relatively small (Higgs and McInnes 2001). Recent Queensland surveys have shown that population growth has offset a slight reduction in participation levels in recreational fishing to reflect a relatively stable number of recreational fishers (Kewagama Research 2002). With the exception of Queensland, little national time series data is available from which to determine trends in the Australian recreational fishing market.

Research illustrates the following trends in recreational fishing activity:

- Anglers are becoming increasingly specialised, as they become better equipped and informed on fishing techniques
- Anglers are becoming less consumptive in their approach to fishing and more aware of practices that result in more sustainable use of seafood resources.

A key driver of this trend is the proliferation of fishing programs, fishing related trade shows and better communication between equipment suppliers and fishers. Greater specialisation and a less consumptive approach to recreational fishing is unlikely to impact on the quantity of sardine bait consumed.   More likely these trends will lead to increased participation in fly and lure fishing and more precise use of bait and terminal tackle.

Commercial bait

Based on the limited growth prospects for the commercial fishery, it is unlikely that the demand for sardine bait will grow significantly. Commercial users of sardine bait are targeting species that are mostly fully exploited. Furthermore, lobbying from other special interest groups representing the environment, tourism and recreational fishing impacts on access to commercial species through the introduction of stricter catch and size limits, green zones (no take) or marine parks. For example, the Great Barrier Reef region of Australian is one area where commercial access and catch and size limits for reef fish have been reviewed in line with new management plans for this significant fishing area and no-take zones introduced.

According to industry sources, IQF bait outsold block frozen in past years although currently the quantities of each sold are approximately equivalent. Amongst commercial users of bait, there is strong preference for block frozen since there are established procedures for their use based on the thawing times of the blocks. Blocks are also considered to be cheaper and easier to store. Some line fishers do prefer IQF bait, since it is perceived to be better quality and more durable on the hooks (Gosbell 2003).

3.2.1.3 Suppliers/competitors

Processors from the south coast of Western Australia and importers dominate the wholesale market for sardine bait. South Australian processors and wholesalers of sardine bait compete with importers and domestic suppliers; they will have some logistical competitive advantage over West Australian suppliers due to their proximity to the large markets on the east coast. However, this does not apply when competing against imports, which can be landed at multiple ports around Australia for a very low price.

Prominent West Australian processors and bait wholesalers are Bremer Fish Processors and its associated company, Bremer Products Pty Ltd, Bevans (WA) Pty Ltd and South East Fisheries. These companies have established a dominant and high profile position in the market place through consistent supply of quality block frozen and IQF sardine bait. Other smaller bait processors operate in Melbourne, Sydney and in some regional fishing centres such as Eden in NSW. Although many of the retailers and end users were not always familiar with the individual processors of Australian bait, they usually associated Australian bait with Western Australia and were generally very positive about bait products from this state (Trade interviews 2002/3).

Numerous companies import sardines for bait, tuna feed, pet food and fish meal. The distribution channels for these imports can be quite complex since importers actively compete amongst each other for business in a number of markets in Australia, and lowest price, not quality is the major selling point (Holt 2003). In some cases bait wholesalers (often with associated retail outlets) import sardines for direct sale or processing into more appropriate retail packs. Whether importing directly or sourcing bait from third party importers, bait wholesalers commonly distribute both imported and Australian sardines. Some of the larger bait wholesalers and retailers in Australia are Bremer Bait and Tackle (NSW), and Tweed Bait Pty Ltd (NSW), Windy Banks Bait Service (NSW), Terry's Bait and Seafoods (QLD).

The following comments by retailers/wholesalers and end users of bait, provide some insight into the perceptions of various bait products:

- "*I prefer to buy Australian product of high quality but price is very important because of the competition*" (Windybanks, wholesaler/retailer, 2003);
- "*A lot of commercial and recreational people buy on price but many are concerned about quality*" (Holt, wholesaler/retailer, 2003)
- "*Recreational fishers prefer sardines*" *(Sardinops sagax) (as opposed to imports of other members of subfamily Clupeidae of slightly different shape)* (Holt, wholesaler/retailer, 2003);
- "*Western Australian sardines are historically well perceived in the market*" (Holt, wholesaler/retailer, 2003)

- “*Without a quality product Australian processors cannot compete*“ (Holt 2003)
- “*Western Australian sardines are the best sardines*” (Gosbell, trap fisher, 2003)
- “*The quality of the sardine is important to commercial line fisherman as they need to be firm to stay on the hook*” (Gosbell 2003)
- “*A lot of the imported sardines particularly from Indonesia are cheap but poor quality*” (Hall, trap fisher, 2003)
- “*Experienced recreational fishers ask for Australian sardines while the inexperienced ask for the cheapest*” (Windybanks, wholesaler/retailer, 2003)
- “*People after trap bait or berley only buy the cheap product*” (Windybanks, wholesaler/retailer, 2003)

The above comments would suggest the following:

- Experienced fishers and some commercial drop line fishers value quality and, in the case of the former, have a preference for Australian sardines.
- Experienced recreational fishers, and possibly commercial line fishers, are prepared to pay for quality Australian sardines
- Western Australian bait suppliers have a strong reputation in the marketplace for producing a quality product.

South Australian processors would be better advised to capitalise on the positive points of differentiation between their product and imported bait in order to take market share from importers. Some potential positive attributes of a South Australian product that could be developed and highlighted through labelling and promotion activists are as follows:

- Australian and South Australian origin of bait (development of a brand)
- Quality of the product
- Suitability for Australian target species

- Disease free status
- Sustainable aspects of the resource

3.2.1.4 Quality requirements

The sardine (*Sardinops sagax*) is considered the benchmark in terms of size and shape; even though some slight variations exist within Australian populations (Holt 2003). An indication of a quality sardine is as follows:

- Firm when thawed (hold on hook) (Gosbell 2003);
- No splitting and/or bloody appearance (Jelinek 2003);
- Glossy shiny appearance and skin intact when thawed (Windybanks 2003)
- Preference for straight fish (no curl) (Windybanks 2003);
- 35–45 grams (Holt 2003);

In terms of imports, bait distributors and retailers have mixed views on the product. Depending on the country of origin some common complaints are:

- USA and South African sardines are often too long for some angling activities;
- Indonesian and Indian fish (Clupeidae species) have a different shape and can spin on the line (i.e. don't 'swim' properly);
- Variable quality i.e. soft and affected by belly burst;
- Concern about disease issues (potential to endanger Australian fisheries);

Comments made during interviews suggest that some of the quality issues associated with imported product are being addressed, as feedback from end-users passes back along the chain to overseas suppliers. For example, the quality of the Indonesian exports is said to have improved dramatically (Holt 2003).

Furthermore, bait distributors and many of the retail outlets expressed considerable support for Australian sardines, particularly those from Western Australia. This was due to sardine quality and consistency and other less tangible factors such as it’s Australian origin (national sentiment), suitable size and shape, and the fact that Australian sardines are not subject to the disease concerns and restrictions on their use that apply to imported sardines (Trade interviews, 2003). However, according to one leading bait supplier in QLD, quality is less of an issue when sardines are used for berley and in the spanner crab fishery (Gosbell 2003). Spanner crabs are caught with baited dillies (crab traps) and sardine bait is primarily valued for its high oil content (Gosbell 2003).

3.2.1.5 Price

The wholesale purchase price for imported sardines has been around $2.40–$2.50/kg however, increasing imports of very cheap product from Indonesia and India and competition amongst importers, has driven the wholesale price down to under $2.00 in many cases. Recent prices quoted by one bait wholesaler/retailer were:

- Imported block frozen and IQF bait: $1.80–$2.25/kg (wholesale price)
- Australian block frozen and IQF bait: $2.25–$2.50/kg (wholesale price)

* IQF is usually slightly dearer than block frozen (Trade interviews 2003).

Importers are able to operate on very low margins since product is cheap and can be delivered to a port close to the market. Anecdotal evidence provided by some bait wholesalers suggest that the market has or is close to bottoming (Trade interview 2003).

Imported sardines arrive as IQF in bags or cartons of various weights (usually 15 kg). Frozen blocks arrive in 2, 2.5 or 2.7 kg blocks. Recently, the USA has reduced its block size from 2.7 to 2 kg, which gives the appearance of better value to customers used to purchasing proportionally more expensive larger blocks (Holt 2003).

Many retailers have a preference for quality Australian product. (Trade interviews 2003). However, bait remains a price sensitive product for commercial fishers who can use substitute products or seek low priced imports during times when Australian sardines are not readily available or too expensive. In addition, many retailers perceive increased profit margins to be more obtainable from imported products, particularly when purchased directly from the importer.

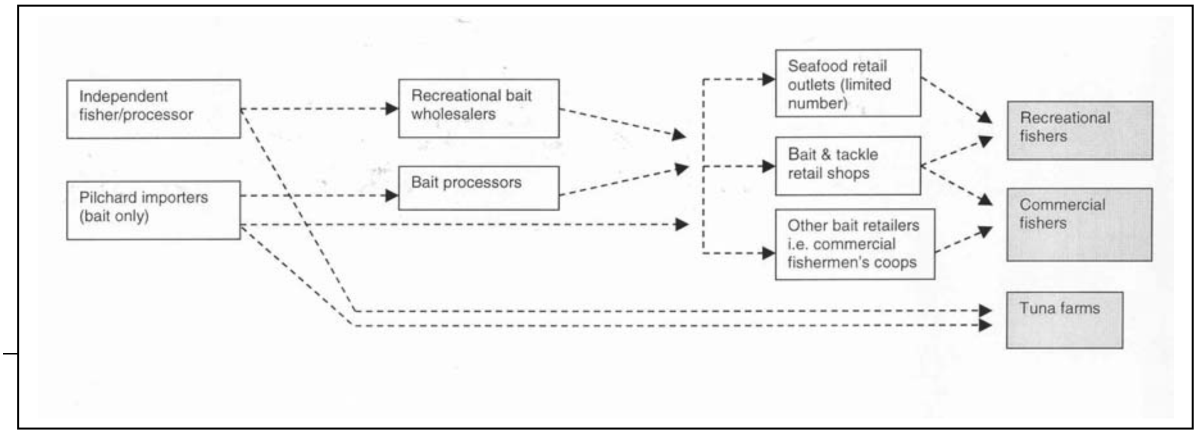
Although the present bait market is a competitive one for existing and potential suppliers, opportunities do exist for low cost South Australian suppliers of quality product, particularly if, as evidence suggests, the price for imported bait has bottomed.

3.2.1.6 Supply chain

The collapse of the domestic sardine fishery brought to an end many of the stable supply chain relationships that existed between fishers, processors, wholesalers and retailers, as importers of cheap overseas product replaced many domestic suppliers. Low barriers to entry for new importers have caused strong competition for market share amongst suppliers resulting in supply chain relationships that are often short term in nature. The current market, particularly for non-edible products, is price driven and unstable for many of the stakeholders.

Australian product is now beginning to re-enter the market in increasing quantities as the TACs for sardines in Western Australia and South Australia are increased in response to recovering sardine fisheries (see Appendix 3.3). Australian companies, particularly those from Western Australia, are now seeking to regain market share in the bait market they once dominated.

Fig. 3.1 Supply chain for the bait industry



From the retail perspective, bait is sold through numerous outlets including bait shops (usually bait, tackle and accessory shops), seafood retail outlets, service stations, small shops and other establishments, usually located close to popular fishing areas. Table 3.4 illustrates the distribution of retail outlets classified as bait shops in each state.

Table 3.4: Number of bait shops in Australia

State	No. of bait shops
Queensland	104
New South Wales/ACT	111
Victoria	54
South Australia	32
Tasmania	3
Western Australia	25
Northern Territory	3

Marketing Pro, 2002

Traditionally bait wholesalers distributed product to the various retailers. A recent trend is importers (and their distributors) bypassing traditional wholesalers to directly target retail bait shops and other bait retailer (eg fisherman's co-ops) (Holt 2003). This has caused some angst amongst long-term wholesalers. As a consequence, many established bait distributors are looking to form more stable business relationships with domestic suppliers of competitively priced quality sardine bait, despite the lower price points of imported product. Bait distributors appear to strongly desire a return to stability in the industry and support appears genuine for emerging Australian bait suppliers (Trade interviews 2003).

3.2.1.7 *Risks & opportunities*

The current volatility of the bait market presents both risks and opportunities for SA processors. The major risk associated with targeting this market relate to the following:

- Large numbers of importers in the market;
- Increasing quality and decreasing price of imports;
- Competition from established domestic suppliers;
- Retailers not supporting quality Australian product;
- Limited market growth;
- Price cutting and 'cowboy' behaviour of a small number of importers.

Many of the opportunities in the bait market derive from the present instability in the supply chain and concerns about quality and disease risk (see 3.1.4) of imported product. Some potential positive attributes of a South Australian product that could be developed and highlighted through labelling and promotion activists are detailed in 3.2.1.3.

Comments by retailers, wholesalers and end users of bait in 3.1.3 indicate that experienced recreational fishers and commercial drop line fishers do care about the quality of the bait they use and will often ask for Australian product. This suggests South Australian processors should attempt to target these segments of the bait market when developing branding and product promotion strategies in order to provide a better product and service than that currently provided by importers.

3.2.1.8 *Recommendations*

Price, quality, and to a lesser extent country of origin are major considerations to bait wholesalers and retailers. South Australian processors will need to develop competitively priced quality bait products that meet or exceed the benchmark set by prominent Western Australian suppliers in order to compete effectively in this market and encourage import substitution. To avoid competing on price alone, South Australian processors should attempt to target the more discerning segments of the bait market namely experienced recreational fishers and gamefishing-boat operators, when developing branding and product promotion strategies. Some potential positive attributes of a South Australian product that could be highlighted to target these segments and build market share are as described in 3.2.1.3, pg 33.

3.3 Human Consumption Market

In Australia, sardines in the fresh form are highly regarded by Australians of Mediterranean/Southern European origin, to whom this species is both culturally significant and a traditional meal solution (Trade interviews 2002/3) (see Appendix 3.4 for classification of the Australian sardine). For other Australians, sardines are often perceived as an oily and strongly flavoured fish commonly used for bait. Some comments provided by a number of retailers suggest that this view is changing as consumers become more adventurous, and cognisant of the health benefits of eating oily fish such as sardines.

Sardines (*Sardinops sagax* and *Sardinella* species) represent a popular meal solution for Australians and are predominately consumed in canned form. According to a spokesperson for Cantarella Bros, marketer of the King Oscar brand, Australia's No. 1 selling canned sardine, consumer interest in health and nutrition remains very high and good sources of protein and key nutrients in addition to great taste will continue to be sought out by our aging and increasingly health conscious populations (Towers 2002).

At the time of preparation of this report, all canned sardines sold in Australia were sourced from overseas.

3.3.1 Processing Segment

The sardine-processing sector is currently very small in Australia and involves preparation of the following products:

- Fresh and frozen fillets (includes fillets in marinate)

- Smoked sardines (butterfly fillets)
- Canned sardines

One operator, Mendolia Fremantle Sardines from Western Australia, dominates the processing of Australian sardines for human consumption. This innovative company markets a range of fillet products and has produced canned products in the past but is not currently doing so (see Appendix 3.5 for Mendolia's product range). A small number of other processors exist in Australia, however the scale of their sardine processing operations is quite small and their level of activity has been intermittent over recent years.

Currently all of Australia's processors either catch their own sardines for processing or source from other suppliers in their immediate area.

3.3.1.1 Size of market

According to a prominent Australian processor, the demand for fillets in Australia is approximately 50–100 tonnes/year. The smoking of sardines would appear to be occurring at very low levels with the main activity confined to one smokehouse in South Australia (Springs Smoked Seafoods). Springs are currently using imported sardine fillets from Thailand for smoking purposes and are satisfied with the pricing and quality of this product (Springs Smoked Seafoods representative pers comm 2003). Only one processor, Mendolia from Western Australia, has the capability of producing canned sardines, but is currently not doing so.

3.3.1.2 Market growth

There is no evidence to suggest that the processing sector is experiencing any significant growth due to increased demand. However, growth in demand for sardines for processing depends on demand factors from the retail and food service sectors and the ability of the industry to consistently supply quality processed products to the market.

3.3.1.3 Suppliers/competitors

The processing of sardine occurs mainly in Western Australia. The type of processing operations and their location are as follows:

Fremantle (WA)	—	2 x companies with filleting machines
	—	1 x company with canning facility
Esperance (WA	—	1 x company with filleting machine
Albany (WA)	—	1 x company with filleting machine

(Industry interview, 2003)

Processors either catch their own sardines for processing or source sardines locally (although smokehouses may use imported product). Sardine processing is usually not the main part of a processing operation but carried out in conjunction with the packing/processing of other more valuable species.

3.3.1.4 Risks and opportunities

Due to the abundance of sardines in Western Australia, the small size of the processing market, and the distance to this market, there is no opportunity for South Australian sardine producers to supply existing processors located in this state. Opportunities for South Australian to process their own sardine products are discussed in 3.2 and 3.3.

3.3.1.5 Recommendations

There is no opportunity for South Australian sardine producers to supply existing processors located in Western Australia.

3.3.2 Retail segment

The retail segment for sardines consists of the following:

- Specialised seafood retailers (independent stores or small chains)—sell sardines as fillets and as fresh and frozen whole fish.
- Supermarkets—sell sardines in canned form and in very small quantities as fillets and as fresh or frozen whole fish

Australian consumers have traditionally consumed larger quantities of milder tasting fish with white coloured flesh than fish, such as sardines, that have a stronger flavour, high oil content and darker flesh (Mason pers. comm. 2003). Sardines in fresh and frozen whole and fillet form are mainly sold through specialised seafood retail outlets in areas with higher populations of Mediterranean/Southern Europeans. Supermarkets retail canned sardines and more mainstream fresh and frozen seafood species that have a strong consumer acceptance and high turnover.

3.3.2.1 Size of market

Specialised seafood retailers

Fresh whole, frozen whole, fillets: Determining the size of this segment for sardines is difficult, due to the inconsistent supply of sardines in recent years. However, the following estimates of the market size for sardine products were provided by a prominent Western Australian processor supplying sardine fillets and fresh whole and frozen whole sardines to retailers in eastern states. They provide an industry perspective of the size of the Australian market for these products (see interviewee 1 in Table 3.6).

- Fillets 52–104 tonnes
- Fresh whole 104–156 tonnes
- Frozen whole 312–468 tonnes

In quantifiable terms, approximately 91 tonnes of fresh whole sardines (and small quantities of frozen sardines) were sold through Sydney and Melbourne

Fish Markets in 2002 for eventual sale through retail outlets, primarily specialised seafood retailers (Table 3.5).

Table 3.5: Quantity of sardines sold at Melbourne & Sydney Fish Markets

Year	**Melbourne (t)**	**Sydney (t)**
2000	57	40
2001	28	34
2002	52	39

Sydney and Melbourne Fish Markets, 2003

*Melbourne data converted from bins (32kg) to tonnes.

These sales represent only a portion of sardine sales, as many retailers source fish outside the wholesale market system. Table 3.6 presents industry comments and estimates of the size of the market for sardines in fresh whole, frozen whole and fillet form.

Table 3.6: Industry estimates of market size

Interviewee	Product	Estimate of market size	Market	Comment
1. WA wholesaler/ processor (2003)	Fillets	1–2 tonnes/week	Australia	Market for fillets not huge
	Fresh whole	2–3 tonnes/week	Australia	Maybe 3 tonnes including going outside the market
	Frozen whole	6–9 tonnes/week	Australia	Frozen is triple that of fresh
2. Melbourne Fish Market Agent/ wholesaler, 2003	Fresh & frozen whole	15 tonne/week	Victoria	Could sell 15 tonne/week of fresh and frozen in Victoria if the supply was consistent. At least 10 of that would go through the market MWFM)
				Retailers sell frozen when fresh is not available
	Fillets			Sell OK and popular with restaurants but a limited market
3. Melbourne Fish Market provedore, 2003	Fresh whole	50 x 32 kg boxes /day (approx. 1.6 tonnes/day		Demand for sardines is 52 weeks/year. MWFM could handle this volume. Buyers chase bigger seller first but will always want sardines. Buyers looking for fresh and quality
3. Frank Theodore, Sales Manager, De Costi Seafoods, Sydney, 2003	Fresh whole		Sydney	Season is only 3 months long so never long enough. When we have them fresh they go. Could sell up to 700 kg of fresh/week from the Pyrmont store alone product were available
	Frozen whole		Sydney	Really a non–event, a bit like bait. Do sell some frozen to food service but only in small quantities
	Fillets	Have 70-80% availability from WA	Sydney	Food service use these but also demand whole
4. Gus Dannoun, Supply Manager, Sydney Fish Market, 2003	Fresh whole	300 kg/day		Could move this amount if spread evenly. Have no trouble moving sardines if pricing is constant

Industry interviews suggest that seafood retailers have a strong preference for fresh fish although this does not appear to be uniform across markets. A number of wholesalers and retailers in Melbourne commented that the Melbourne retail market is reasonably accepting of frozen, when fresh is either unavailable or too expensive. This is supported by observations of frozen sardines thawing in a number of retail shops in the Queen Victoria markets, Melbourne near other shops that were selling fresh sardines.

In comparison to Melbourne, Sydney retailers were very dismissive of the frozen product. An exception to this statement was one brand of frozen imported Portuguese sardines observed in several retail shops at SFM, which reportedly had some acceptance amongst consumers and food service due to their high quality (see Appendix 6). Based on these limited observations, the Melbourne market would appear to offer more opportunities for frozen product than the Sydney market.

Supermarkets

Fresh whole, frozen whole, fillets: Supermarkets in Australia sell only very small quantities of fresh and frozen sardines products. Communication with national staff from Coles Supermarkets revealed that sales of fresh and frozen sardines in QLD, NSW, Victoria, South Australia and Western Australian were very small in Queensland and almost non-existent in other states. In QLD, Coles preferred seafood supplier indicated that between February and October 2003 only 15 cartons (150 kg) of whole frozen sardines were sold to Coles and one carton (10 kg) of frozen fillets to a BI–LO store.

Canned: At present Australia produces no canned sardines. However, sardines are a significant component of the imported canned fish category and are ranked third in terms of volume and value behind tuna (20,347 t, $94 M) and salmon (8,141 t, $43 M). The major sardine brands of Cantarella/King Oscar, John West and Brunswick account for 65% of the market, in terms of sales and are all imported (Retail World Grocery Guide 2002). Table 3.7 indicates the quantities of canned sardines imported over recent years.

Table 3.7. Quantity of canned sardines imported into Australia

Year	Quantity (t)	Value ($'000)
1997–1998	3,226	17,770
1998–1999	3,695	18,263
1999–2000	4,758	22,559
2000–2001	4,769	25,365
2001–2002	4,115	22,641

Source: Australian Fisheries Statistics 2002

In 2001–2002, consumption of canned sardines declined by 650 tonnes in comparison to 2000–2001. However, it is unclear whether this represents a trend of declining consumption in this category.

Mendolia Fremantle Sardines are the only company in Australia with the capacity to can Australian sardines. Issues with sourcing sardines halted canning operations several years ago. However, the company is proposing to re-launch their canned sardine range in the near future (Mendolia pers comm. 2003).

3.3.2.2 Market growth

A number of seafood retailers and other participants in the industry were asked to comment on what was required to further develop the sardine market (Table 3.8).

Based on these comments the following is required to grow the retail market for sardines:

- Consistent supply of sardine products to seafood retailers
- Promotion of sardines by the sardine industry and retailers
- A quality product

- Realistic pricing

Table 3.8. What is required to grow the market for sardine fillets

Business type	Comment
Retailer (Melbourne, Queen Victoria Markets)	Quality is all important
Retailer (Melbourne, Queen Victoria Markets)	Sales pitch by staff is required to market seafood that the customer is not familiar with
Retailer (Sydney)	Sardines need to be consistently available
Wholesaler/importer (Melbourne)	Must be handled delicately and precisely and distributed through the right agent. The market can certainly grow.
	Must be sold from premise that they are for human consumption (move away from bait image)
Smoker/processor (Cairns)	Need to reduce the price ($14/kg wholesale price is too expensive)
Seafood School (Sydney)	Butterfly fillets are the best way to overcome consumer reluctance.
Wholesaler (Brisbane)	Need marketing–they need to be pushed
	Fillets need to be cheaper ($15/kg wholesale price too expensive)
	Need to be packed and presented very well
Restaurant (Sydney, Darling Harbour)	The restaurant trade is very faddish. If you could get some of the big name restaurants using them everyone would be using them

Specialised seafood retailers

Fresh whole: Interviews with seafood retailers suggests that the fresh market has considerable scope to grow provided there is a continuity of supply and the quality of the product is of a high standard.

Retailers commented that fresh sardines were frequently unavailable and that this was a source of frustration. Availability of sardines varies considerably, leading to uncertainty on local markets. According to Frank Theodore, from the large De Costi Seafoods retail chain in Sydney, the supply of fresh sardines is small and inconsistent and the market remains undeveloped. In Melbourne, an agent and large seafood wholesaler from MWFM suggested that the Victorian retail market could absorb 15 tonnes/week of mainly fresh and 780 tonnes/year of frozen sardines if supply was consistent.

Frozen whole: The opportunity to supply retailers with frozen sardines does not appear to show a lot of growth potential for the following reasons:

- Frozen imported sardines have been widely available for a number of years (from domestic and imported sources) without strong growth in the market
- Frozen sardines are not well perceived by Sydney retailers, and in Melbourne are considered a substitute when fresh is not available.

Fillets: The following factors suggest there is some growth potential in the market for sardine fillets:

- Urban populations are becoming more cosmopolitan and looking for new eating experiences (sardines are increasingly common on the menu of quality restaurants);
- More mainstream forms of seafood are becoming increasing expensive (eg $12-13/kg for Nile Perch) in comparison to sardines;
- Perception that ‘sardines’ are an oily fish, high in omega 3s and with health benefits;
- The supply of fillets has been very inconsistent over recent years.

Mendolia Fremantle Sardines are the largest producers of fillets in Australia and have contributed greatly to growing the market for sardine fillets in Australia through heavy promotion of the product to specialised seafood retailers. However, it is clear that the national coverage by this and other Western Australian suppliers of fillets is not exhaustive, as a number of retailers interviewed mentioned that fillets were frequently unavailable.

Supermarkets

Fresh whole, frozen whole, fillets: The potential growth in this market would appear to be limited by demand factors as well as the following features of supermarket retailing:

- The supermarket business model offers little sales support and customer advice for seafood products
- Supermarkets favour seafood products with strong consumer acceptance and turnover
- Supermarkets are sensitive to products that result in waste or that require markdowns to move

(Industry interview, 2003)

Supermarkets may be the only be a viable distribution option in areas where the local demographic was familiar with sardines and significant demand already existed for the product. One supermarket chain seafood manager suggested that he would look at stocking sardine fillets if the supplier could build a strong case, supported by detailed market research, to show that demand existed for the product. To illustrate this point the manager provided an example where fresh pizzas were stocked in 12 stores located in areas where consumers were demanding this product. However, the manager also suggested that many consumers would not know how to prepare fresh sardine fillets and that fresh product would possibly compete with canned sardines, currently retailing for as little 89 cents/can (Appendix 3.7).

Canned sardines

Imported figures indicate that the canned sardine market is relatively stable in terms of the quantity consumed. Any new Australian entrant into this market would need to focus on taking market share from overseas brands.

Canned sardines remain a popular choice in the canned fish market. ABARE statistics show that, in terms of the quantity imported, they are third behind tuna (tuna imports exceed those for sardines by five to one) and salmon. This segment is dominated by premium quality brands, which are more expensive on a per gram basis than most canned tuna products. According to an article in Retail World (2002) sardines are being re-discovered as the health benefits are being found. The article also provides the following comment by a spokesman for the King Oscar brand of sardines:

Omega-3s, in tuna also in abundance in sardines, have been linked to a number of health benefits including reduced incidences of heart disease, strokes and Alzheimer's. Sardines are also an excellent source of calcium, needed to maintain strong healthy bones and reduce osteoporosis. The key to getting consumers back to sardines is offering them a choice of varieties like tomatoes, springwater and olive oil; 'added value' and 'healthier' types" (Towers, 2002).

In broad terms, the canned fish market continues to show strong growth compared to many other supermarket categories, partly driven by the strong performance of variants such as flavoured tuna and tuna in springwater (Retail World 2003). According to a report in Retail World, 2002, buyers always show an interest in new lines offering more varieties to consumers. Buyers are looking into value added products and environmentally-friendly packaging. Health claims are also receiving more attention (e.g. low sodium). The market leaders (in canned fish category) believe trends shaping this category in the near future will focus on innovation and new flavours.

3.3.2.3 Suppliers/competitors

Specialised seafood retailers

Fresh whole: Seafood retailers can source fresh sardines from:

- Markets direct (SFM or MWFM),
- Wholesalers purchasing from the markets, or
- Wholesalers purchasing direct from fishers.

MWFM receives some fresh sardines from southern NSW but usually do not receive fresh product from any other state (MWFM agent, 2003). SFM on the other hand receives significant quantities of fresh whole sardines from Western Australia, NSW and lesser amounts from Victoria (Dannoun, 2003).

Numerous fishers in NSW, and Victoria provide a relatively intermittent supply of small quantities of fresh whole sardines direct to the fish markets and/or seafood wholesalers in each of these states. Suppliers from these states and those from Western Australia compete with South Australian fishers to supply specialised seafood retailers (see Appendix 3.3 for sardine production by state). However, since many east coast fishers operate small boats and target sardines in the off-season for other species, established Western Australian suppliers with their considerable supply capability and established distribution channels to markets on the east coast, particularly to Sydney, are the major competitors.

Larger seafood wholesalers with extensive distribution networks have considerable influence in the specialised seafood retail market. South Australian sardine suppliers will need to form strategic alliances with one or more of these key distributors in order to effectively and efficiently distribute their product. South Australian sardine suppliers seeking to target specialised seafood retailers will need to service wholesalers and wholesale markets more effectively than their competitors. As mentioned in 3.3.2.2 some means of doing this include:

- The ability to provide consistent supply to seafood retailers;

- Product promotion;
- Producing a quality product;
- Realistic pricing

Frozen whole: Seafood retailers can source frozen sardines from:

- Wholesalers sourcing domestically, or
- SWFM and MWFM (occasionally)
- Importers

The retail market for frozen whole sardines is competitive and this product is also imported in significant quantities (see example in Appendix 6). Furthermore, this market pays little or no premium for human consumption quality frozen sardines when compared to the bait market, which is very demanding in terms of quality specifications (South Australia bait processor 2003). As a result, a number of bait processors now manufacture to human consumption standard, allowing wholesalers of their product to supply markets.

Under current marketing arrangements the market for frozen sardines does not appear particularly attractive for South Australian processors, given the additional competition from imports and opportunities to supply the much larger bait market. However, this market has been poorly serviced in terms of supply and product quality and very little effort has been placed on its development. Growing this market would require more innovative approaches to product marketing, presentation and development of a high quality frozen product.

Fillets: The current market for fillets is not sufficiently large enough to be particularly attractive (see 3.3.2.1). Producing a filleted product involves investment in a filleting machine and other product development expertise if flavours are to be added to the product line. At the same time, a significant sales volume is required in order to justify the capital expense. At present, the market is very small and requires product promotion activities to assist its growth (McArdle 2003). Attempting to enter the value added market too quickly potentially involves large capital expense, and low market acceptance of hastily developed products.

However, should this market develop in the future, a collaborative approach to this type of operation amongst Port Lincoln processors/fishers would require:

- Investment of resources in product promotion and industry development activities
- Cost sharing for processing equipment
- Developing a consistent supply of fish for processing
- Logistics issues (e.g. transport to markets)

Supermarkets

Fresh whole, frozen whole and fillets: Frozen sardines were not observed in any supermarkets during the research despite the fact that small quantities are occasionally sold through this channel. The large supermarket chains purchase seafood from preferred suppliers and other seafood suppliers must normally supply through these consolidators. Table 3.9 illustrates the preferred suppliers of fresh and frozen sardines to Coles supermarkets in a number of Australian states (does not mean the product is stocked).

Table 3.9: Coles Supermarkets preferred suppliers of fresh and frozen sardine products

State	Supplier	Origin & form of frozen sardines
Queensland	Global Seafoods	Whole fish, source unknown
	Sams Seafood	Whole fish from Portugal and Indonesia
NSW	De Costi Seafoods	Crumbed fillets, source unknown
Victoria	Australian Gourmet Seafood	Fresh and frozen
South Australia	Cappo Bros	Whole fish, source unknown

(Coles staff pers comm. 2003)

Supermarkets have little interest in fresh and frozen sardine products at present and would not be able to provide the product support required to promote the product and educate the public. However, certain supermarkets may be a viable distribution option in areas where the local demographic was familiar with sardines (see 3.3.2.2).

Canned sardines: At present, the entire range of canned product in Australia is imported (see Appendix 3.7). The main companies involved in the market and their share of value are shown in Table 3.10:

Table 3.10: Canned sardines – brand / %share

Brand	% share of market	
	Value*	Volume**
King Oscar	24.2	11.5
John West	22.6	14.8
Brunswick	18.4	19.5
Paramount	8.9	9.5
Riviana	3.5	3.5
Safcol	3.4	4.5
Santa Maria	3.2	3.2
PL/generics	13.2	30.7
Others	2.6	2.8

(Retail World Pty Ltd, 2001) *Total grocery value = $30.5 million, **Total volume = 2801 tonnes

The history of seafood canning operations in Australia illustrates that access to seafood inputs is crucial to a successful cannery. The canning operation of Mendolia's in Western Australia did show that a high quality Australian product can compete successfully with imports provided it is actively promoted. According to Jim Mendolia, their brand sold exceptionally well in Australia and at one stage was outselling the King Oscar brand on the domestic market. The experiences of this company and the relatively large market for canned product in Australia suggest that a small, efficient canning operation may have some potential in South Australia. Further detailed research would be required to determine the viability of such an enterprise.

3.3.2.4 Quality

Specialised seafood retailers

Fresh whole: Fresh sardines are a fragile and highly perishable fish that can become bloody and spoil quickly if handled poorly. An important aspect of quality is the 'freshness' of the fish, which is largely a combination of the time since catch and the integrity of the cool chain during this time. Therefore, maintenance of the cold chain from catch to retailer is particularly crucial. Some of the visual aspects of the fresh product that denote quality are:

- Firmness of flesh (fish not collapsed in appearance)
- No odours (smell fresh)
- Absence of waterlogged appearance (from floating in ice water)

(Theodore, 2003)

'Freshness' is only one of a number of factors affecting quality in the eyes of customer. Some of the risks for fresh product are damage from heat abuse and/or physical damage during transport, particularly by road. The type of packaging also influences the perception of quality. In Sydney 80% of retailers are in the suburbs and their preference is for smaller boxes containing 10-12 kg of sardines (Dannoun, pers com). According to a prominent MWFM provodore, fresh sardines in smaller containers with careful icing were much more attractive to buyers (retailers) for the following reasons:

- less prone to damage in smaller containers
- easier to handle and store (don't require repackaging)
- easier in terms of purchasing (less wastage as only buy what is needed)

Frozen whole: Thawed fish will not have the same appearance as quality fresh fish. However, provided they are handled carefully prior to and during processing they should still have the following characteristics:

- Shiny and colour underneath
- No odours
- Firmness of flesh

(Retailer, Queen Victoria markets, 2003)

Supermarkets

Canned sardines: Defining the actual attributes of a quality canned sardine product is difficult and beyond the scope of this product. However, physical damage and the degree of 'freshness' of fish prior to canning will impact on the eating qualities of the fish.

Fillets: An indication of quality sardines is as follows:

- Firm to touch
- Shiny appearance
- No 'off' odours

(Retailer interviews 2003)

Seafood retailers in Melbourne's Queen Street markets commented that smaller trays of fillets (1-2 kg) were preferable as this enabled display of small quantities of product while other trays could be kept in the main cool storage until required.

Sardines destined for filleting have similar requirement to those for the fresh market, namely freshness and an absence of physical damage (Slattery 2003). Freshness is a function of the time since harvest and the degree to which the cold chain is maintained over this period. Physical damage is an issue with many current practices, which involve the harvesting of large quantities of sardines in each shot using purse seine nets. Individual fish are damaged from contact with other fish, contact with the net and during brailing or pumping onto the boat. Existing processors in Western Australia who are focussed on the human consumption market work with smaller quantities of sardines in their nets and use brails to transfer the catch into brine or ice slurries for transport to processing facilities.

3.3.2.5 Price

Specialised seafood retailers

Fresh whole, frozen whole, fillets: The market price for fresh sardines is very sensitive to the volumes caught and periods of high catch are usually characterised by lower prices. The wholesale prices for sardines at Sydney and Melbourne markets presented in Fig. 3.2 and 3.3 has some influence on the retail price for fresh sardines while Table 3.11 presents examples of retail prices.

Fig. 3.2. Average price for fresh sardines sold at Sydney Fish Markets (wholesale price)

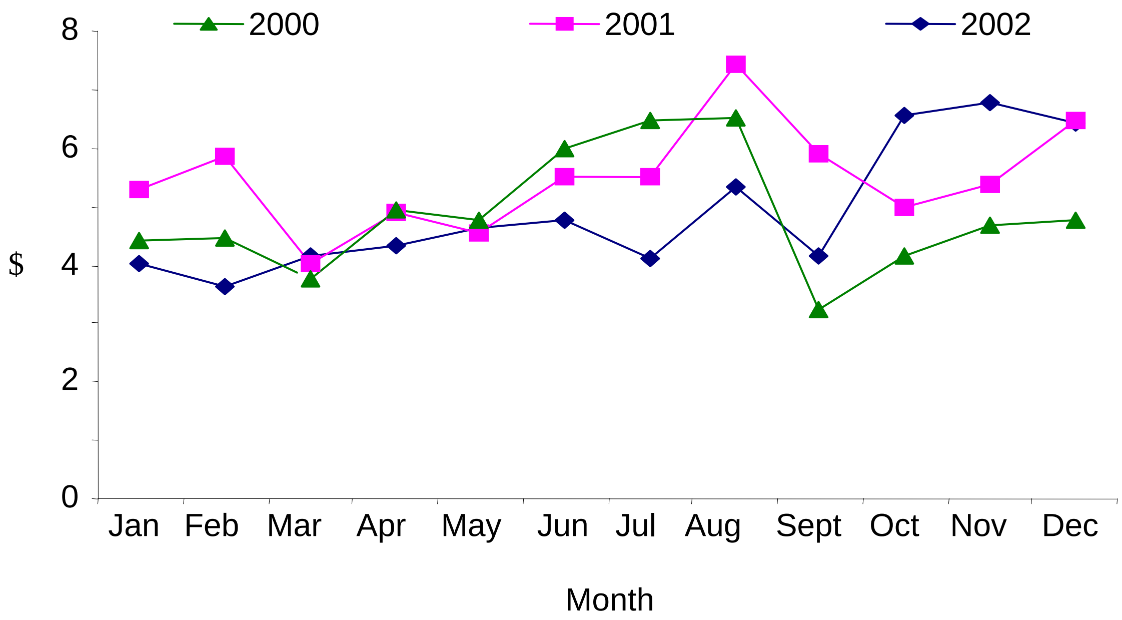


Fig. 3.3. Average price for fresh sardines sold at Melbourne Fish Markets (wholesale price)

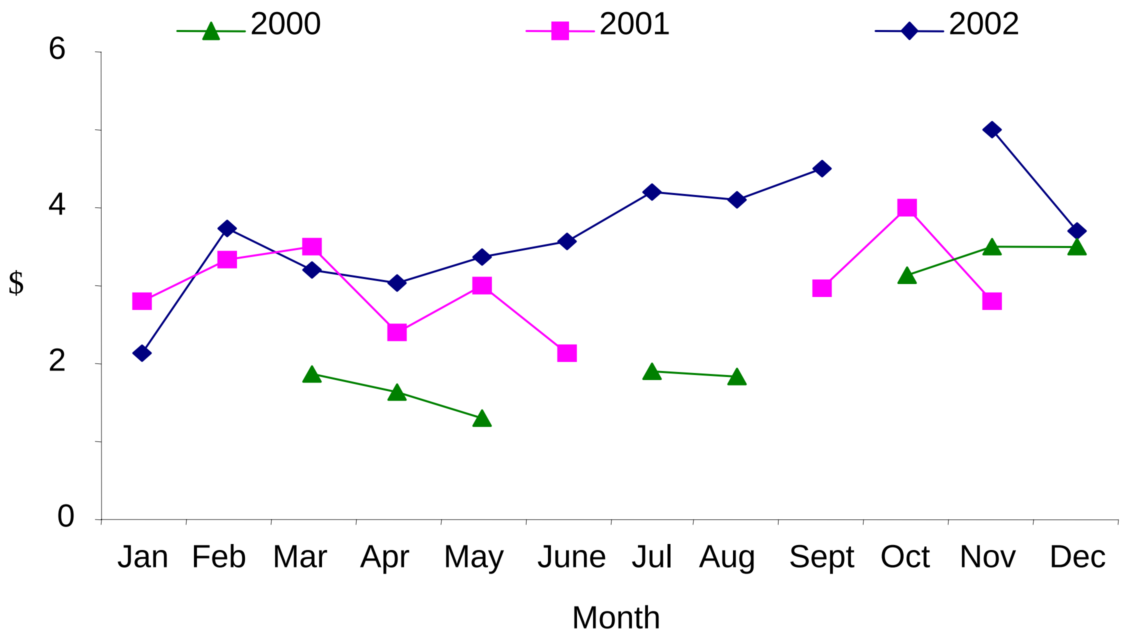


Table 3.11. Prices for fresh and whole sardines

Product	Place	Retail price/kg
Fresh whole	Queen Victoria Market retail shop	$6.00
"	Sydney Fish Market retail shop	$7.99
"	WA retail shop	$5.99
Frozen whole (Portugal) (Appendix 3.6)	Sydney Fish Market retail shop	$8.90
Frozen	Sydney Fish Market retail shop	$9.99/2.5kg block (bait)
Frozen	Sydney Fish Market retail shop	$12.00/2 kg block (bait)
Fillets	Various seafood retail outlets	$20.00 - $26/kg
Cold Smoked fillets (Springs)	Coles, Brisbane	$5.20 (150g pack)
Marinated fillets	Specialised seafood retailer, Brisbane	$48.99/kg

Prices for fresh sardines were consistently higher in Sydney than in other states as indicated in Tables 3.11–3.12. A large variety of IQF and block frozen sardines from domestic and overseas sources were observed in specialised seafood retail outlets, with many of these products presented in very basic packaging. Several retailers indicated that these products were purchased for both human consumption and bait. From a marketing perspective, this is a less than ideal situation and does not assist in developing the human consumption market for frozen sardines.

The profitability of sending South Australian fresh sardines to eastern markets is strongly influenced by the cost of freight, particularly airfreight. Table 3.12 indicates standard Australian Air Express charges for perishable goods. A representative of the company commented that these are starting prices and can drop by as much as half depending on the customer and the volume of business. South Australian suppliers of fresh sardines have slightly cheaper freight to Melbourne and Brisbane than WA suppliers and more expensive freight to Sydney.

Table 3.12: Australian Air Express freight charges

Depart	Arrive	Surcharge	Price/kg
Adelaide	Melbourne	$23.17	$0.96
"	Sydney	"	$1.75
"	Brisbane	"	$1.75
Perth	Melbourne	"	$1.42
"	Sydney	"	$1.64
"	Brisbane	"	$2.19

(Australian Air Express pers comm 2003)

Supermarkets

Canned sardines: King Oscar sardines retail for $2.99–3.29/105 g can (see Appendix 3.7). However, other private brands such as Black and Gold sardines retail for as little as $0.69/125 gram can. The price range for canned products illustrates the premium that is paid for the quality end of the market. The top brands also invest considerable resources into packaging, development of new varieties and promotion activities. Any prospective canning operation in South Australia would need to account for the cost of these activities in addition to those for the actual canning operation.

3.3.2.6 Supply chain

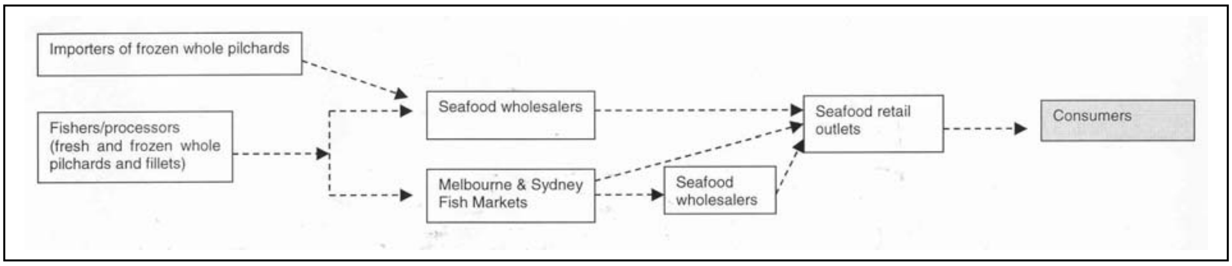
Specialised seafood retailers

Fresh whole, fresh frozen, fillets: Figure 3.4 illustrates the supply chain for the specialised seafood retail segment of the human consumption market. While the price for sardines is volatile, particularly for fresh product, the actual supply chains are relatively stable for the following reasons:

- The fresh and frozen market for sardines is quite small, they are a low priced product and wholesalers' and retailers' have little incentive to cut prices and compete aggressively for market share
- In general the market for fresh sardines is undersupplied

Fresh sardines are either marketed by fishers through the auction systems at Adelaide, Sydney and Melbourne Fish Markets to retailers and wholesalers or through other supply chains that involve wholesalers linking fishers directly to retail chains.

Fig. 3.4 Supply chain for retail segment



Communication with a leading agent at MWFM indicated that approximately 70% of the fresh sardines for human consumption in Victoria are marketed through MWFM. While it was not possible to establish a percentage for SFM, the following factors suggests that a large percentage of sardines consumed in NSW are distributed through these markets:

- A large percentage of fresh and frozen sardines sold at the market originate from Western Australia. SFM provides a free pickup service from the airport and, in some cases, from depot for frozen product (usually trucked), which is a strong incentive for distant suppliers (Dannoun, 2003);
- Sardine fishers in NSW and northern Victoria are small operators with unsophisticated distribution channels. SFM is a practical and convenient means of marketing their catch.

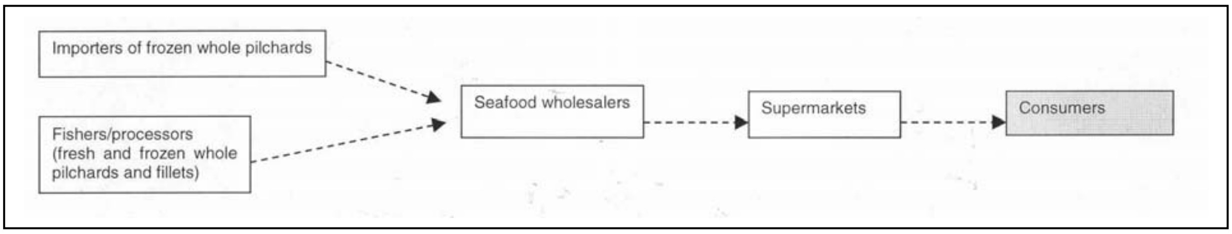
Supply chains that link fishers with retailers without the fish markets require good communication between fishers and wholesalers and greater emphasis on the timing of the catch, timing of deliveries, handling and quality aspects.

Fishers in NSW supply both the Sydney and Melbourne Fish Markets, depending on their location and demand at each market. Fishers in Victoria tend to focus on the Melbourne Fish Market although product is sent to the Sydney Fish Market from time to time. West Australian fresh sardines are regularly air freighted for sale at Sydney Fish Market and, to a lesser extent, Melbourne Fish Market while frozen product is sent to both markets. West Australian and South Australian sardines are also marketed through SAFCOL and SAMTAS Seafoods in Adelaide (P. Rogers, pers comm.).

Supermarkets

Canned sardines: Canned sardines are mainly sold in supermarkets (Fig 3.5), smaller grocery shops and convenience stores. However, they are also sold in many gourmet delis. Representatives for the major brands provide sales support for their product range and coordinate marketing activities. Many of the corporate owners of the major brands have been operating in Australia for a long time and have developed a high profile for their brands.

Fig. 3.5 Supply chain for supermarket segment



3.3.2.7 Risks and opportunities

Specialised seafood retailers

Fresh whole, frozen whole: While low volume, the market for fresh sardines, and to a lessor extent frozen sardines, appears to be irregularly and inadequately supplied. The two main issues in entering this market are logistics of moving product to market and the development of a supply chain.

The market for fresh sardines offers a low risk entry point into the human consumption market and an opportunity to develop supply arrangements that include SFM and MWFM as well as more stable arrangements involving partnerships with key wholesalers to target a wide range of seafood retailers. MWFM and SFM, while volatile, do provide valuable exposure and promotion of new brands, provided the product can be supplied consistently to a high standard. Arrangements that bypass the fish markets require good communication between fishers and wholesalers and greater emphasis on the timing of the catch, timing of deliveries, handling and quality aspects. However, this pathway to the market does offer stability and an ability to grow the market, provided product can be supplied in a consistent manner.

After developing a supply chain to access the fresh whole sardine market and build some volume, South Australian processors would have the ability to grow their business through the introduction of a quality frozen product or possibly a fillet product, although the market for the latter is quite small at present.

The supply of frozen product to retailers involves competing directly with competitively priced imported product. Furthermore, the market for frozen sardines does not appear to pay processors a premium over that for the bait market. However, much of the product observed in the freezer sections of retail outlets, in block and IQF (individually quick frozen) form was in simple packaging that did not clearly identify that the product was for human consumption. Should a South Australian processor wish to enter the human consumption market with a frozen product, packaging and labelling that will appeal to the target market and a product of the highest quality should be developed for that market. This would support a premium price for the product as well as assist in growing this segment of the sardine market.

In terms of logistics, road freight costs from Port Lincoln to Adelaide will have a large bearing on the viability of targeting the fresh market. Airfreight charges from Adelaide to Melbourne, Sydney and Brisbane (Table 3.14) would suggest that South Australian processors have lower freight costs to Melbourne and slightly higher charges to Sydney in comparison to Western Australian suppliers.

Fillets: Producing a filleted product involves investment in a filleting machine and other product development expertise if flavours are to be added to the product line. At the same time a significant sales volume is required in order to justify the capital expense. At present, the market is very small and requires product promotion activities to assist its growth (McArdle 2003). Therefore, South Australian processors looking to enter this market should adopt a long term view and be prepared to invest resources in promotion of their product and industry development activities. Furthermore, as mentioned in 3.2.3 a collaborative approach to this type of operation amongst Port Lincoln processors/fishers would have merit terms of the following areas:

- Investment of resources in product promotion and industry development activities;
- Cost sharing for processing equipment;
- Developing a consistent supply of fish for processing;
- Logistics issues (e.g. transport to markets).

Supermarkets

Fresh whole, frozen whole, fillets: As discussed in 3.3.2.1 and 3.3.2.2 the supply of these sardine products to supermarkets is not an attractive option for the following reasons:

- The supermarket business model offers little sales support and customer advice for seafood products;
- Supermarkets favour seafood products with strong consumer acceptance and turnover;
- Supermarkets are sensitive to products that result in waste or that require markdowns to sell.

Cannery

Developing a cannery involves very high capital costs, significant human capital and a high utilisation rate in order to be viable. Of equal importance are the marketing and distribution strategies for the outputs; another complex area. However, the market for canned sardines in Australia exceeds 4,000 tonnes and a correctly branded Australian product offers a number of potentially attractive marketing points. For example:

- Made in Australia;
- Health benefits (good fit with baby boomer demographic);
- Clean, green image of South Australian fisheries;
- Sourced from a sustainable fishery.

3.3.3 Food Service Market

In food service sardines are exclusively referred to as sardines to avoid the connotation of bait. Restaurants purchasing fillets for entrees primarily drive demand in this market.

At only 50–100 tonnes (see 3.3.1), consumed by both the specialised seafood retail (see 3.3.2) and food service markets, the market for fillets in Australia is quite small. The development of the foodservice market for fillets is due largely to efforts of the company Mendolia Fremantle Sardines. Located in Western Australia, Mendolia's remain the dominant supplier of very high quality fillets to Australian restaurants and have developed their brand to such an extend that the term 'Freo sardines' is often used in reference to their product.

As a small, relatively expensive item, fillets are prepared mainly as entrée in restaurants and are reasonably common in establishments servicing customers looking for new eating experiences. As a species with a relatively strong 'fishy' flavour, sardines will not rival odourless, skinless fish as a menu choice, however, 'sardines' do have appeal to many customers familiar with the canned product. According to a representative of Sydney Seafood School, the marketing of fillets (butterfly) to customers in food service and retail is the best way to overcome consumers' reluctance to purchase sardines.

New entrants to this market need to consider the size of the market, the cost of establishing a filleting operation and the strength of the Mendolia brand. Since many of these issues are discussed under 'fillets' in 3.3.2 and similar supply chains operate for food service as do for retail, this section will not revisited these areas. Never-the-less, the entry of a new supplier of quality fillets into this market, while increasing competition, may also serve to grow the market as the product becomes more consistently available to wholesalers and customers in restaurants become more accustomed to the product.

3.4 Conclusions and Recommendations

3.4.1 Products and target markets

Recommendations for target products and markets are presented in order of priority:

High priority

1. Commercial and recreational bait to markets in Queensland (largest market), New South Wales, Victoria and South Australia.
   - South Australian processors will need to develop competitively priced quality bait products that meet or exceed the benchmark set by prominent Western Australian suppliers in order to compete effectively in this market.
   - To avoid competing on price alone, South Australian processors should attempt to target the more discerning segments of the bait market namely experienced recreational fishers and commercial drop line fishers, when developing branding and product promotion strategies. Some potential positive attributes of a South Australian product that

could be highlighted to target these segments and build market share are as follows:

- Australian and South Australian origin of bait
- Quality of the product
- Suitability for Australian target species
- Disease free status
- Sustainable aspects of the resource

2. Fresh whole sardines for human consumption in Adelaide, Melbourne and Sydney markets.

    - South Australian fishers should seek to enter the human consumption market through supply of fresh whole product to specialised seafood retailers in Adelaide, Sydney and Melbourne. This will require an investigation of the logistical issues involved in moving product from Port Lincoln to these markets.
    - Supermarkets are not an attractive channel for distributing non-canned sardine products.

Lower priority

3. Fillets for human consumption

    - Sardine processors looking to develop capacity to supply fillets should adopt a long term view, adopt a collaborative approach with other Port Lincoln fishers/processors and be prepared to invest resources in promotion of their product and industry development activities. Specialised seafood retailers and food service (restaurants) are the most attractive markets for this product

4. Canning operation (should this option be pursued)

    - In the first stage, investigate the potential and viability of extending the product lines of one of the two existing canneries in South Australia, John West in Port Lincoln and Safcol cannery near Adelaide. Should this not prove feasible then investigation of a ‘green field’ cannery for sardines in Port Lincoln would require detailed research to determine the viability of such a project.

3.4.2 Comment

1. Commercial and recreational bait to markets in Queensland (largest market), New South Wales, Victoria and South Australia:

   - large volume market;
   - opportunity to capitalise on concerns with imported product through delivery of high quality disease free Australian product;
   - no restrictions on use of South Australian sardines;
   - potential to build stable supply chains with key bait distributors at the expense of imports;
   - potential to capitalise on lower freight costs to the large QLD market in comparison to Western Australia.

2. Sales as fresh whole sardines for human consumption in Adelaide, Melbourne and Sydney markets:

   - minimal processing required;
   - good fit with current research to lift the quality of sardine caught and processed;
   - provides an established supply chains for the introduction of value added products at a later date to grow the value of the business;
   - Melbourne and Sydney markets appear to be inadequately serviced at present;
   - potential to grow volume through stable supply chain with key wholesalers (e.g. agents and provodores in Melbourne markets).

3. Fillets for human consumption

   - provide a good ‘fit’ with the marketing of fresh whole product;
   - advantage of longer shelf life products;

- potential to tap into South Australia’s ‘fine food’ image through alignment with suitable food identity;
- potential to grow the market through marketing of products that are ‘easy to prepare’ for consumers.

4. Canning operation (should this option be pursued)
   - potential to add value to sardines through partnership with an existing South Australian canning operation;
   - significant marketing advantages of an Australian product;
   - large volume market;
   - long shelf life and export potential to niche markets.

Appendix 3.1 Petfood Market

Sardines comprise a significant part of fish based pet food in Australia. Prominent examples of pet food enterprises include the Safcol pet food cannery in Adelaide, Uncle Ben's (Mars) pet food plants in Bathurst and Albury–Wodonga and Bush's Pet Foods, Sydney. Pet food manufactures operating in Australia rely heavily on cheap seafood imports for their inputs and with few exceptions are extremely sensitive to the price of ingredients. Pet food companies are generally not discerning on quality except in the case of ingredients destined for some cat foods. However, even in the cat food market, the price of ingredients remains a critical issue and cheap imports satisfy much of market demand (Former Mars employee, 2003).

Sardines are also utilised in aquaculture feeds, with the factory operated by Triabunna Fish Meal Pty Ltd in Tasmania a prime example. Fish destined for fish meal undergo substantial processing during the manufacturing process and, in consequence, the quality requirements of manufacturers are not high. As is the case with pet food manufactures, price is a major issue when sourcing inputs.

The mariculture, pet food and fish meal industries were not considered to be priority markets and therefore not reviewed in this report because:

- they do not demand high quality sardines;
- they do not pay a significant premium for quality;
- they can source cheap imports;
- they show little or no preference for Australian sardines.

In consequence, there would appear to be little opportunity for South Australian sardine fishers and processors to add any value to sardine supplied to any of these three markets by improving quality of further processing of the product.

APPENDIX 3.2 Imports; Restrictions and Conditions

3.2.1 Restrictions on Imports

The Australian sardine is the same species found off California, Peru, South Africa, Chile and Japan and is closely related to the European sardine (*Sardina sardineus*). Due to disease concerns, a number of restrictions govern the import and use of sardines, mackerel and herrings used for bait (Appendix 3.1).

Post entry, some of the main requirements for importers, wholesalers and end users of imported product are:

General

- No restriction for:
    - NZ sardines;
    - imported gilled, gutted and head off product;
- On arrival the baitfish must be moved under written quarantine to a Quarantine Approved Premises (cold store or end-user's premises);
- No interstate movement of specified baitfish can occur without written permission from AQIS.

Above a latitude of 30°S

- End—users must be licensed or registered for fishing or aquaculture purposes by relevant State department of primary industries;
- Imports permissible for use by commercial or recreational fisherman or bait supply shops;
- At any time of the year a Quarantine Approved Premise cold store (QAP) must release for use no more than **5** tonnes of specified baitfish (*Sardinops, Scomber* and *Clupea* combined) per week to any one end user company.

Below a latitude of 30°S (excluding WA rock lobster fisheries)

- End—users must be licensed or registered for fishing or aquaculture purposes by relevant State department of primary industries;
- At any time of the year a QAP must release for use no more than **84** tonnes of specified baitfish (*Sardinops, Scomber* and *Clupea* combined) per week to any one end user company;
- All specified baitfish for use **between June 1 to November 30** must be completely thawed before leaving the Quarantine Approved Premises for feeding purposes.

Specific rules for lobster bait

- The fish may only be released from the QAP cold store during the period of **October 15 to June 30**. Release of sardines and mackerel outside this period is prohibited.
- QAP cold stores must only release imported sardines and mackerel to processing companies or rock lobster fishermen that are licensed by the relevant Commonwealth or Western Australian government authority.

3.2.2 Australian Quarantine and Inspection Service Export Import Conditions

3.2.2.1 PC01441

Whole round specified finfish (*Clupea / Sprattus, Scomber* & *Sardinops* sp). For importers situated, and onselling to any end-users, north of 30°S.
This condition requires product to be held at a Quarantine Approved Premise.
Sardines, mackerel and herring for bait to be imported and used north of 30°S only.

Pre-Entry Requirements

1. Each consignment must be accompanied by a copy of this Import Permit or a means of identifying the permit (eg permit number).
2. Each consignment must be accompanied by consignment specific certification issued by the competent authority/ies in the country of export stating:

(a) identification of fish species (scientific name and common name) in the consignment;

(b) that the fish were wild caught;

(c) that the fish were not grown or harvested in an aquaculture system at any stage;

(d) that the consignment does not contain other fish species;

(e) that the fish were processed in premises (including vessels) approved by and under the control of the competent authority; using methods approved by the competent authority/ies; and

(f) that during processing the fish were washed and frozen with clean water, using methods approved by the competent authority/ies; and

(g) that the product is free from visible lesions associated with infectious disease.

The certificate must bear the name(s) and address(es) or approval number(s) of establishment(s) at which the finfish were processed and the name and address of the consignor and the consignee. The certificate must be signed by a person authorised by the competent authority and bear an impression of the official stamp on each page.

Post Entry Requirements

3. On arrival the baitfish must be moved under written quarantine direction to a Quarantine Approved Premise (cold store or end-user's premises).
4. The cold store or end user's premises must abide by all Quarantine Approved Premise (QAP) Criteria 2.5.
5. End-users must be licensed or registered for fishing or aquaculture purposes by the relevant State department of primary industries.
6. A written quarantine direction is required for any movement of the baitfish between Quarantine Approved Premises.
7. No interstate movement of specified baitfish is to occur without written permission from AQIS.
8. The fish must only be released from the coldstore to:

a) commercial or recreational fishermen whose vessels are registered to fish in waters north of 30°S only; or

b) bait supply shops located above a latitude of 30°S.

9. At any times of the year, a Quarantine Approved Premise must release for use no more than five (5) tonnes of specified baitfish (*Sardinops, Scomber* & *Clupea* combined) per week to any one end user company. Records of release of baitfish (including release to boats, shops or other end-users) must be maintained by the Quarantine Approved Premise for audit purposes.
10. Records and documents must be retained by the importer and cold store for a minimum of 12 months for AQIS auditing purposes.

3.2.2.2 PC01443 Conditions for the importation of sardines and mackerel for use south of 30°S (excluding WA Rock Lobster Fisheries)

This condition requires product to be held at a Quarantine Approved Premise.

Pre-Entry Requirements

1. Each consignment must be accompanied by a copy of this Import Permit or a means of identifying the permit (eg permit number).
2. Each consignment must be accompanied by consignment specific certification issued by the competent authority/ies in the country of export stating:

(a) identification of fish species (scientific name and common name) in the consignment;

(b) that the fish were wild caught;

(c) that the fish were not grown or harvested in an aquaculture system at any stage;

(d) that the consignment does not contain other fish species;

(e) that the fish were processed in premises (including vessels) approved by and under the control of the competent authority;

(f) that during processing the fish were washed and frozen with clean water using methods approved by the competent authority/ies; and

(g) that the product is free from visible lesions associated with infectious disease.

The certificate must bear the name(s) and address(es) or approval number(s) of establishment(s) at which the finfish were processed and the name and address of the consignor and the consignee. The certificate must be signed by a person authorised by the competent authority and bear an impression of the official stamp on each page.

Post Entry Requirements

3. On arrival the baitfish must be moved under written quarantine direction to a Quarantine Approved Premise (cold store or end-user's premises).
4. The cold store or end user's premises must abide by all Quarantine Approved Premise (QAP) Criteria 2.5 conditions for the storage and handling of specified baitfish for aquaculture use south of latitude of 30° South.
5. End-users must be licensed or registered for fishing or aquaculture purposes by the relevant State department of primary industries.
6. A written quarantine direction is required for any movement of the baitfish between Quarantine Approved Premises.
7. No interstate movement of specified baitfish is to occur without written permission from AQIS.
8. All specified baitfish for use between the period of June 15 to November 30 must be completely thawed before leaving the Quarantine Approved Premise for feeding purposes. The baitfish may be refrozen after thawing providing they are adequately marked to designate that thawing has taken place. Records of thawing must be maintained by the QAP.
9. Records of release for baitfish must be maintained by the Quarantine Approved Premise for audit purposes.
10. If the end user is unable to utilise the collected specified baitfish (Sardinops and Scomber) due to bad weather or other conditions, the baitfish must be returned to the AQIS approved cold store or be disposed of under quarantine control, i.e. under written quarantine direction for deep burial, incineration or other method approved by AQIS. The cold store must maintain records of returned or destroyed product for audit purposes.

3.2.2.3 PC1446 Sardines (S*ardinops *sp) and mackerel (*Scomber *sp) for western Australian rock lobster bait

This condition requires product to be directed and held at a quarantine approved premises.

1. A valid copy of this AQIS Import Permit (or a method of identifying the Import Permit such as the Import Permit number) and all required documentation must accompany each consignment. Alternatively, necessary documentation will need to be presented to AQIS at the time of clearance. In order to facilitate clearance, airfreight or mail shipments should have all documentation securely attached to the outside of the package, and clearly marked "Attention Quarantine". Documentation may include Import Permit (or Import Permit number), manufacturer's declaration and invoice. The importer must meet all costs associated with the importation of this product.

2. A copy of the Import Permit must accompany each consignment to the final quarantine approved premises.

Certification/declaration requirements

3. Each consignment must be accompanied by consignment specific certification issued by the Competent Authority in the country of export, which states:

a) identification of fish species (scientific name and common name) in the consignment; and

b) that the fish were wild caught; and

c) that the fish were not grown or harvested in an aquaculture system at any stage; and

d) that the consignment does not contain other fish species; and

e) that the fish were processed in premises (including vessels) approved by and under the control of the Competent Authority, using methods approved by the Competent Authority; and

f) that during processing the fish were washed and frozen with clean water, using methods approved by the Competent Authority; and

g) that the product is free from visible lesions associated with infectious disease.

The certificate must bear the name(s) and address(es) or approval number(s) of establishment(s) at which the finfish were processed and the name and address of the consignor and the consignee. The certificate must be signed by a person authorised by the Competent Authority and bear an impression of the official stamp on each page.

Post entry requirements

4. On arrival the sardines and mackerel must be moved under written quarantine direction to a quarantine approved premises (QAP) coldstore 2.5.
5. A written quarantine direction is required for any movement of the sardines and mackerel between QAPs.
6. QAP coldstores must only release imported sardines and mackerel to processing companies or rock lobster fishermen that are licensed by the Government of Western Australia Department of Fisheries (www.fish.wa.gov.au). Records of release must be maintained by the QAP coldstore.
7. The sardines and mackerel may only be released from the QAP coldstore during the period of October 15 to June 30. Release of sardines and mackerel outside this period is prohibited.
8. No interstate movement of sardines and mackerel is to occur without written permission from AQIS.
9. Records and documents as specified under QAP criteria 2.5 must be retained by the importer and the coldstore for a minimum of 12 months for AQIS auditing purposes.

PLEASE NOTE: It is the importer's responsibility to ensure compliance with the Government of Western Australia Department of Fisheries (www.fish.wa.gov.au). This may include maintaining bait usage data including species, volumes and regions utilised.

Appendix 3.3 Quotas and Sardine Production By State

The regulatory environment for the sardine fishery is in a state of flux as fish stocks recover from the devastating Australia wide ‘kills’ of 1995 and 1999. Regulations governing total allowable catch (TAC) vary from state to state depending on the resource status, the political environment and other factors. The current status of access to sardines is as follows:

A3.3.1 Queensland

The taking or possession of sardines for trade or commerce is not permitted in Queensland.

A3.3.2 New South Wales

The sardine fishery in NSW is not governed by a TAC, however a ‘trigger’ level of 198 tonnes will activate a management review of the fishery. Only small quantities of sardines have been caught in the state over the last three years (Table 3.13). Catches occur mostly in Twofold Bay (Eden) and Nowra with small numbers of sardines are also being caught off Wollongong for the Sydney Fish Market. Access to the previously productive fishery in Jervis Bay is now restricted by a new marine park. Much of the Eden catch is marketed south into Victoria.

Table 3.13. NSW sardine/herring production

99/00		00/01		01/02	
Tonnes	**$’000**	**Tonnes**	**$’000**	**Tonnes**	**$’000**
75	na	39	na	40	na

NSW Department of Fisheries, 2003

A3.3.3 Victoria

Sardines not part of a designated fishery in Victoria and there are no catch restrictions. Historically, a significant sardine/anchovy industry was based on Lakes Entrance and contributed to a fishmeal plant. Currently, a small but significant sardine fishery exists in Port Phillip Bay and supplies markets for pet food, recreational bait and human consumption (Table 2.14). Reasonable quantities are sold through the Melbourne Fish Market. Fishers in the bay operate small boats and many target sardines in the off-season for other species.

Table 3.14. Victorian sardine production

99/00		00/01		01/002	
Tonnes	**$’000**	**Tonnes**	**$’000**	**Tonnes**	**$’000**
200	334	287	654	665	2 050

ABARE and FRDC, 2002

A3.3.4 South Australia

South Australia has a large sardine resource that is recovering strongly (Table 3.15). The fishery is managed through the issue of 14 licences, permitting each holder to catch 1500 tonnes/year. The majority of the harvest feeds the southern bluefin tuna industry located in Port Lincoln and approximately 7 licence holders target sardines solely for this purpose. Other licence holder supply the tuna market as well as processing their catch for recreational bait and to a small extent, the human consumption market.

Sardine boats operate solely out of Port Lincoln and fish the adjacent Spencer Gulf and other sheltered waters.

Table 3.15. South Australian sardine production

99/00		00/01		01/02	
Tonnes	**$'000**	**Tonnes**	**$'000**	**Tonnes**	**$'000**
3 836	2 685	7 368	5 157	12 165	8 516

ABARE and FRDC, 2003

A3.3.5 Western Australia

Before a major sardine mortality event in 1999, the WA sardine catch was over 10 000 tonnes and the state was a dominant supplier of quality sardines for the human consumption and recreational bait markets (Table 3.16). The fishery is centred on the south coast of the state and includes the important fishing ports of Albany, Bremer Bay and Esperance. The sardine quota is determined by a Management Advisory Committee (MAC) and approved by the relevant Minister. During 2001/2002, a TAC of 1430 tonnes was set for the south coast and 720 tonnes for the west coast bringing the total TAC to 2 150 tonnes. In this year, fishers in the south coast caught 980 tonnes of their 1 430 tonnes quota. In 2002/2003, the TAC was further increased to a combined total of approximately 4 000 tonnes. For 2003/2004, the MAC has recommended to the Minister for a 1500 tonne quota in each of the 4 zones that make up the west and south coast fishery, providing WA with a potential TAC of 6000 tonnes for the sardine fishery. In addition, on the West Coast an additional 1500 tonne quota has been recommended for other small pelagics, which include sardines (in reality principally *S. lemuru*). Much of the west coast catch is marketed to Port Lincoln tuna operations.

Table 3.16. Western Australian sardine production

99/00		00/01		01/02	
Tonnes	**$'000**	**Tonnes**	**$'000**	**Tonnes**	**$'000**
1 463	1 244	870	783	1 610	1 449

ABARE and FRDC 2003

A3.3.6 Tasmania

Tasmania has a very small sardine fishery managed under permit conditions. The catch of the current 5 holders is destined mainly for the Triabunna Fish Meal Plant or frozen for tuna feed. The sardine fishery shows little potential for growth as the resource is found in sheltered waters along the northern and eastern coasts where fishers primarily target shark, squid, gar and other high value species. Furthermore, logistics issues, an absence of onboard freezing capability in current vessels targeting this species, and low public support for an increase in resource exploitation indicate the sardine industry in Tasmania will remain very small.

Appendix 3.4 Classification Of The Australian Sardine

Sardinops sagax (Family Clupiedae, Order Clupeiformes) is the current species name for sardines. ‘Sardine’ is the preferred marketing name for product destined for human consumption although ‘pilchard’ is also generally considered acceptable. The species was given the common name ‘Australian sardine’ during 2005.

Appendix 3.5 Mendolia Fremantle Sardines

Appendix 3.6 Imported Portuguese Sardines

Appendix 3.7 Canned Sardines

we apologise no product image
Adria
Sardines in Tomato 125g
$1.39 1 Add to List
Supermarket

Black and Gold
Sardines in Oil 125g
$0.69 1 Add to List
Supermarket

Black and Gold
Sardines in Tomato 125g
$0.69 1 Add to List
Supermarket

we apologise no product image
Brunswick
Sardines in Spring Water No Added Salt 106g
was $1.59 $1.39 1 Add to List
Supermarket

we apologise no product image
Delamaris
Sardines 120g
was $1.59 $1.39 1 Add to List
Supermarket

we apologise no product image
Delamaris
Sardines in Hot Sauce 115g
was $1.59 $1.39 1 Add to List
Supermarket

John West
Scottish Sardines in Oil 110g
$2.95 1 Add to List
Supermarket

John West
Scottish Sardines in Tomato Sauce 110g
$2.95 1 Add to List
Supermarket

JOHN WEST
John West
Sardines in Spring Water 110g
$2.99 1 Add to List
Supermarket

we apologise no product image
King Oscar
Sardines in Soya Oil 105g
$2.99 1 Add to List
Supermarket

we apologise no product image
King Oscar
Sardines in Spring Water 105g
$3.29 1 Add to List
Supermarket

we apologise no product image
King Oscar
Sardines No Added Salt 105g
$2.99 1 Add to List
Supermarket

we apologise no product image
King Oscar
Sardines in Soya Oil 105g
$2.99 1 Add to List
Supermarket

we apologise no product image
King Oscar
Sardines in Spring Water 105g
$3.29 1 Add to List
Supermarket

we apologise no product image
King Oscar
Sardines No Added Salt 105g
$2.99 1 Add to List
Supermarket

we apologise no product image
King Oscar
Sardines 2 lay 105g
$3.49 1 Add to List
Supermarket

we apologise no product image
Kit-E-Kat
Sardines 410g
Special $0.95* 1 Add to List
Supermarket

Safcol
Sardines In Oil 120g
Special $1.45 1 Add to List
Supermarket

Safcol
Sardines In Tomato 120g
Special $1.45 1 Add to List
Supermarket

we apologise no product image
Snappy Tom
Sardines in Smoked Salmon Jelly 400g
was $1.59 $1.15* 1 Add to List
Supermarket

CHAPTER 4 FACTORS AFFECTING RATES OF DETERIORATION IN SARDINE QUALITY

Richard Musgrove[1], John Carragher[1], Coby Matthews[1] and Steve Slattery[2]
[1]Product Quality and Value-Adding Program, SARDI Aquatic Sciences
[2]Centre for Food Technology, Queensland Department of Primary Industries

This investigation of the biological and ecological factors affecting the rates of deterioration in sardine quality in the immediate post-harvest period (i.e. net to processing factory) was carried out with the assistance of four sardine fishing vessels and three sardine processing companies involved in value-adding. Concerns over the protection of intellectual property relating to sardine value-adding processes and practices of vessel and factory operations demanded that the information reported in this chapter is not attributable to an identifiable vessel or factory. For this reason any information that could reveal the identity of the source of the data has been omitted.

4.1 Introduction

This study uses the QIM (Quality Index Method) developed by Bremner (1985) for whole fish quality assessment. The method was modified for quality assessment of sardines during the immediate post-harvest period (i.e. catch and transport to jetty and processing factory) for the purposes of this work. The QIM originated in Tasmania and has been used widely, particularly in Europe (Martinsdottir, 2002) and the USA (Nielsen, 2005). North Atlantic fishery species for which the method as been adapted include cod (*Gadus morhua*), plaice (*Pleuronectes platessa),* haddock *(Melanogrammus aeglefinus),* ocean perch *(Sebastes marinus)*, pollock *(Pollachius spp.)* (QIM – Eurofish 2003) and octopus (*Octopus vulgaris*, Vaz-Pires and Barbosa, 2004). As this wide acceptance suggests, the method is adaptable and allows systematic, objective and straightforward assessment of whole fish and other seafood quality. QIM can be used can be used at any point on the supply chain and requires no special equipment (Neilsen, 2005)

4.2 Method

Eight sampling trips were undertaken on purse–seine fishing vessels from 2003-2005. On seven other occasions (in 2004-5), sardine vessels were sampled as they unloaded fish at the wharf in Port Lincoln. Sampling took place between March and December and on each occasion information on the time of the catch, the quantity of fish caught, the quantity loaded into each holding tank, the prevailing weather conditions, water temperature, latitude and longitude of the shot was collected. On some trips temperature data from the holding tanks was also recorded. Sardines were sampled at various stages of the harvest and post-harvest process during each trip.

4.2.1 Scoring fish deterioration using QIM

QIM

Data were collected on each fish's physical appearance using QIM (Table 4.1, Fig 4.2). The QIM was based on visual assessment of the changing appearance of fish during post-harvest handling (Table 4.1). Points (0-3) were awarded within each physical category (e.g. degree of rigor, skin firmness, eye clarity, firmness of belly, vent condition and gill colour) as deterioration progresses, the higher the score the poorer the fish quality, with the maximum score equaling 21. Table 4.1 includes all those characters used on sardines in this study; several included in the original method (Bremner 1985, i.e. skin firmness, presence of slime on the body, mucus on the gills, fish smell, firmness of scales, gut colour and eye shape) contributed little to the assessment and were left out after initial field work. This was generally due to species-specific attributes and to the short length of each fishing trip (4-17h).

Physico-chemical parameters

Data were also collected on each fish's length (Total length, TL), sex and gut fullness. The muscle and body cavity temperature, and muscle and gut pH of every third fish was also recorded in the first year of the study, using a 3mm ministab temperature sensor and an intermediate junction pH sensor respectively, attached to a WP-80 pH-mV-temperature meter (TPS Instruments).

Muscle temperatures were taken through a small slit made in lateral musculature. Body cavity temperature was taken by insertion of the probe through a ventral incision; the body cavity was then opened and gut pH taken through a slit in the stomach wall.

Percent gut fullness was estimated and scored as 0-25, 25-50, 50-75 or 75-100%.

The time needed to process each fish determined the number of fish taken at each sampling point (i.e. net or holding tank).

Table 4.1 Data taken on fish physical appearance (QI) and physico-chemical parameters.

Body Area	Parameter	QI			
		0	**1**	**2**	**3**
Body	**Appearance**	very bright	bright	slightly dull	dull
	Stiffness	pre-rigor	rigor	post-rigor	
Eyes	**Clarity**	Clear	slightly cloudy	cloudy	
	Shape	Normal	slightly sunken	sunken	
	Blood	no blood	slightly bloody	very bloody	
Gills	**Colour**	typical red	slightly faded	faded	
Belly	**Discolouration**	Absent	detectable	moderate	excessive
	Firmness	Firm	soft	burst	
Vent	**Condition**	normal/ slight break	exudes	excessive opening	
Body Cavity	**Blood**	Red	dark red	brown	
Muscle	**Temperature**				
	pH				
Body cavity	**Temperature**				
Gut	**pH**				
Sex					

Fig 4.1 Changes in gill colour and eye clarity with time

Gill colour score = 2 (bottom left) also has a cloudy eye (score = 2) which is bloody (score = 1). See Table 4.1 for parameters and scores and Fig 4.7 for timing.

Score	Gill colour	Eye clarity
0		
1		
2		

4.2.2 Net sampling

Six to ten live sardines were taken from the purse-seine net (Fig 4.2) before pumping or brailing to the holding tank. A further 6-10 fish were taken from the net shortly before the net was emptied (by this time most fish remaining in the net were dead). The first fish sampled were handling controls; those at the end were used to assess the effect of confinement time in the net.

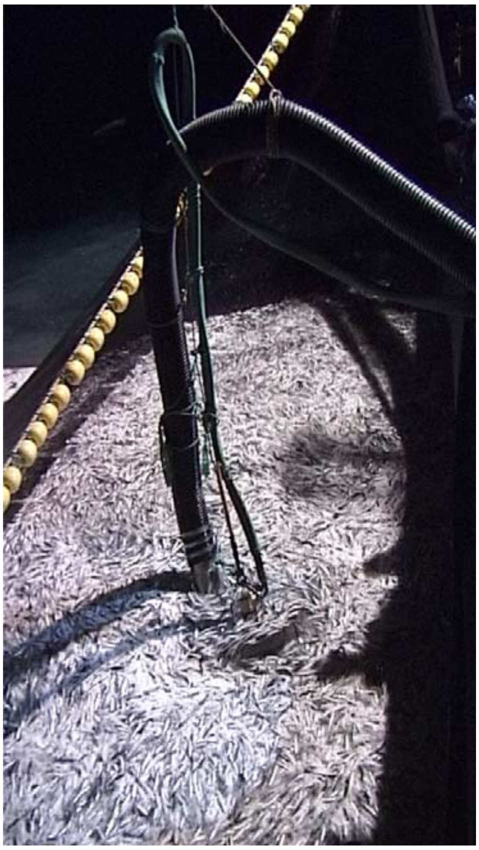


Fig. 4.2 Fish are pumped from the purse seine net into a holding tank.

Samples were taken at this point using a long-handled dip net.

4.2.3 Holding tank sampling

Six fish were taken from the top 0.5m of the a holding tank once filling of that tank began (Fig 4.3), two hours after the first fish were loaded into that tank and two hours after the last fish were loaded into the last tank to be filled (Table 4.2). They were analysed as described above.

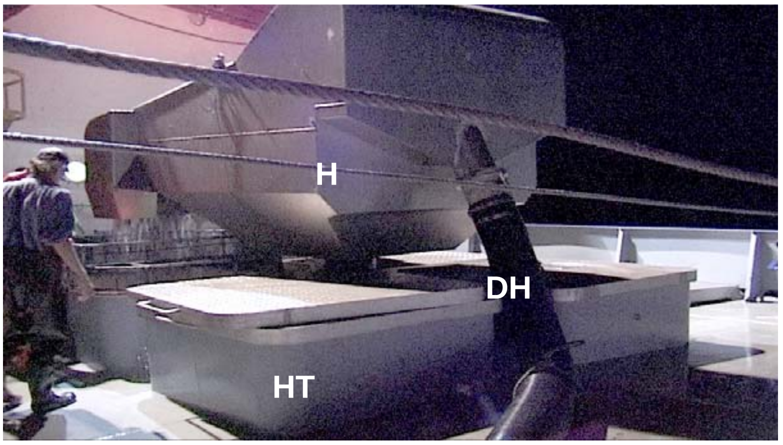
Six fish were then taken from the first-used holding tank and the last-used holding tank when emptying of those tanks commenced. The fish were analysed as described above.

Fish were also sampled upon arrival of the boat at the jetty and subsequently at the factory before freezing (IQF).

Fig. 4.3 Holding tank (HT).

a) and b) Fish are pumped into the top of a hopper (H), from where they fall into holding tank (HT). The excess water flows overboard via a drain hose (DH). c) HT lid open, showing contents. A freezer coil (FC) is attached to the starboard wall of the tank.

a.



b.

c.

Table 4.2 Stages of on-board handling at which fish were sampled and codes applied.

Stage	Code (ref Fig 4.2)
Start of net haul	S
End of net haul	F
Fish in 1st and last holding tanks for ~2 h	HTA1 and HTB1
Fish in same holding tanks when boat ties up at jetty	HTA2 and HTB2
Fish in 1st and last bins processed at the factory	FB1 and FB2

4.2.4 Water temperature and plankton sampling

Temperature data loggers were set up in holding tanks to record the temperature throughout the holding process. Loggers were placed at the top, middle and bottom of selected holding tanks prior to fish loading, using canisters attached to weighted lines. Data were recorded at two-minute intervals throughout the holding process, with the loggers retrieved just prior to pumping of fish into jetty bins.

Once pursing began, triplicate vertical plankton trawls were carried out; using paired conical nets, each with internal diameter of 0.255m and a mesh size of 300 m. The trawls were commenced at 40m, the depth at which the fish are generally captured. Plankton samples were then frozen for later identification to family level (refer Appendix 3).

4.2.5 Gut fullness and fish QI

The correlation between gut fullness and fish QI was examined as it was originally suggested that there could be a direct relationship between the two variables. If this was the case, gut fullness at harvest could be used to predict likely sardine deterioration rate. To facilitate this process, a laminated card, showing basic fish anatomy and where to cut to view gut contents, would be produced to assist fishers.

The time at which fish were caught was also examined with respect to gut fullness and subsequent deterioration as it had been suggested by industry that those caught early in the evening had fuller guts than those from morning catches and were more prone to belly burst. Data from each trip were analysed separately to allow for differences in time, especially relevant for those samples taken almost exclusively at the jetty and thus expected to show the closest relationship between the two variables.

4.2.6 Date and tank/fish-bin effects on QI

An examination was made of the relationship between QIs of sardines arriving at the jetty and boat involved, and date of each field trip with each holding tank (i.e. A and B) and fish bin included as variables. It was hypothesised that quality of fish unloaded at the jetty from different holding tanks would vary depending on tank-loading order from seine net, initial tank temperature and storage temperature regime.

Ice hours (refer 4.1.7) could not be calculated for these data as temperature loggers could not be placed on boats prior to arrival at the jetty.

4.2.7 Ice hours and fish deterioration

An examination was made of the relationship between QIs of sardines at the jetty and the time held, and refrigerated seawater tank (RSW) temperatures experienced (i.e. ice-hours), on the boat. Ice hour data were calculated for the six trips for which there was a temperature record from the time the first fish were removed from the net to the arrival of the vessel at the jetty. Calculations were carried out following Bremner et al (1987):

Ice hours = rate of deterioration (r) x storage time (hours).
Where $r = (1 + 0.1t)^2$ and t = temperature in ^{o}C over a given storage period, in this case fractions of an hour, as temperature was taken at two minute intervals.

Holding tank water temperatures were logged at two-minute intervals from the time the fish were put into the tank. Ice hour data were compared to the QI of fish at unloading with the expectation that there would be a positive correlation between between the two parameters.

4.2.8 Muscle and body cavity temperature and fish deterioration

Sardines were sampled throughout the harvest and postharvest process and assessed for QI. Body cavity and muscle temperatures were measured from every third fish selected during this sampling process. The difference between body cavity and muscle temperature (i.e BMTD) was calculated, converted to Ice hours (IH_{BMTD}) and compared with the QI of each of these fish.

4.2.9 Data analysis

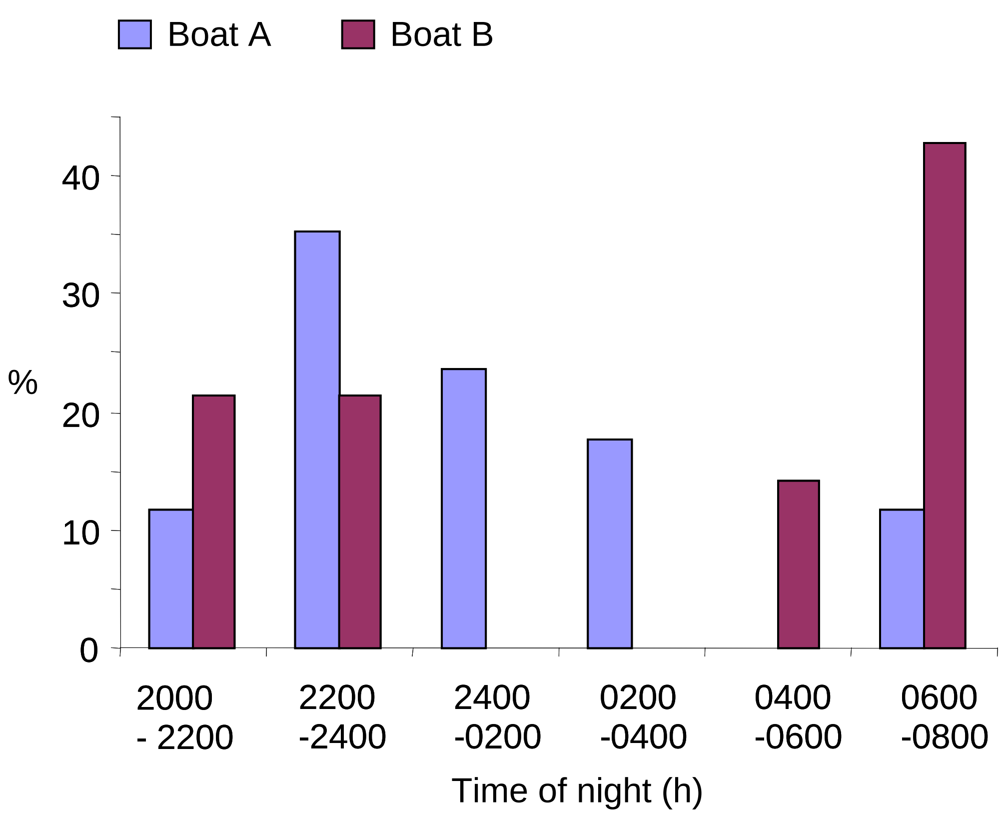
Histograms, scatter grams and box and whisker plots were used to elucidate data patterns and data analysed with GLM (Type III Sum of Squares) (ANOVA and ANCOVA) and Regression Curve Estimation modules in SPSS. Data were log transformed when necessary to maintain normality. Posthoc tests (Tukeys HSD) were used to establish the significance of results. If normality and other assumptions of parametric analysis could not be achieved through transformation, use was made of Kruskel-Wallis tests in SPSS Non-Parametric module.

4.3 Results

4.3.1 Catch time and tank loading

This ranged between 20:00 and 08:00 hrs (Fig 4.4). Boat A loaded most of its fish around midnight, Boat B, between 0600 and 0800h. Catch time itself was not always known however temperature data logs indicated when fish were loaded into holding tanks.

Fig. 4.4 Percentage of tank loading taking place during the period 8pm to 8am for Boats A and B. (n=12 trips).



4.3.2 Catch size

This varied between 4 and 80 tonnes depending on boat. Mean catch was under 15 tonnes/trip.

4.3.3 Hold water temperatures

Most holds were chilled to low temperatures (range –2 to +5 degrees) before fish were loaded. After loading, the elevated body temperature of the fish caused the hold water temperature to rise by 6 - 18 degrees, and cooling occurred at 1 to 3 degrees per hour thereafter. On a number of trips there was a substantial temperature differences between the water at the top and bottom of a single holding tank, with water up to 10^{o}C warmer at the top, suggesting poor water circulation, a poor refrigeration system and/or poor chilling coil placement. At unloading, hold water temperatures were –0.6 to 6 degrees.

4.3.4 Time to unloading

Time to unloading ranged between 4 and 17 hrs after the fish were caught. In 2003 some catches were transferred from sardine boat to tuna feed boats at sea for immediate feeding out. This was less common in 2004 and 2005.

4.3.5 Changes in QI

QI changed markedly with time. The maximum score achieved was 12.5 out of a possible 21 (Fig 4.5a and b), using the 10 parameters detailed in Table 4.1. Of the 10 parameters, only 4 (i.e body appearance, body stiffness, eye clarity and gill colour) commonly changed and thereby contributed substantially to the overall QI during the relevant timeframe (Fig 4.6). It has to be acknowledged that, in the majority of cases, most of the changes are from score 0 to 1, on a scale that goes to either 2 or 3. The exceptions are “eye clarity” and “gill colour” where the scores reach 2 (cloudy) and 2 (very dark, faded) (the maximum scores), respectively. Overall, these 4 parameters contributed 77% of the QI (Boat A 74% and Boat B 80%). Body stiffness was common after two hours, reaching a plateau (i.e. all fish are stiff with a score of “1”) at approximately 5 hours; a change in gill colour was evident during the first 2 hours, plateauing between 5 and 7 hours and eye clarity became progressively worse with time (Fig 4.7, 4.8).

Fig. 4.5a Breakdown of percentage total QI allocated at each time interval during onboard sampling for Boat A. N=189 fish

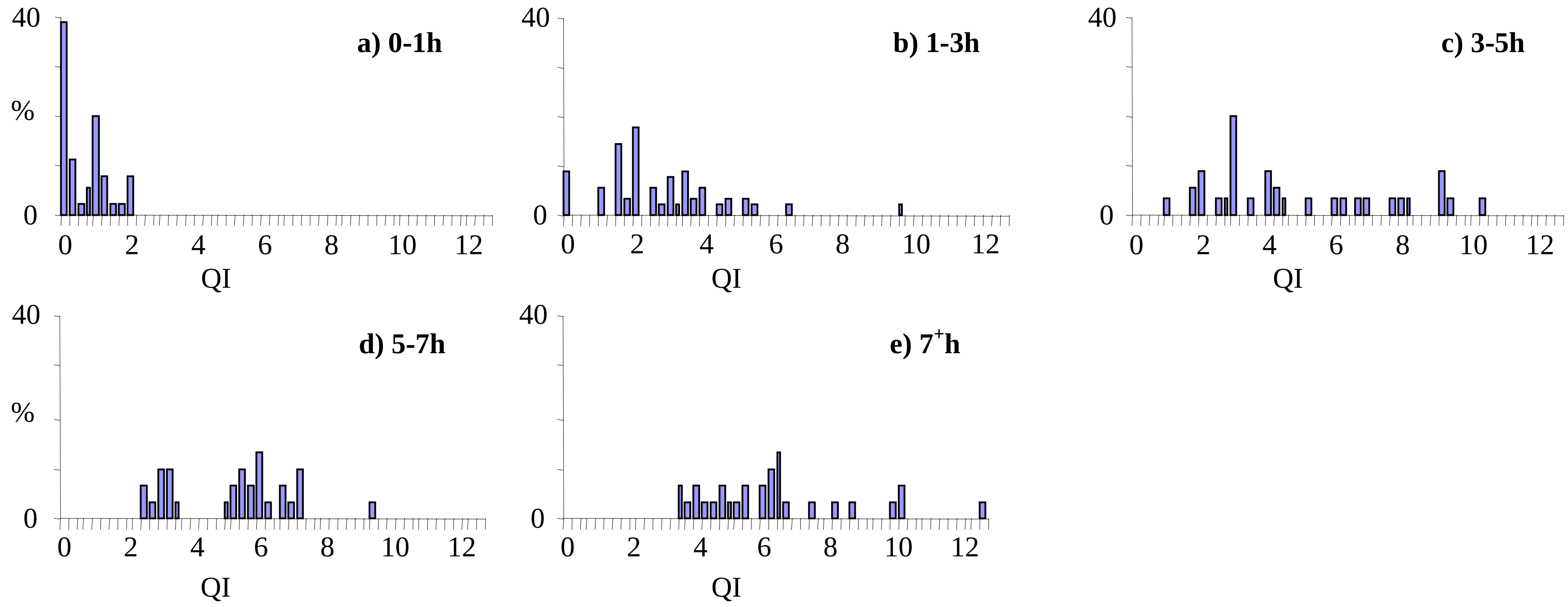


Fig. 4.5b Breakdown of percentage total QI allocated at each time interval during onboard sampling for Boat B. N=72 fish

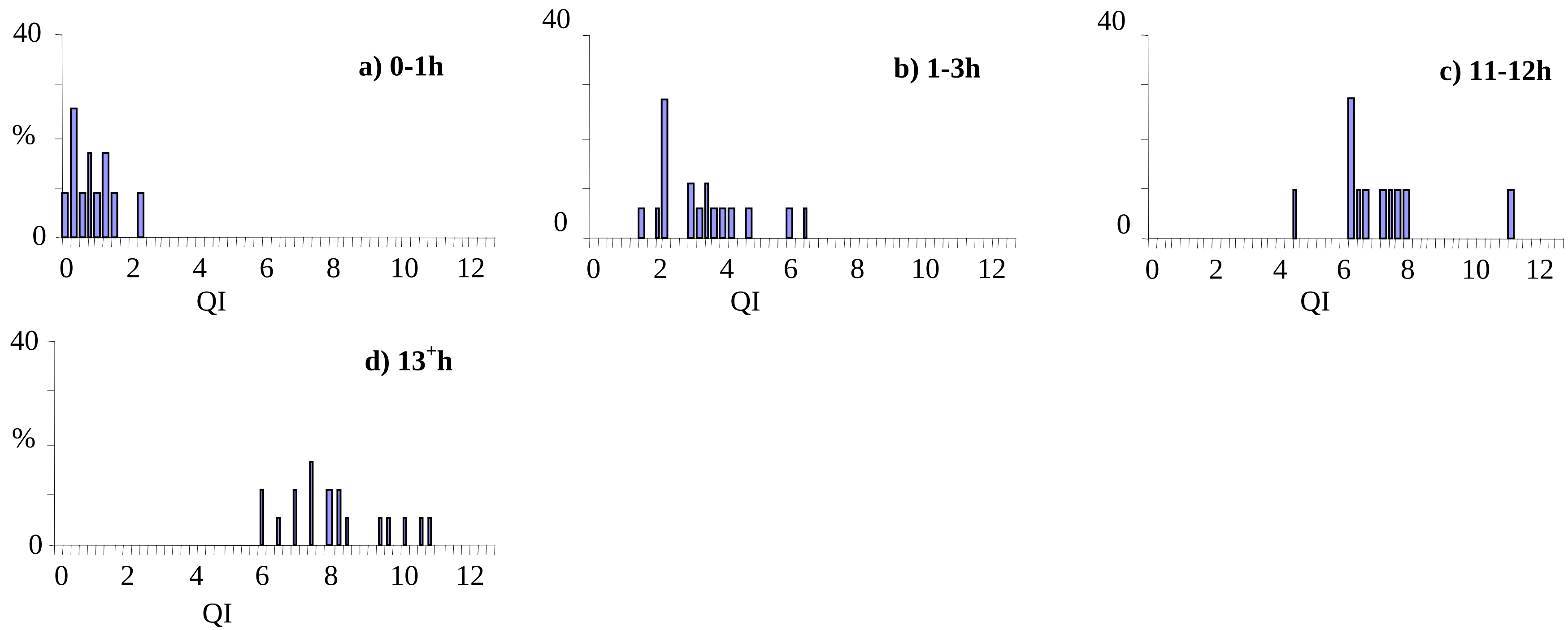
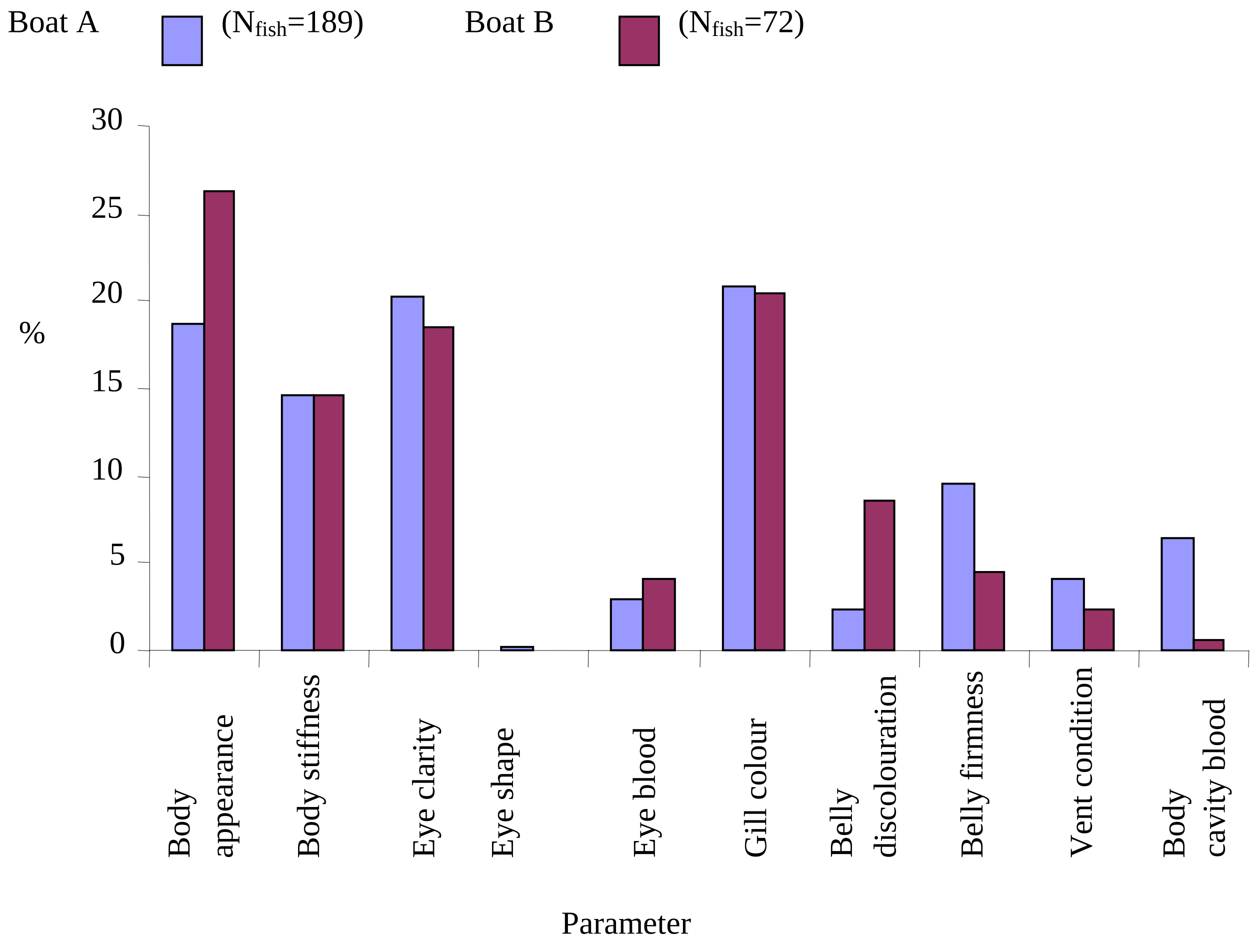


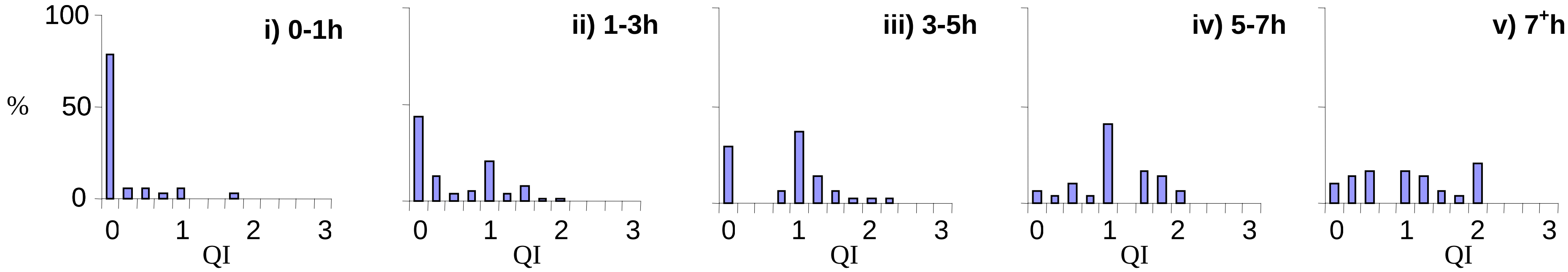
Fig. 4.6 Percentage of total QI allocated to each parameter during onboard sampling.



Changes in some of these parameters were due to the death of the fish (eg body stiffening due to rigor mortis; gill colour darkening as the blood clots, and oxy-haemoglobin changing to met-haemoglobin), but the time at which they became apparent was affected by harvest and post-harvest factors (particularly temperature and stress).

Fig. 4.7 Percentage of fish having a given QI within a time interval (hours (h)) for body appearance, body stiffness, eye clarity and gill colour. Boat A onboard sampling only. N=189 fish

a) Body Appearance



b) Body stiffness

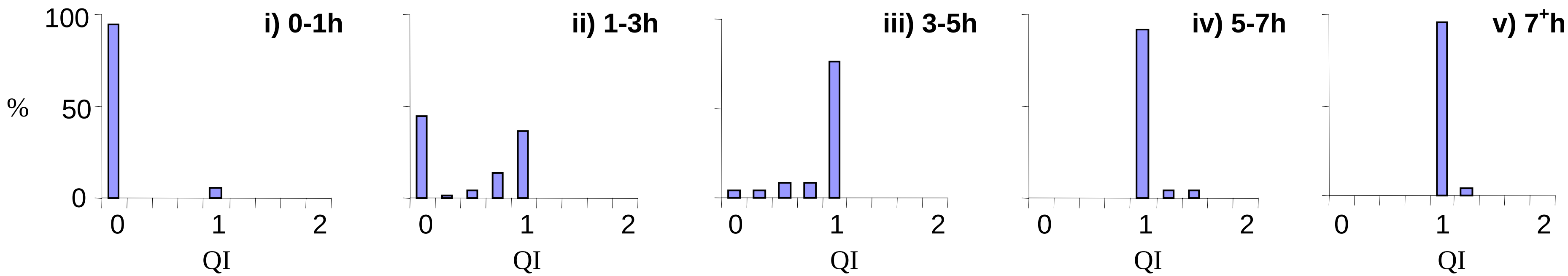
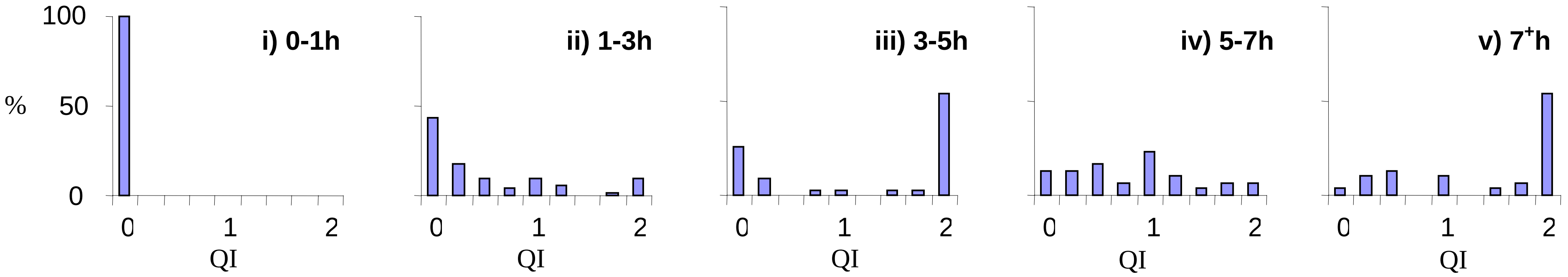


Fig. 4.7. Percentage of fish having a given QIM score within a time interval (hours (h)) for body appearance, body stiffness, eye clarity and gill colour. Boat A onboard sampling only. N=189 fish

c) Eye clarity



d) Gill colour

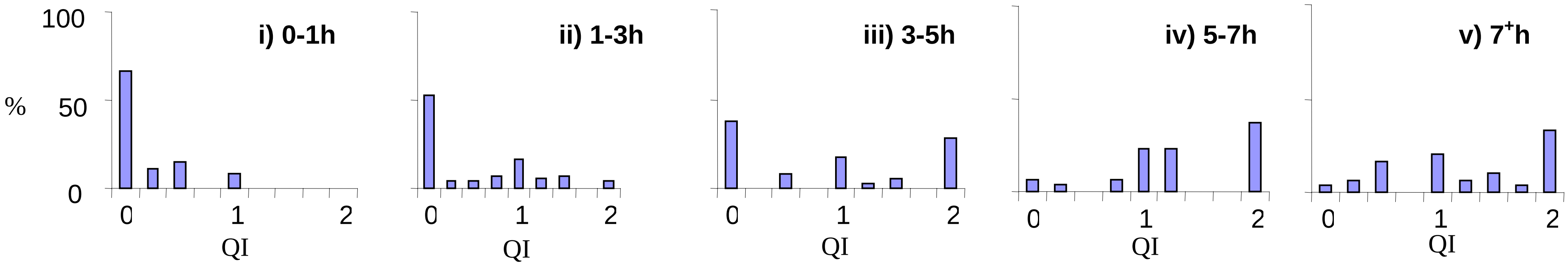


Fig. 4.8 Percentage of fish having a given QI within a time interval (hours (h)) for body appearance, body stiffness, eye clarity and gill colour. Boat B onboard sampling only. N=72 fish

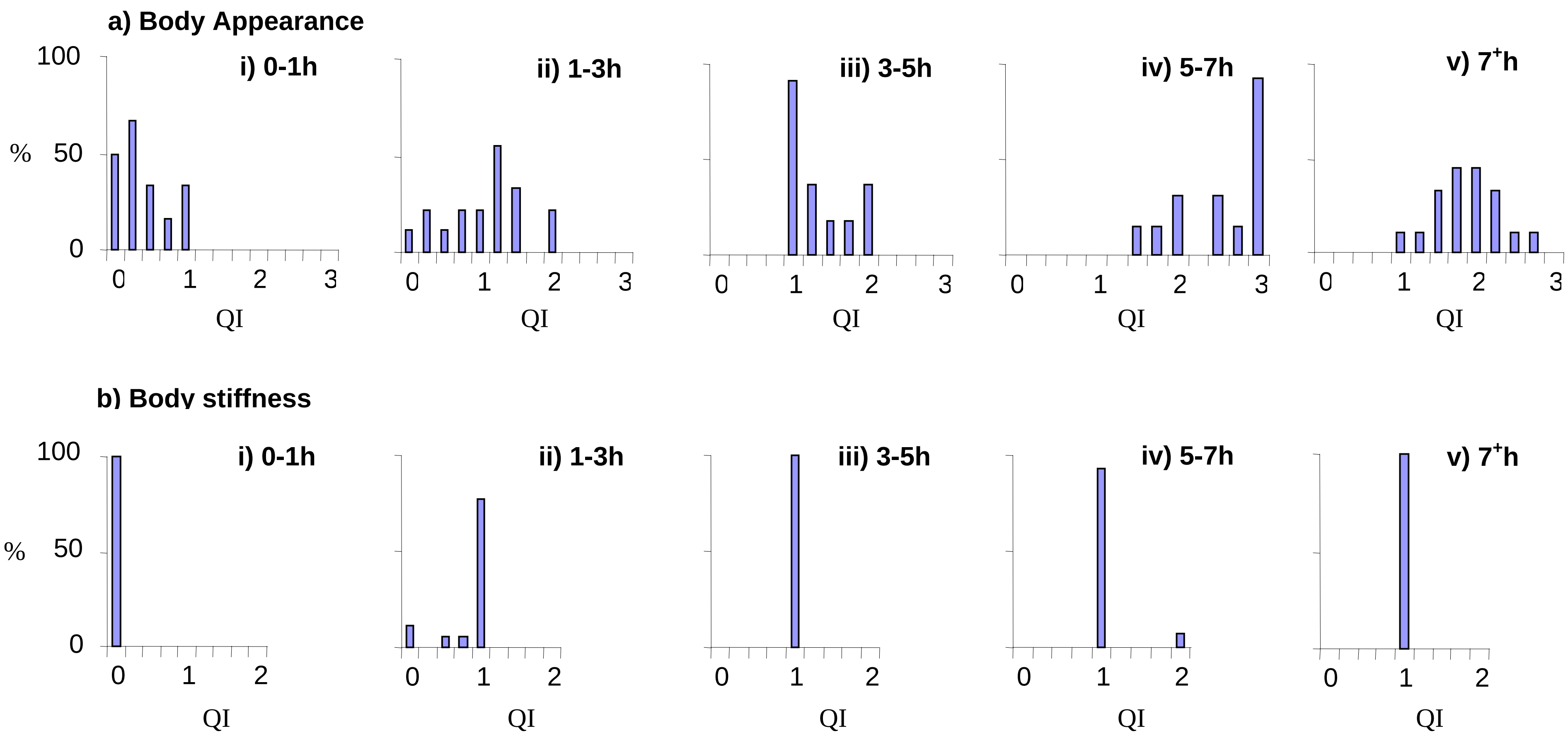
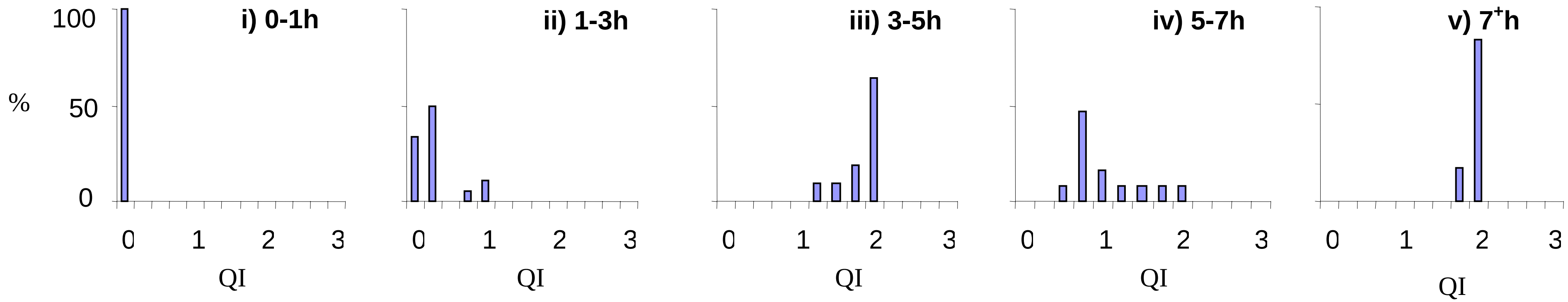
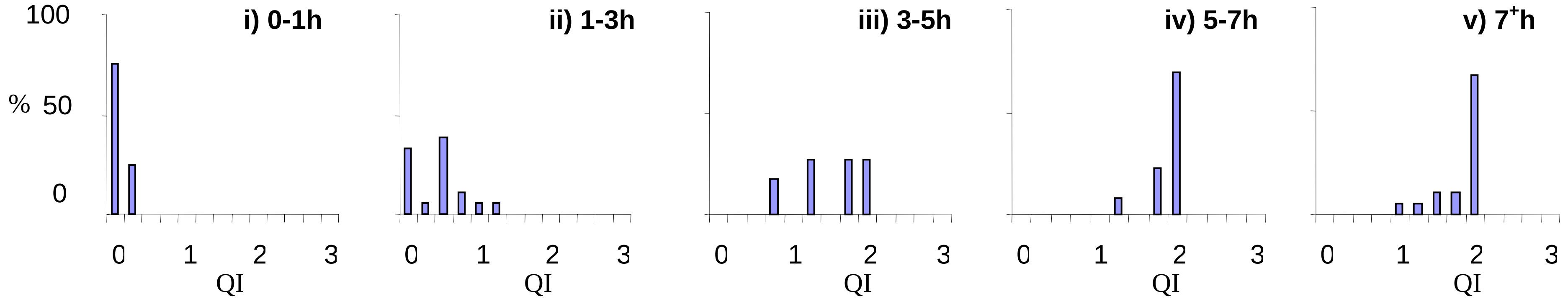


Fig. 4.8. Percentage of fish having a given QI within a time interval (hours (h)) for body appearance, body stiffness, eye clarity and gill colour. Boat B onboard sampling only. N=72 fish

c) Eye clarity



d) Gill colour

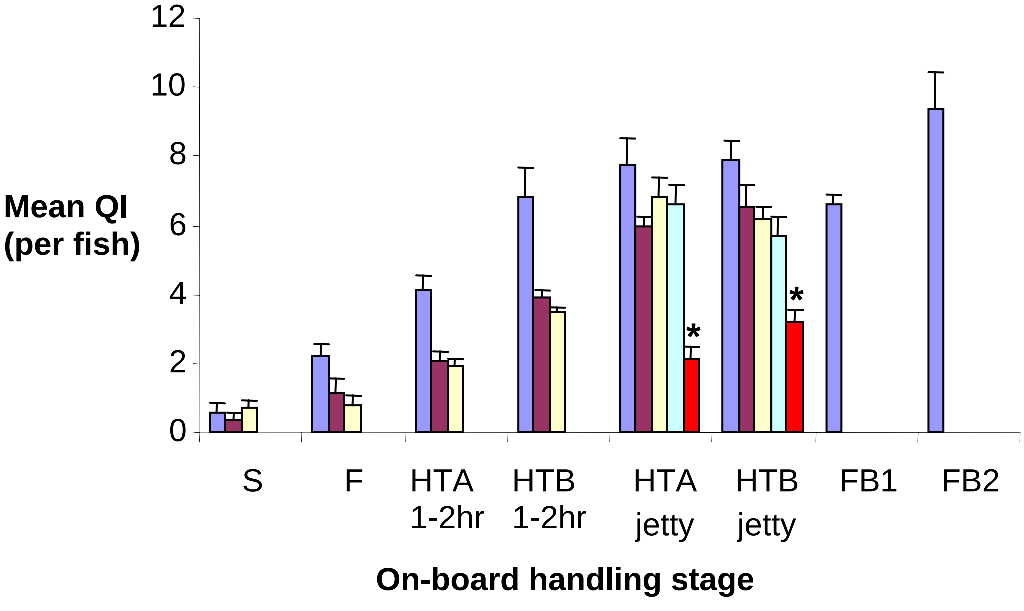


4.3.6 Change in fish QI with on-board handling stage

Sardine QI increased with successive stages during on-board handling. Mean QI (± SE; n=6 fish at each timepoint) for 5 trips where data are directly comparable are shown in Figure 4.9. Each separate trip on each boat is shown as a different colour. Not all boats or trips were sampled at all timepoints.

Sardines sampled directly from the pursed net have a very low QI (Fig 4.9), and those fish sampled at the start of uplift (S) have a lower score than those fish which have been retained in the purse net for 1-3 hours during uplift (F) (0.5 cf 1.5, respectively). As sardines are moved through the hopper and into the holding tanks (HTA and HTB) the QI steadily increases to a maximum score recorded after unloading into fishbins (FB) at the jetty.

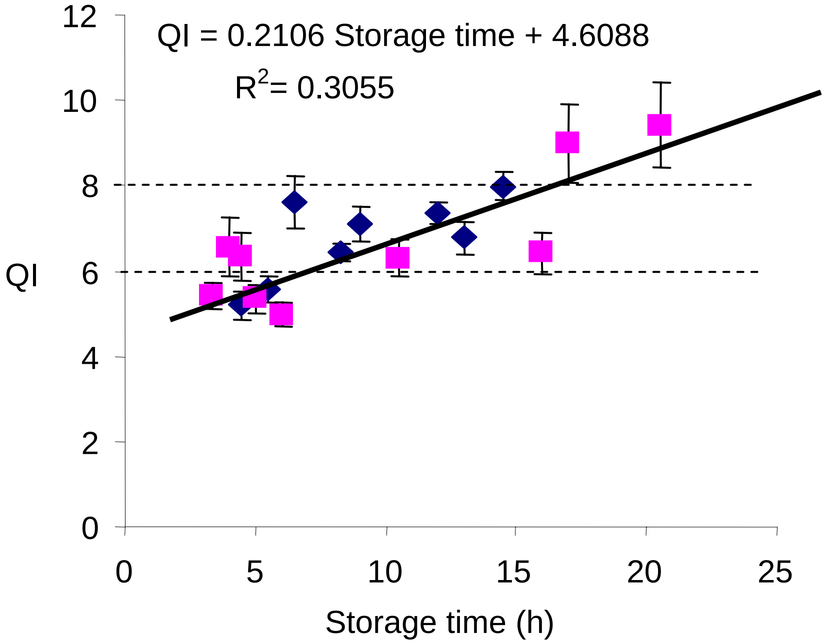
Fig. 4.9. Mean QI per fish for each on-board handling stage.
Each colour represents a separate trip. N=6 fish per stage per trip



When boats returned to the jetty to unload, the average QI commonly reached 6 – 8 (the maximum score for this scale is 21). Whilst a score of 8 does not suggest these sardines were unsuitable for further processing into various valued-added products, it is evident that on one of the surveyed trips the QI at the jetty was only ~3 (Fig 4.9, red columns,"*"). This suggests it is possible to maintain sardines in good condition whilst still undertaking all of the necessary catching and on-board handling processes.

Typically QI increased with storage time. Fig 4.10 illustrates the relationship between the two variables, in this case QI from fish sampled at the jetty in relation to storage time in onboard tanks. There were no significant differences between boats for the QI vs Storage time relationship (ANCOVA, F= 1.147, P=0.286) so the data were pooled and regression analysis performed on the raw data (F= 74.793, P< 0.001, Fig 4.10). These data suggest that if a lower limit of QI = 6 is preferable, tank storage time should be no longer than about 6h, increasing to about 16h if QI = 8 is acceptable. Only 31% of the variability in QI was explained by change in storage time (Fig 4.10). The QI limit for value-adding has yet to be set by the fishers.

Fig. 4.10 Storage time in onboard tanks vs mean QI (±SE). Boats sampled at jetty. Horizontal lines at 6 and 8 represent possible QI limit for value-adding. Regression line based on raw data. Boat A◆ : n (fish) = 80. Boat B■ : n (fish) = 92

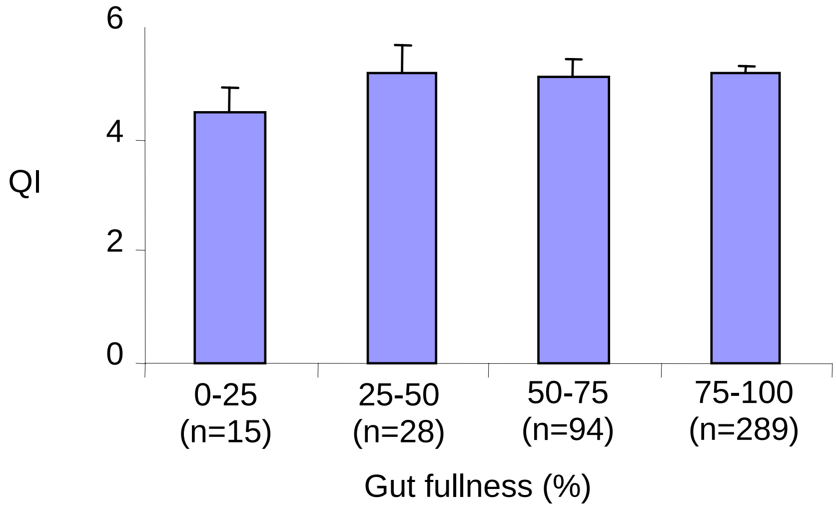


4.3.7 Gut fullness, tank loading time and QI

Data were examined from 12 trips (Fig 4.11). There was no relationship between gut fullness and QI for any of the trips ($r^2 \leq 0.220$, $F \leq 2.82$, $P \leq 0.124$; overall regression: $r^2 = 0.001$, $F = 0.15$) and no differences between gut fullness levels on the basis of QI (Kruskell-Wallis, ^{2} = 0.985, P=0.805). As there was no direct relationship between gut fullness and QI, the development of the proposed laminated card was discontinued, being of limited use in the prediction of sardine deterioration rate.

Fish were caught at varying times of night; of 10 trips (11 shots) examined, three shots were pumped into holding tanks between 1700h and 2200h, four between 2200h and 0300h and four between 0300h and 0800h. There was no effect of tank loading time on QI (Boat A; Kruskell-Wallis, ^{2} = 0.596, P=0.742; Boat B, Kruskell-Wallis, ^{2} = 0.001, P=0.973). There was no data on loading times for the remaining 2 trips (A 26/10/04 and A 17/11/04).

Fig. 4.11 Mean sardine QI (+ SE) at each % gut fullness category.
N=12 trips. (n) = total number of fish at each % gut fullness category.



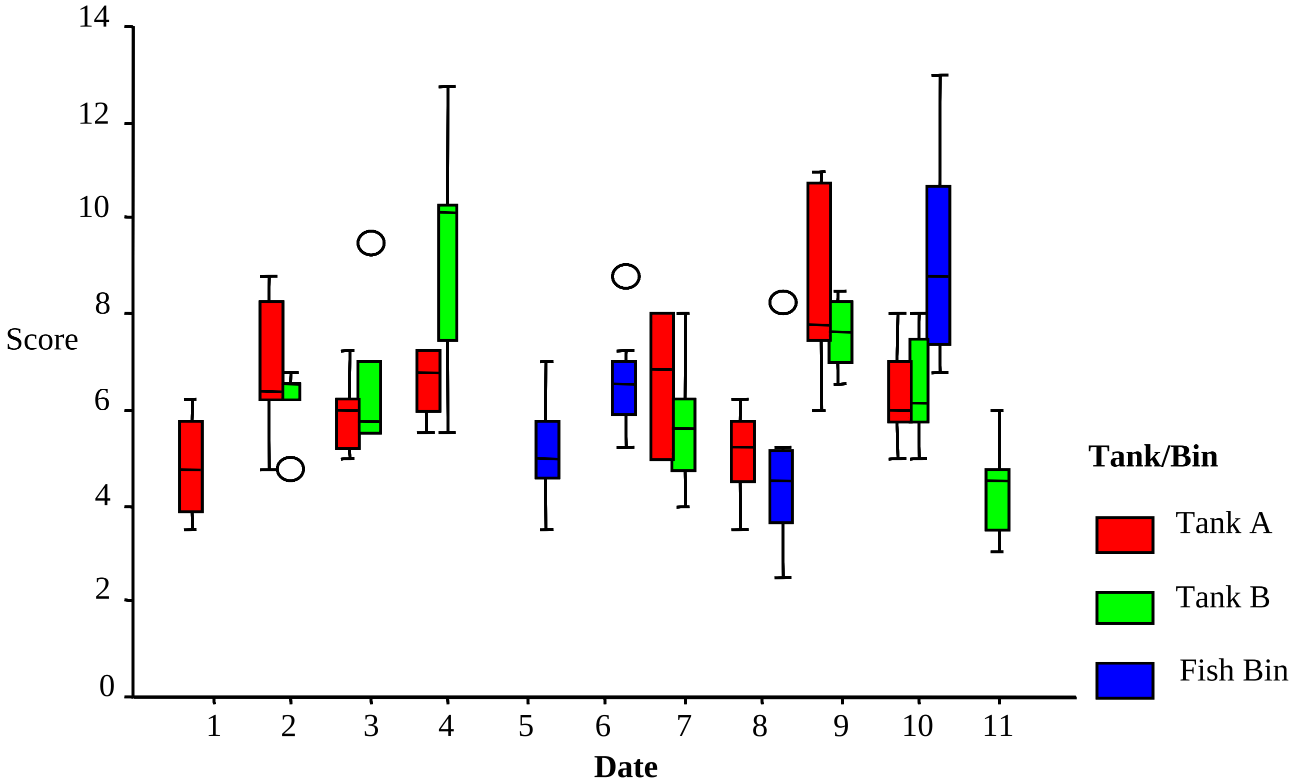
4.3.8 Date and tank/fishbin effects on QI

Analysis was carried out on samples taken from boats at the jetty (either from holding tanks just prior to, or from fish bins immediately after unloading). The box-plot initially produced (Fig 4.12) suggested that boat and date did affect QI.

Fig. 4.12 Box and whisker plots for QI for selected trips/dates.

Data are from tanks just prior to, or from a fish bin just after unloading at jetty. Tank A and B represent the tanks for which the fish were assessed for that trip. The box represents the inter-quartile range which contains 50% of values. The whiskers are lines that extend from the box to the highest and lowest values, excluding outliers (circles). The line across the box indicates the median. N =132.

Date Key: 1. 14/05/03, 2. 19/06/03, 3. 26/11/03, 4. 18/12/03, 5. 26/10/04, 6. 17/11/04, 7. 19/05/04, 8. 27/05/04, 9. 26/06/04, 10. 15/08/04, 11. 16/05/03



Date Key

This was confirmed by ANOVA, as there were significant differences between QI for different boats/dates (P=0.001, Table 4.3). There was also a significant interaction between tank/bin and boat/date but no significant tank or bin effects.

Table 4.3 Effect of boat/date and tank/fishbin on QI. ANOVA table

Source	**Type III Sums of Squares**	**Df**	**Mean Square**	**F**	**Sig**
Corrected model	1.415	18	0.078	9.290	0.001
Intercept	83.480	1	83.480	9863.437	0.001
Tank/bin	0.037	2	0.018	2.171	0.118
Boat/Date	0.994	10	0.099	11.744	<0.001
Date*Tankbin	0.200	6	0.033	3.948	0.001
Error	1.058	125	0.085		
Total	90.752	144			
Corrected Total	2.473	143			

Because of this interaction the data set was split and analysed as either holding tanks or fish bins as follows.

4.3.8.1 Holding Tanks

There was a significant effect of date (F= 10.271, P<0.001) but no date-tank interaction (F= 1.825, P=0.104). Post hoc tests (Tukeys HSD) were performed on the data (Table 4.4) suggesting a worsening in quality between the first trip on the Boat A and subsequent trips on the same vessel.

Table 4.4 Tukeys HSD for multiple comparisons between final boat/date-specific QI for holding tank samples (i.e. holding tanks A and B).

A = Boat A, B = Boat B , C = Boat C, * = <0.05, ** = $\leq$0.001, NS = non significant.

		Boat/Date							
		A 19/6/03	**A 26/11/03**	**A 18/12/03**	**B 19/5/04**	**B 27/5/04**	**B 26/6/04**	**B 15/8/04**	**C 16/5/03**
Boat/Date	**A 14/5/03**	**	*	**	NS	NS	**	*	NS
	A 19/6/03		NS	NS	NS	NS	NS	NS	**
	A 26/11/03			*	NS	NS	NS	NS	**
	A 18/12/03				NS	**	NS	NS	**
	B 19/5/04					NS	*	NS	*
	B 27/5/04						**	NS	NS
	B 26/6/04							NS	**
	B 15/8/04								**

The Boat B showed a similar pattern with trips on the 19th and the 27th of May 2004 showing significantly better quality fish than that on the 26th of June 2004.

4.3.8.2 Fish Bins

There was a significant effect of date (F= 23.456, P<0.001). Post hoc tests (Tukeys HSD) were performed on the data as follows (Table 4.5).

Table 4.5 Tukeys HSD for multiple comparisons between boat/date-specific QI for fish bin samples.

A = Boat A, B = Boat B, NS = non significant**.**

		Boat/Date		
		A 17/11/04	**B 27/5/04**	**B 15/8/04**
	A 26/10/04	*	NS	**
Boat/	**A 17/11/04**		**	**
Date	**B 27/5/04**			**

Boat B fish in bins on the 15th of August 2004 were significantly poorer quality than those caught by the same vessel on the 27th of May 2004 and by the Boat A on the 26th of October and 17th of November 2004. Similarly, a decrease in fish quality was noted for the Boat A between the 26th of October 2004 and the 17th of November, 2004; the latter fish were also of poorer quality than those produced by the Boat B on the 27th of November 2004.

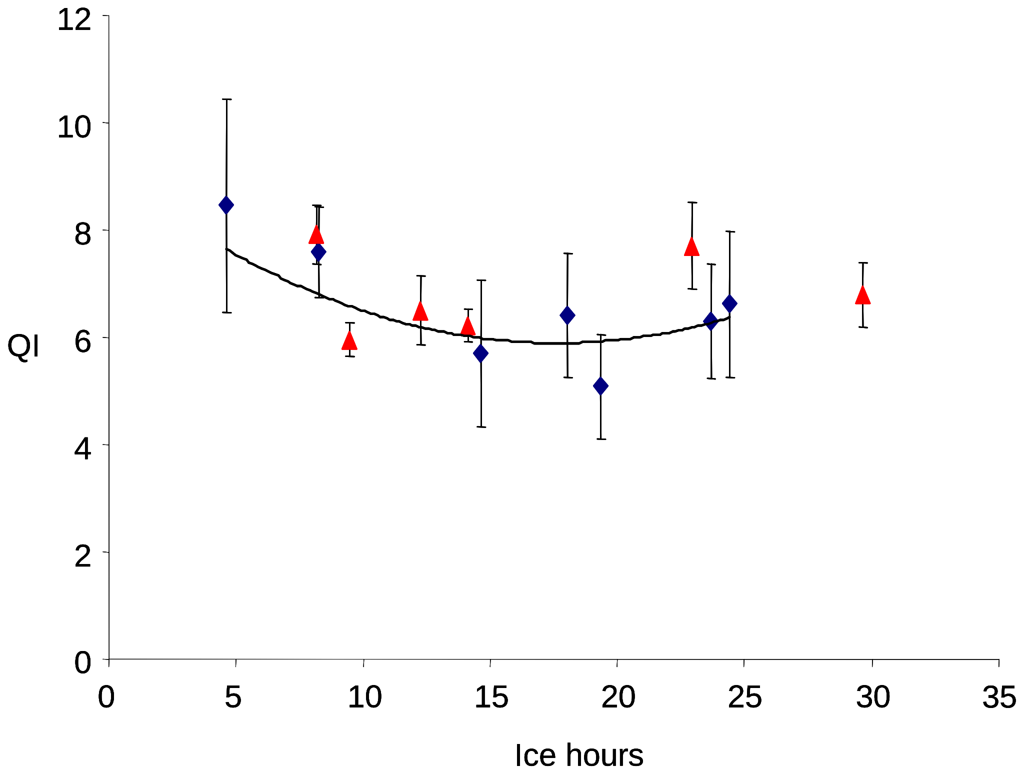
4.3.9 Ice hours and fish deterioration

A positive correlation might be expected between Ice hours and QI, however this was not the case. Boat A showed no significant relationship (F= 2.011, P = 0.106, ANOVA) and there was a significant negative relationship for Boat B (Fig 4.13, R^2 = 0.372, , F= 4.535, P = 0.002). The first two points for Boat B originate from separate tanks sampled on the 26th of June 2003. This date also produced the only marked stomach/intestine or belly burst found in the data set (9.7% and 1.4% respectively, n = 72) and the only ripe gonads (8%) which possibly accounts for the higher than expected mean QI. Only one fish showed rupture and had ripe gonads.

Deterioration of fish deep in each tank could not be assessed as samples could only be taken from the top 0.5m of water in each case.

Fig 4.13 Mean final sardine QI (+SE) against Ice hours

Boat A ▲. Boat B ◆: regression line: $QI = 11.003 - 0.588IH + 0.016\ IH^2$ where IH = Ice hours, R^2=0.372



4.3.10 Muscle and body cavity temperature difference as Ice hours (IH_{BMTD}), storage time and fish QI

There were highly significant positive correlations (Fig 4.14) between IH_{BMTD} and QI (Table 4.6) for all field-trips tested.

Fig 4.14 The relationship between Ice hours and QI for samples taken during 5 trips.

Ice hours derived from belly cavity:body muscle temperature difference (BMTD) and storage time. Refer Table 4.8 for regression statistics.

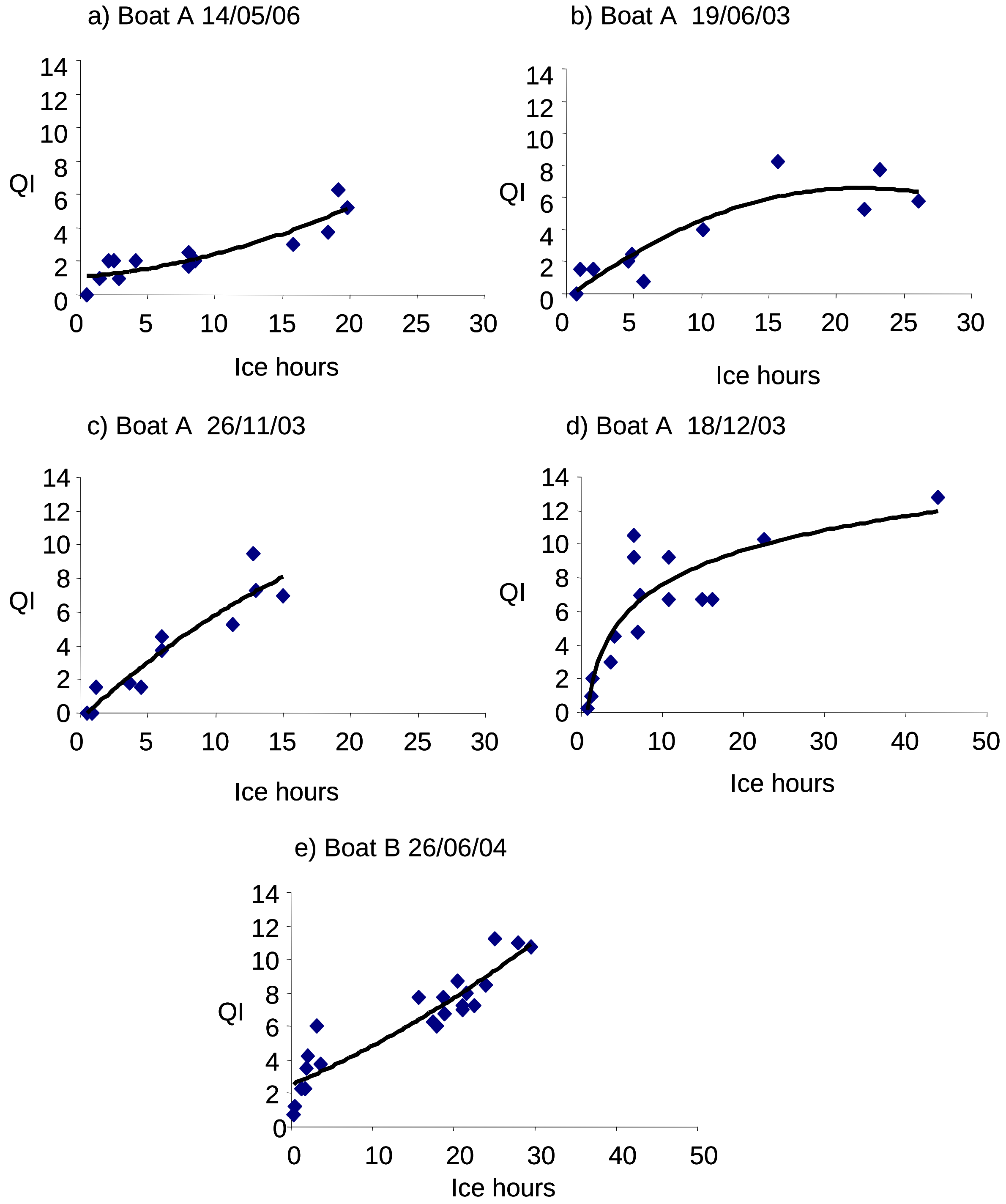


Table 4.6. Change in QI and IH_{BMTD} for each of five field trips: regression statistics.

A = Boat A, B = Boat B . The parameters represent the best fit derived using the Curve Estimation protocol in SPSS. A 18/12/03 fitted a logarithmic model (QI = a + (b x Ln (IH_{BMTD})); data from the remaining trips fitted the quadratic model (QI = a + (b x IH_{BMTD}) + (b_2 + IH_{BMTD}^2)).

Boat/Date	a	B	b_2	R^2	P
A 14/05/03	1.076	0.064	0.007	0.821	<0.001
A 19/06/03	-0.299	0.634	-0.015	0.813	0.001
A 26/11/03	-0.319	0.728	-0.011	0.884	<0.001
A 18/12/03	0.860	2.932		0.763	<0.001
B 26/06/04	2.499	0.209	0.003	0.855	0.006

These data indicate that autolysis had an effect on sardine QI. Autolysis is the exothermic breakdown of the viscera and muscle tissue as a result of the continuing action of endogenous, and possibly prey-derived, digestive enzymes in the stomach after death (Hobbs, 1982). Belly cavity temperatures were up to 8.4°C warmer than those of the muscle, suggesting gut breakdown was extremely active and even present within tanks on trips when temperature was relatively well controlled such as A 19/06/03 Tank B and B 26/06/04 Tank B (Table 4.7).

Table 4.7. Maximum and minimum water temperature and belly cavity-muscle temperature difference (BMTD) (^oC) In storage tanks from the time fish were loaded until arrival at the jetty for samples taken during four trips on the Boat A (A) and one on the Boat B (B).

Boat/Date	Tank	Temperature (^oC)		BMTD (^oC)	
		Min	Max	Min	Max
A 14/05/03	Tank A	6	17.5	2.5	7.6
A 19/06/03	Tank A	3	11.5	1.4	5.5
	Tank B	-0.5	8	3.4	8.4
A 26/11/03	Tank A	-0.5	4.5	3.2	4.6
	Tank B	0	3	3.5	5
A 18/12/03	Tank A	-2	18.5	2.2	4.3
	Tank B	-2	14	4.8	8
B 26/06/04	Tank A	-8.5	3.5	1.1	2.8
	Tank B	-1	12	0.8	4.6

Most fish had full guts (Table 4.8, Range = 3.1 to 3.7 out of a possible 4, N=431), providing abundant substrate for digestive enzyme activity, which may have resulted in rapid autolysis and general post mortem fish deterioration. There were no differences in gut fullness between trips (Boat A, χ^2 = 2.110, P=0.550; Boat B , χ^2 = 6.67, P = 0.247) and very few instances of burst bellies. Boat A showed 3.4% burst stomachs or intestines upon dissection (no burst bellies) spread over 8 trips (N=387 fish). The belly was considered "burst" if there was an externally-visible rupture in the body wall. For one trip Boat B, showed 9.7% burst stomachs or intestines and 1.4% burst bellies, overall (6 trips - burst stomachs/intestines and burst bellies) the figure was 4.5% (N=176).

Table 4. 8. Mean gut fullness for 12 trips, 5 of which were also used in the body temperature-QI analysis.

Fullness scale runs from 1-4; 1 = 0-25%, 2 = 25-50%, 3 = 50-75% and 4= 75 – 100%. A = Boat A, B = Boat B.

	Whole Sample			Fish for which body temperature also taken		
Boat/date	Mean	SE	N	Mean	SE	n
A 14/05/03	3.47	0.13	62	3.5	0.24	21
A 19/06/03	3.50	0.13	36	3.5	0.19	12
A 26/11/03	3.56	0.10	36	3.4	0.23	12
A 26/10/04	3.72	0.12	25			
A 17/11/03	3.72	0.09	46			
A18/12/03	3.71	0.08	48	3.8	0.11	16
B 26/06/04	3.52	0.09	69	3.6	0.16	21
B 19/05/2004	3.5	0.15	12			
B 27/05/2004	3.13	0.18	24			
B 15/08/2004	3.46	0.18	24			
B 08/03/2005	3.45	0.20	20			
B 09/03/2005	3.58	0.18	24			

Ward et al (2000) reported plankton in the guts of Norwegian sprats associated with rapid autolysis leading to a high incidence of belly burst. As shown above, belly burst was not an issue in this study although two trips (14/05 and 19/06/03) did demonstrate elevated initial (i.e. net) BMTDs compared to the other dates analysed (Fig.4.15). Of these only the 19th of July showed a high percentage of copepods (Table 4.9). The final QIs recorded for this trip were similar to or lower than those for the remaining trips analysed, suggesting that prey species had little effect on quality.

Fig 4.15 Change in QI and in BMTD (T^{o}C) with time for each of five field trips (a-e). ▲ QI □ BMTD

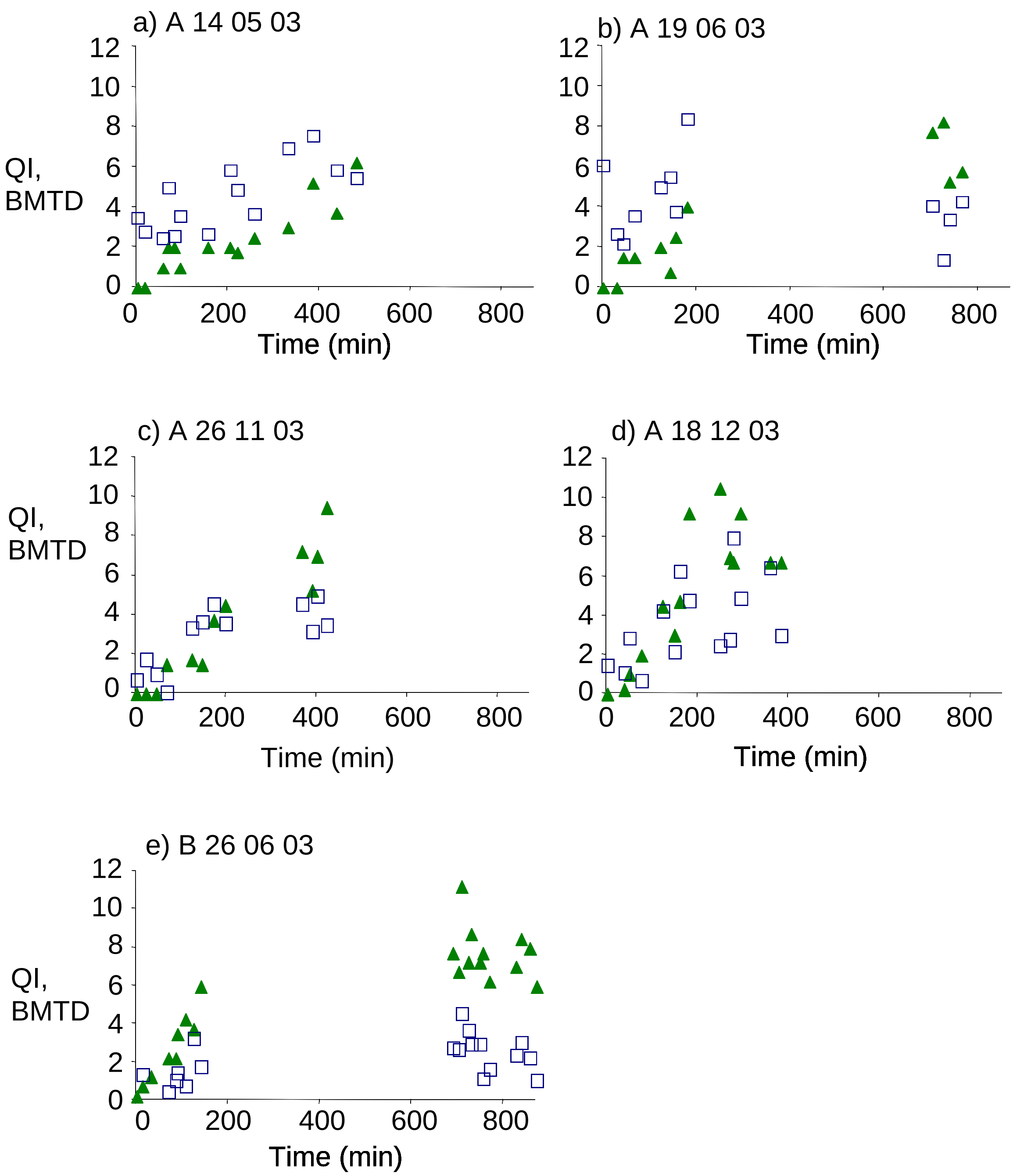


Table 4.9. Pooled invertebrate groups scored from sardine stomachs collected on five different sampling events.

Data is mean individuals (± SE) and the mean % of the invertebrate group found per sampling event (n = 10).

	Individuals per sampling event scored from sardine stomachs				
	02.04.03	14.05.03	19.06.03	26.11.03	18.12.03
Copepoda	1.6 (0.3) 6.5%	0.8 (0.3) 13.4%	4.3 (1.5) 63.9%	2.2 (0.6) 5.7%	4.4 (0.9) 8.6%
Cladocera	0	0.1 (0) 1.2%	(0) 1.0%	(0.1) 0.3%	2.5 (0.8) 5.0%
Other crustaceans	1.5 (0.5) 6.4%	0.6 (0.1) 10.5%	1.4 (0.2) 20.3%	0.8 (0.3) 2.2%	1.4 (0.4) 2.7%
Worms	0.2 (0.1) 0.8%	0 (0) 0.6%	(0.1) 1.5%	0 (0) 0.1%	0 (0) 0.1%
Eggs	19.2 (7.2) 80.2%	4.0 (0.7) 70.3%	0.8 (0.2) 11.4%	34.9 (6.8) 91.4%	42.3 (7.4) 83.3%
Others	1.5 (0.4) 6.1%	(0.1) 4.1%	(0.1) 2.0%	(0.1) 0.4%	0.2 (0.1) 0.3%
Total	24.0 (7.2)	5.7 (0.9)	6.7 (1.9)	38.3 (7.1)	51.0 (7.7)

Finally, a greater initial decrease in gut pH might have been expected with the increase in BMTD. There was no change in pH with time during any of the trips (Regression analysis, $P \geq 0.05$) and the samples from the 19th of June showed similar gut pH values (Kruskel Wallis, $\chi^2 = 0.910$, P= 0.688) to fish sampled on the 14th of May and the 26th of November (Table 4.10) despite differences in initial BMTD and prey found in stomachs. This suggests that gut pH is not necessarily affected by the predominance of copepods in a meal. Having stated that, the last trip analysed (18th December) showed a significantly lower overall gut pH (Mann Whitney U = 287.5, P=0.001) than the other trips analysed (Table 4.10) and the same number of copepods were found in guts sampled from the

18th of December and the 19th of June, although the percentage was very different (8.6% cf 63.9%), with the former trip showing a predominance of eggs (83.3%). Although this suggests that further work is needed on the prey-specific effects on gut pH (a topic somewhat outside this project's brief) it is clear that despite some changes in pH, belly burst was not an issue during most trips. As mentioned previously, Ward et al (2000) suggested increased stomach acidity, resulting from feeding on zooplankton, was associated with post-mortem belly burst in Norwegian sprats. It may be that widespread belly burst was not found in the present study because pH effects were relatively limited.

Table 4.10. Mean sardine gut pH (±SE) taken from four trips on Boat A.

Boat/Date	pH	SE	n
14/05/03	4.21	0.312	19
19/06/03	3.89	0.153	12
26/11/03	4.03	0.107	12
18/12/03	3.38	0.075	16

4.3.11 Other Analyses

Three further variables (initial seawater temperature, maximum RSW tank-water temperature and tons loaded into tanks) were also subjected to regression analysis against QI for each of boats A and B. For Boat A, initial water temperature showed a slight (r^2 = 0.13, F= 6.38, P= 0.002) decline in QI with increasing seawater temperature suggesting other influences on the data set not apparent from this or previous analyses. The biological significance of this result is doubtful though, given the small amount of variability explained by the regression. A similar conclusion could be drawn from the significant decline in QI with increasing tonnage loaded into tanks (r^2 = 0.22, F = 5.46, P= 0.008) found in the Boat B data.

4.4 Discussion

Issues such as gut fullness, seasonality (i.e. boat/date), degree hours and time of loading (i.e. late evening vs early morning) were expected to significantly affect QI of the sardines caught during this study. It had also been predicted that all of the above factors would affect the degree of belly burst in the catch. The latter was one of the major driving forces behind the project and considered a limitation to value-adding. However, very few fish were found with burst bellies, suggesting that the problem is not as widespread as initially thought, and certainly not preventing any value adding to this fishery. That stated, fish were only sampled from the top of the on-board holding tanks in all cases. This should not necessarily be considered a limitation as it is these fish (i.e. those that float) that are considered to be the best of the catch and so most suitable for value-adding.

It is likely that visceral post-mortem autolysis caused by digestive enzyme activity (Gildberg and Rao, 1980, Dalgaard, 2002) would have contributed to the observed increase in sardine QI with time. Visceral autolysis, as indicated by the change in BMTD over time in storage (i.e. Ice hours) would have contributed to softening of muscle tissue, influencing elements contributing to QI such as belly firmness, belly burst and the presence of gut cavity blood. Having stated that, one of the deficiencies in the data is the limited number of empty guts, a function of the fishers targeting feeding schools as suggested by similarity in gut fullness between trips/dates/times. It may be that once guts contain even a small amount of food, and digestive enzyme production is stimulated (Kapoor et al, 1975), this contributes significantly to autolysis but not necessarily to belly burst. A full belly also doesn’t necessarily predispose a fish to post-mortem belly burst. Gildberg (1978) suggested that enzyme activity might not have been fully induced in capelin (*Mallotus villosus*) caught with a full belly immediately after feeding. Gildberg (1978) also suggested that undigested food could effectively absorb digestive enzymes, limiting the gut wall's exposure to soluble enzymes until remaining food was digested.

Capelin are susceptible to belly burst, particularly when feeding on red copepods (*Calanus finmarchicus*). Ingested C *finmarchicus* have been associated with a low tissue pH (down to 3.2) (Gildberg and Raa, 1979) in capelin. There is also a reported association between low post mortem tissue pH, weakened connective tissue and heavy feeding periods in the species (Gildberg and Raa 1980).   We observed low levels of belly burst in *S. sagax*, presumably attributable to plankton species and strength of connective tissue during periods of heavy feeding. C *finmarchicus* appears to be limited to the Northern Hemisphere. It has not been reported from south eastern Australia (Ritz et al, 2003) and there are no data on the species for South Australian waters. Ritz et al (2003) report a similar (but not red) species (*Calanus australis*) as reaching high abundances in south-eastern coastal and oceanic waters. It is presumably this species that accounted for some copepod occurrences in sardine guts (Appendix 3) although we could not verify this, as the samples were too fragmentary. It is suggested that if pH is the driver for belly burst, mediated by the prey ingested, then plankton reported from *S sagax*, within the physical and temporal confines of this study, rarely cause belly burst, even when guts are full.

As stated previously, autolysis does occur in these fish, contributing to increase in QI and reduction in marketability of the product. One of the early suggestions to be tested in this project was the sea-based purging net (corf). Fish to be value-added would be transferred to the net from the purse-seine and allowed to purge stomachs for a time before loading into holding tanks. The idea was to reduce stomach-enzyme-mediated autolysis. This proved too difficult logistically and there was an understandable reluctance on the part of the fishers to investigate the idea. Given the closure of this avenue, other methods must be found to maintain sardine quality through the onboard storage process to allow entry of the product into premium markets. This could include more rapid water temperature reduction through more efficient RSW holding tanks and reduction in the quantity of fish loaded into tanks to maintain water circulation and facilitate cooling. Consideration should also be given to limiting the practice of topping up nearly-full, cold tanks with the later shots containing relatively warm fish, causing a temperature spike and accelerating deterioration of fish already in the tank. Fish should also be iced between unloading at the jetty and arrival at the processing factory. Both dedicated on-board value-adding tanks and jetty-to-factory transport bins could be chilled using flow ice (also called slurry ice or slush ice, Pineiro et al., 2004). Pineiro et al., 2004 found that flow ice had a faster chilling rate than RSW or flake ice, suggesting it would be more efficient at slowing autolysis. The ice within the product is also microscopic so would cause less damage to transported fish than flake ice.

Certain parameters proposed by Bremner (1985) were not used in assessment of the condition of this species. Ten out of the original 17 parameters were included in the QIM, with 4 (i.e. gill colour, eye clarity, body appearance and body stiffness) accounting for 76% of the overall QI. Other parameters not used either showed little change (eg skin firmness, gut colour, visibility of the iris) or were not evident (eg slime on the body and mucus on the gills). Fish smell was not markedly evident at any stage during the sampling process and thus was not a useful indicator. Sardines are delicate; their scales readily come off due to the physical abrasion occurring during pursing and during the subsequent pumping process. Scales were therefore of no use in monitoring change in fish quality during subsequent storage in holding tanks. Useful parameters also vary with fish species. For example Huidobro et al (2000) found the odour of the fish and the gills, the colour of the gills and the clarity and shape of the eyes were most important when assessing Gilthead seabream. Olafsdottir et al (2004) reported changes in the gills and eyes of cod (*Gadus morhua*) being more noticeable and thus more important to final QI. This work included experiments on cod in Iceland, UK, Italy, Spain, Germany Norway and Denmark.

The usefulness of the QI is in its adaptability to many species of fish. The relatively low scores (i.e. 12/21) here reflect the relatively short time the trials were run - these fish are frozen (either block, or IQF) soon after capture and were not assessed further. Scores of 6-8 are considered the upper limit for value-adding this species considering the market (i.e. bait or human consumption) according to some industry members. Other studies using QI have assessed fish and other seafood held fresh on ice for varying periods to determine shelf life (e.g. Huidobro et al. 2000, Larsen et al. 1992, Olafsdottir, et al. 2004, Sveinsdottir et al. 2003, Vaz-Pires and Barbosa, 2004). For example, Larsen et al (1992) held cod over 14 days on ice, reaching scores averaging 18. Vaz-Pires and Barbosa (2004) held octopus for 8 days on ice and reached a mean score of 16. Neither Olafsdottir et al or Larsen et al indicated the maximum shelf life for cod but Vaz-Pires and Barbosa suggested 8 days as the outside limit for fresh-chilled octopus and Huidobro et al considered 15 days to be the outside limit for gilthead seabream (*Sparus aurata*) using a QIM with 8 parameters, giving a total of 15 demerit points. Sveinsdottir et al reported the shelf life of Atlantic salmon kept on ice to be 20-21 days. Sardines (*Sardina sardineus*) held on ice have a shelf life of up to four days (Triqui and Bouchriti, 2003), with fish still “very fresh” with a QI of 9 at two days. Triqui and Bouchriti used a very similar QIM to that used here and regarded a QI of 22 (at 4 days) as being the outside limit for saleability in local (Moroccan) markets. In the present study many *Sardinops sagax* samples had visibly deteriorated (QI of 6-8) by the time unloading occurred at the jetty (7-15 hours RSW storage, Fig 4.10). RSW tanks were rarely kept at or below 0^{o}C and fish never kept on ice for transfer to the factory, all of which compromises quality. Market expectations may be somewhat different here too. In the local market a QI >8 may be considered unsuitable for value-adding as human food.

Finally, one of the major current issues for value-adding sardines is the standardisation of the quality of fish going to market. The QIM provides a framework for such work. The setting of the QI acceptability threshold would involve market acceptability trials including taste testing, microbiological studies to determine safe levels of bacteria on/in the product, and work to determine safe rancidity levels and should be included as a essential element of any further value adding work on this species.

CHAPTER 5 ECONOMIC EVALUATION OF AT-SEA POST-HARVEST HANDLING PROCEDURES FOR THE SA SARDINE FISHERY

Julian Morison, Matthew Ferris and Amanda Hamilton, EconSearch Pty Ltd., PO Box 746, Unley BC, SA 5061

e c o n s e a r c h

28 February 2005

Abbreviations

BCR	Benefit-Cost Ratio
CBA	Cost-Benefit Analysis
IRR	Internal Rate of Return
NPV	Net Present Value

5.1 Introduction

5.1.1 Background

EconSearch Pty Ltd was contracted by SARDI to conduct an economic evaluation of at-sea post-harvest handling procedures for the SA Sardine Fishery.

The task for this section was to undertake an economic evaluation of the various processing options developed as part of the FRDC project, "Optimising at-sea post-harvest handling procedures for the SA Sardine Fishery". The cost benefit analysis component includes consideration of any changes in equipment requirements and fisheries management requirements arising from proposed changes in post-harvest handling procedures.

The specific steps for the project were:

1. Prepare questionnaire for survey;
2. Conduct survey (12 licence holders) with face-to-face interviews (in Port Lincoln);
3. Collect/collate other data –prices, catch, days fished and GVP;
4. Collate and record survey data;
5. Develop and test model with current (base case) data;
6. Re-estimate model for each scenario reflecting the various processing options developed as part of the study;
7. Analyse results;
8. Prepare report.

5.1.2 Method of Analysis

The method of analysis employed in this study, cost-benefit analysis, conforms to South Australian government guidelines for conducting evaluations of public sector projects (Department of Treasury and Finance 1997). Sensitivity analysis was conducted to assess the extent to which the results were dependent upon the value of uncertain variables.

The starting point for a financial evaluation is to develop the 'base case' scenario, that is, the benchmark against which other options are compared. For the purpose of this evaluation the 'base case' was defined as the 'do nothing' scenario or status quo. It is important to note that the base case is not necessarily a 'spend nothing' scenario.

Given that costs and benefits were specified in real terms (i.e. constant 2005 dollars), future values were converted to present values by applying a discount rate of 7 per cent.

A 10-year time horizon was used in the evaluation and results were expressed in terms of net benefits, that is, the incremental benefits and costs of the 'with investment' scenario relative to those generated by the 'base case' scenario. The evaluation criteria employed for these analyses were as follows.

- Net present value (NPV) – discounted project benefits less discounted project costs. Under this decision rule the 'with investment' scenario was considered to be potentially viable if the NPV was greater than zero. The NPV for the 'with investment' scenario has been calculated as an incremental NPV, using the standard formulation (Department of Finance 1991):

  NPV = PV ('with investment' benefits – 'base case' benefits) – PV ('with investment' costs– 'base case' costs)

- Benefit-cost ratio (BCR) – the ratio of the present value of benefits to the present value of costs. Under this decision rule the 'with investment' scenario was considered to be potentially viable if the BCR was greater than one. The ratio was expressed as:

  BCR = PV ('with investment' benefits – 'base case' benefits) / PV ('with investment' costs– 'base case' costs)
- Internal rate of return (IRR) – the discount rate at which the NPV of a project is equal to zero. Under this decision rule the 'with investment'

scenario was considered to be potentially viable if the IRR was greater than the benchmark discount rate (i.e. 7 per cent).

5.2 Data Collection and Definition of Items

5.2.1 Survey of Licence Holders in the Fishery, 2001/02

The questionnaire for the survey was drafted by the Econsearch consultants and subsequently modified after consultation with Dr Tim Ward (Program Leader, SARDI) and Dr Richard Musgrove (Senior Research Scientist, SARDI). In August 2003, all licence holders were sent an introductory letter from Dr Ward encouraging them to participate in the survey. All licence holders were then contacted by the consultants to confirm their participation in the study and to arrange a convenient time to conduct a face-to-face interview. A copy of the questionnaire was sent to all participating licence holders prior to interview. In September 2003, interviews were conducted with 12 of the fishery's 14 licence holders. All 14 licence holders demonstrated a willingness to participate in the study, however, two licence holders did not own/operate their licenses during the 2001/02 fishing season and were therefore excluded from the study. The previous owners of these two licenses did not fish during 2001/02 but leased their quota to other licence holders in the fishery.

5.2.2 Updating the Survey, 2002/03

The 2002/03 economic indicators for the South Australian Sardine Fishery were derived using a range of primary and secondary data and survey–based 2001/02 indicators. The following information was used to adjust the 2001/02 indicators to reflect the fishery's performance in 2002/03:

- SARDI data were used to reflect changes in catch size and its value between 2001/02 and 2002/03. Catch and value data were used to determine the gross income in the fishery.

- Information on the change in fishing effort[1] (number of days fished) between 2001/02 and 2002/03 was used to adjust the costs of inputs that were assumed to vary with fishing effort. These inputs included labour, fuel, repairs and maintenance (R&M), bait and provisions.
- Price information from input suppliers was used to adjust prices that had changed, for example fuel.
- The consumer price index (CPI) for Adelaide was used to adjust the cost of inputs to reflect local levels of inflation.
- Estimates of licence values were adjusted to reflect the change in average gross income per licence holder between 2001/02 and 2002/03.

5.2.3 Investment Data

The evaluation of the processing options required information about the processing equipment and associated costs. Phil Dallimore (Ice Technologies Pty Ltd) provided data regarding:

- Equipment costs
- Installation costs
- Operating costs
- Life of equipment
- Maintenance costs

5.2.4 Other Information

A market analysis, prepared as part of this FRDC project[2], provided useful background to the current position in the bait and human consumption markets and provided recommendations regarding branding, product positioning, pricing strategy, distribution and promotion.

---

[1] Fishing effort data from SARDI Aquatic Sciences were adjusted to reflect the change in the number of active licence holders in the fishery.

[2] “Optimising at-sea post-harvest handling procedures for the sardine”.

5.2.5 Definition of Terms[3]

Gross value of production (GVP) is the total year's catch for the whole fishery valued at the landed beach price.

Gross income is the income received by the individual licence holder from the sale of fish prior to any deductions for freight and selling charges.

Cash costs include the payments for hired labour and materials and services (including payments on capital items subject to leasing, rent, interest, licence fees and repairs and maintenance). If family or other labour were unpaid, an estimate of the cost of labour was made based on the time spent on fishing business related activity.

Cash operating surplus is the difference between gross income and total cash costs. It has been calculated with the imputed value of unpaid labour included in cash costs.

Depreciation is a non-cash cost representing the wear and tear on capital items during the year. It has been calculated using information on the age, current value and current replacement cost of each item.

Earnings before tax is defined as cash operating surplus less depreciation.

Earnings before interest and tax is defined as cash operating surplus less depreciation plus interest.

Capital is defined as the value placed on assets employed by the fishing business. It includes the total gross value of the boat, including the value of the hull, engine and other on-board and shore based plant, equipment and structures. Estimates are also reported for the value of licences.

Rate of return to fishing gear and equipment is calculated by expressing earnings before interest and tax as a percentage of the capital value of fishing gear and equipment. The rate of return to fishing gear and equipment provides an indication of the impact of management changes on the fishery.

Rate of return to total capital is calculated by expressing earnings before interest and tax as a percentage of total capital. This gives a measure of the

[3] Where possible definitions have been kept consistent with those used by Brown (1997) in ABARE's *Australian Fisheries Survey Report*.

economic performance of the fishery for those interested in investing in a boat and licence.

5.3 Economic Overview Of The SA Sardine Fishery

5.3.1 Gross Value of Production

The catch levels shown in Table 3.1 indicate that total catch in the SA sardine fishery has fluctuated significantly since the establishment of the fishery in 1990/91. Only 145 tonnes of sardines were caught during 1991/92, because very few licence holders took up sardine fishing on a full time basis or purchased purpose built fishing gear (Mackie 1995).

In 1992/93 catch in the fishery increased to 1,230 tonnes. In 1993/94, management arrangements for the fishery were reviewed and a three-year experimental period for the fishery was introduced, coinciding with the advent of the tuna farming industry in Port Lincoln. Catch levels increased annually until 1995/96, reaching 3,708 tonnes. Although catch declined slightly in 1996/97, it increased significantly in the following year (1997/98) to over 6,000 tonnes. In 1998/99 and 1999/00, catch declined considerably as a result of a significant sardine mortality event occurring across the entire distribution of the Australian sardine population during October 1998 to May 1999 (Gaut 1999). Sardine stocks regenerated quickly, however, resulting in a significant increase in catch in 2000/01 and 2001/02.

Catch increased by 79 per cent between 2001/02 and 2002/03 as a result of an increase in the total allowable catch from 17,750 tonnes to 36,000 tonnes.

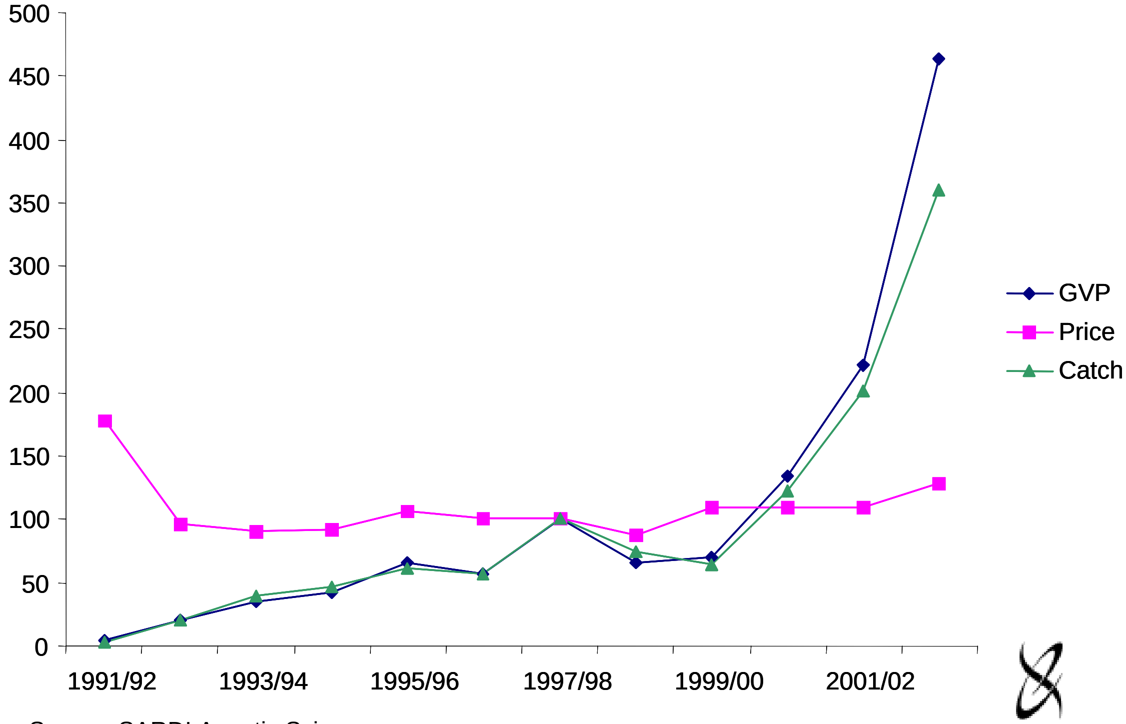
Table 5.1 Sardines catch and value of catch, South Australia, 1990/91 to 2002/03

	Catch (tonnes)	Value of Catch ($'000)
1990/91	na	na
1991/92	145	164
1992/93	1,230	757
1993/94	2,377	1,360
1994/95	2,803	1,630
1995/96	3,708	2,524
1996/97	3,428	2,197
1997/98	6,041	3,846
1998/99	4,465	2,500
1999/00	3,836	2,685
2000/01	7,368	5,157
2001/02	12,165	8,516
2002/03	21,741	17,827

Source: SARDI Aquatic Sciences.

Figure 5.1 illustrates how the value of the fishery has changed over the period 1991/92 to 2002/03. The nominal value of the sardine catch in 2002/03 was more than three and a half times its value in 1997/98, which in turn was three times the value recorded in 1993/94 when the fishery's experimental period commenced. This significant increase in value corresponds closely with increased catches to meet the growing demand for feedstock from Port Lincoln's tuna farming industry. Figure 5.1 shows that the average price of sardines in the SA Sardine fishery has been relatively steady in nominal terms over the period 1992/93 to 2001/02 (i.e. \$0.62/kg in 1992/93 and \$0.70/kg in 2002/03) but increased by 17 per cent between 2001/02 and 2002/03.

Fig. 5.1 GVP, price and catch indices for the South Australian Sardine Fishery (1997/98=100)

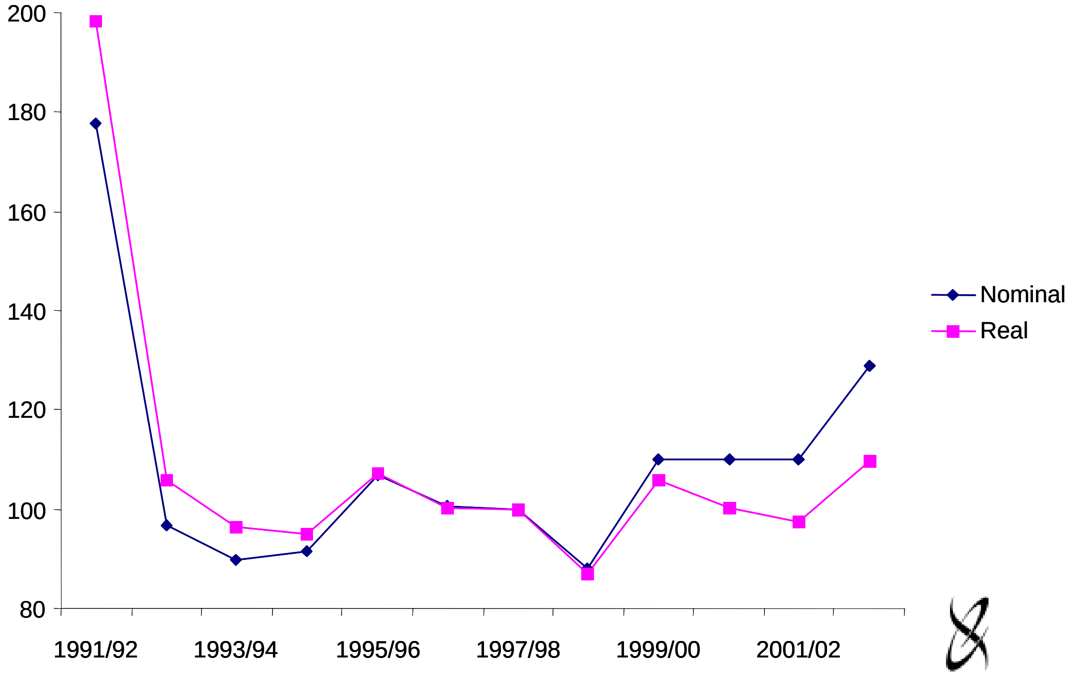


Source: SARDI Aquatic Sciences.

Figure 5.2 shows that the 29 per cent increase in the nominal beach price of sardines over the six-year period from 1997/98 to 2002/03 was equivalent to a 10 per cent increase in the real price[4].

[4] Nominal price refers to the beach price in the current year's dollars. Real price is the nominal price adjusted for the purchasing power of money. The CPI (consumer price index) has been used to make this adjustment (ABS 2003). It enables meaningful comparisons of prices to be made between years.

Fig. 5.2 Price indices for the South Australian Sardine Fishery (1997/98=100)



Source: SARDI Aquatic Sciences.

5.3.2 Cost of Management

South Australian commercial fisheries operate under full cost recovery. Accordingly, licence fees are set to cover the cost of managing the fishery. Management services include:

- annual reports on biological and economic indicators;
- policy and management services;
- regulatory/legislation and licensing services;
- compliance services;
- directorate services;
- extension services;
- research services (including the FRDC levy); and
- the services of various committees.

For the purpose of this analysis, the cost of providing these management services has been assumed to be equal to the gross receipts from licence fees in the fishery (Will Zacharin, pers. comm.).

Table 5.2 shows actual licence fee receipts for the fishery for the period 2000/01 to 2003/04. The following observations can be made for the period 2001/02 to 2002/03:

- licence fees as a percentage of GVP fell from 5.0 per cent to 2.4 per cent as a result of the significant increase in GVP;
- the cost per kilogram of sardines declined from $0.03 to $0.02 as a result of the significant increase in catch; and
- the cost per licence remained relatively constant.

Table 5.2 Cost of management in the SA Sardine Fishery, 2000/01 to 2003/04

	Licence Fee ($'000)	Gross Value of Production ($'000)	Fee/GVP (%)	Catch (tonnes)	Fee/Catch ($/kg)	Licence Holders (No.)	Fee/Licence Holder ($/licence)
2000/01	331	5,157	6.4%	7,368	$0.04	14	$23,633
2001/02	423	8,516	5.0%	12,165	$0.03	14	$30,224
2002/03	434	17,827	2.4%	21,741	$0.02	14	$30,974
2003/04	940	n.a.	-	n.a.	-	14	$67,145

Source: PIRSA Fisheries, SARDI Aquatic Sciences

Fees per licence holder increased by 117 per cent between 2002/03 and 2003/04 reflecting the need for additional research into the impact of harvesting large quantities of sardines on higher-order species in the ecosystem which was, in turn, associated with the significant increase in the fishery’s total allowable catch from 9,100 tonnes in 2000/01 to 36,000 tonnes in 2002/03 (Steve Shanks, PIRSA, pers. comm.).

5.3.3 Financial Performance Indicators

The major measures of the financial performance of the surveyed boats in the SA sardine fishery are shown in Table 5.3.

5.3.3.1 Income

Total recorded sardine catch in South Australia increased by 79 per cent between 2001/02 to 2002/03 while gross receipts from the sale of sardines rose 109 per cent over the same period (Table 1). The average gross income per licence in the fishery was estimated to be just over $1.5 million in 2002/03 (Table 3).

5.3.3.2 Costs

For the fishery as a whole, about 64 per cent of total cash costs were attributable to labour costs in 2002/03, by far the largest individual cost item. The other significant cash costs were repairs and maintenance (12 per cent) and fuel (6 per cent).

Table 5.3 Financial performance in the SA Sardine Fishery, 2001/02 and 2002/03 (average per licence)

	2001/02		2002/03	
	All Licences	Share of TCC [a]	All Licences	Share of TCC
Gross Income	**$845,076**		**$1,516,323**	
Costs				
Fuel	$49,054	9%	$51,766	6%
R&M	$94,882	17%	$101,307	12%
Provisions	$3,712	1%	$3,963	0%
Labour	$300,551	53%	$539,280	64%
Licence fee	$30,146	5%	$30,893	4%
Quota leasing cost	$30,486	5%	$35,708	4%
Insurance	$13,589	2%	$31,708	4%
Interest	$9,719	2%	$13,415	2%
Admin and Other	$33,197	6%	$38,700	5%
Total Cash Costs	**$565,335**	100%	**$846,740**	100%
Cash Operating Surplus	**$279,741**		**$669,583**	
Depreciation	**$109,228**		**$158,633**	
Earnings Before Tax	**$170,513**		**$510,950**	
Earnings Before Interest & Tax	**$180,232**		**$524,365**	
Capital				
Fishing Gear & Equipment	$1,037,731		$1,507,109	
Licence Value [b]	$3,183,333		$5,711,865	
Total Capital	**$4,221,064**		**$7,218,974**	
Rate of Return to Fishing Gear & Equip	**17.4%**		**34.8%**	
Rate of Return to Total Capital	**4.3%**		**7.3%**	

[a] Total cash costs.

[b] Licence value has been calculated according to the average value indicated by licence holders in the survey and updated to 2002/03 according to changes in gross income per licence holder between 2001/02 and 2002/03.

Source: EconSearch analysis.

5.3.3.3 Cash Income and Profit

The labour costs reported in Table 3.3 are comprised of payments to skippers and crew, as well as an imputed wage to operators and other family members who are not paid a wage directly by the business. Accordingly, cash operating surplus was calculated by including imputed wages as part of cash costs. The 2002/03 cash operating surplus per licence was estimated to be almost $670,000.

Cash operating surplus and earnings before tax (business profit) indicate the capacity of the operator to remain in the fishery in the short to medium term. In 2002/03, the average earnings before tax was over $510,000 per licence.

5.3.3.4 Return on Investment

There are a number of interpretations of the concept of return on investment. For the purpose of this analysis it is appropriate to consider investment as the capital employed by an average licence holder in the fishery. Capital includes boats, licence/quota, fishing gear, sheds, vehicles and other capital items used as part of the fishing enterprise. It does not include working capital or capital associated with other businesses operated by the licence holder. The return on investment has been calculated as the net profit after depreciation as a percentage of the total capital employed.

The average return on investment for the fishery is reported in Table 3.3. The rate of return to boat capital (i.e. fishing gear and equipment) for 2002/03 was 34.8 per cent. Capital investment in boat capital was estimated to be around $1.5 million per licence holder. There was investment in new boats in the fishery in 2002/03 with PIRSA licensing records indicating that three new boats (over 10m in length) were registered during the year. This is reflected in an increase in the average capital value of fishing gear and equipment per licence holder and an increase in depreciation between 2001/02 and 2002/03.

The rate of return to total capital (i.e. fishing gear, equipment and licence) in 2002/03 was estimated to be 7.3 per cent, based on a total capital value of approximately $7.2 million per licence holder.

The value of licences represents a significant part of the capital used by each licence holder in the fishery. The reported licence value of $5.7 million for 2002/03 in Table 3.3 was estimated by adjusting the 2001/02 licence value to reflect changes in the average gross income per licence holder between 2001/02 and 2002/03.

5.4 An Economic Evaluation Of Investment In At-sea Post-harvest Handling Equipment

5.4.1 The Costs and Benefits of the Post-harvest Handling Equipment

Tables 5.4 and 5.5 list, in qualitative terms, the costs and benefits associated with the ‘without investment’ (base case) and ‘with investment’ scenarios. The evaluation was undertaken from a licence holder perspective and consideration given to those benefits and costs likely to occur over a 10-year time period. The tables also provide an indication of the likely distribution of the costs and benefits between stakeholder groups. In this analysis, the majority of costs and benefits will be incurred by the sardine licence holders. Clearly, if this type of investment is successful, benefits will also accrue to the wider community due to the increased economic activity generated by the fishery. However, these flow-on benefits have not been estimated as part of this analysis; nor are they normally included in a cost benefit analysis.

Table 5.4 The benefits from investment in at-sea post-harvest handling equipment

Scenario	Benefit	Beneficiary	Valued in Monetary Terms	Source of Information
Base Case (Do Nothing)	Market values attached to sale of sardines in bait market	Sardine fishers	Yes	Licence holders, SARDI, EconSearch analysis
With Investment (in at-sea post-harvest handling equipment)	Market values attached to sale of sardines in bait market	Sardine fishers	Yes	Licence holders, SARDI, EconSearch analysis
	Market values attached to sale of sardines in human consumption market	Sardine fishers	Yes	Licence holders, SARDI, EconSearch analysis

5.4.2 Data Used for Quantifying Benefits and Costs

This section of the report details the method and sources of information used to estimate the benefits and costs listed in Tables 5.1 and 5.2.

5.4.2.1 Benefits

This project's milestone marketing report (Onley, 2003) identified the sale of fresh whole sardines to Melbourne and Sydney as priority target markets for the South Australian Sardine fishery. The following reasons were given for targeting these markets:

- minimal processing required;
- good fit with current research to lift the quality of sardine caught and processed;
- provides an established supply chains for the introduction of value added products at a later date to grow the value of the business;

Table 5.5 The costs of investment in at-sea post-harvest handling equipment.

Scenario	Cost	Bearer of the Cost	Valued in Monetary Terms	Source of Information
Base Case (Do Nothing)	Cost of fishing	Sardine fishers	Yes	Licence holders, EconSearch analysis
With Investment (in at-sea post-harvest handling equipment)	Equipment and installation costs associated with the investment	Sardine fishers	Yes	Phil Dallimore (Ice Technologies Pty Ltd)
	Ongoing operating and maintenance costs of the equipment	Sardine fishers	Yes	Phil Dallimore (Ice Technologies Pty Ltd)
	Other operating costs (e.g. scraper replacement)	Sardine fishers	Yes	Phil Dallimore (Ice Technologies Pty Ltd)
	Cost of fishing	Sardine fishers	Yes	Licence holders, EconSearch analysis

- Melbourne and Sydney markets appear to be inadequately serviced at present; and
- potential to grow volume through stable supply chain with key wholesalers (e.g. agents and providores in Melbourne markets).

As the marketing report points out (this volume), an accurate study is required to determine the logistics and viability of moving fresh product from Port Lincoln to Adelaide, Sydney and Melbourne Markets. Assuming sardines are sent to Adelaide from Port Lincoln by road and air freighted to Sydney and Melbourne at a discount rate, respective freight costs of $2.00/kg and $2.50/kg for Melbourne and Sydney may be achievable. Based on these figures, recent wholesaler prices of around $3.70 (Melbourne) and $4.05/kg (Sydney) and commissions of 7.5 per cent would yield beach prices in the range $1.25/kg to $1.40/kg.

5.4.2.1 Costs

a) Fishing Costs

Details of average fishing costs were provided in Table 5.3.

b) Equipment Costs

The analysis has been undertaken to assess investment in equipment with processing loads that vary from 5 to 50 tonnes of sardines in a 12 to 48 hour period. Based on these parameters, it is very difficult to determine equipment and operational costs and the estimates below, provided by Phil Dallimore (Ice Technologies Pty Ltd), are indicative only.

As a guide to equipment selections and capital costs, the DWT-1.30 would produce enough Flo-Ice (at 40 per cent ice concentration) in a 12 to 14 hour period to 'chill' around 5 tonnes of sardines from 19 deg C to 0 deg C. The base cost for one of these machines is around $77,500 plus GST, delivered to Adelaide.

The largest model DWT-4.30 complete with pre-chiller will produce enough Flo-Ice in a 22 to 24 hour period to chill around 50 tonnes from 19 deg C to 0 deg C. The base cost for one of these machines is around $215,000 plus GST, delivered Adelaide.

If the ozone system is required to be integrated into the Flo-Ice plant, the additional cost ranges from $17,500 to $20,000 plus GST.

c) Installation Costs

This can vary greatly and is dependent upon vessel requirements. As an indication, recent cost estimates for installation of a DWT-1.30 on a vessel in Port Lincoln were put at $50,000. Without doing proper costings for a specific vessel, it is difficult to put a reasonable 'budget' on what is required for a specific Flo-Ice machine.

The Flo-Ice machine only requires a filtered water supply to the ice generator, three phase power supply to control panel and filtered water supply to the marine condenser. It has to be installed in a 'dry' area with suitable access for servicing and the Flo-Ice is then piped from the machine to the sardine holding tanks or processing areas. The extent of work required and associated costs to 'deliver' the Flo-Ice cannot be determined at this stage as 'vessel' factors and availability and use of storage facilities will be a critical factor.

d) Operating Costs

The DWT-1.30 has power input of nominal 10 kW (per hour) and the DWT-4.30 is nominal 45 kW. Before actual operating costs can be determined information on the fuel costs, generator efficiencies, etc are required. For the purpose of this analysis generating costs of $0.20/kW hour has been assumed.

e) Life of Equipment

Assumed to average ten years - there are units that have been in service for this period of time and are still performing.

f) Maintenance Costs

This will depend on how well the water is filtered, equipment usage, supply of uninterrupted power, how well the unit is maintained, etc. Maintenance costs could be as little as $3,000 per year but could also increase if there is compressor failure, loss of refrigerant or problems with electrical supply. For example, a replacement refrigerant charge could cost between $2,500 and $7,500 plus GST. A maintenance cost of $3,000 per annum has been assumed for the DWT-1.30 and $5,000 per annum for the DWT-4.30.

The scrapers on the ice generator generally get replaced every two to three years but this is dependent on water quality and equipment usage. Replacement parts for this exercise could range between $3,000 (DWT-1.30) and $15,000 (DWT-4.30). It has been assumed that this cost is incurred every second year.

5.4.3 Results of the Economic Evaluation

5.4.3.1 Results of the evaluation using base assumptions

The results of the evaluation using the base assumptions, as outlined above, are provided in Table 5.6 for a small scale investment and Table 5.7 for a large scale investment. Detailed spreadsheets for the economic evaluation are provided in Table 5.10.

Table 5.6 Economic evaluation of post harvest handling: small scale [a]

Beach Price Equivalent	Net Present Value ($'000)	Benefit Cost Ratio	Internal Rate of Return
Marketing 50t/an			
$1.25/kg	-68.1	0.7	-3.1%
$1.40/kg	-17.4	0.9	4.6%
Marketing 100t/an			
$1.25/kg	70.0	1.3	15.5%
$1.40/kg	170.5	1.8	26.5%

[a] DWT-1.30: will produce enough Flo-Ice (at 40 per cent ice concentration) in a 12 to 14 hour period to 'chill' around 5 tonnes of sardines from 19 deg C to 0 deg C.
Source: EconSearch analysis.

Table 5.7 Economic evaluation of post harvest handling: large scale [a]

Beach Price Equivalent	Net Present Value ($m)	Benefit Cost Ratio	Internal Rate of Return
Marketing 200t/an			
$1.25/kg	-15.1	0.97	6.2%
$1.40/kg	188.0	1.33	15.9%
Marketing 400t/an			
$1.25/kg	507.7	1.84	29.0%
$1.40/kg	913.7	2.51	44.1%

[a] DWT-4.30: complete with pre-chiller will produce enough Flo-Ice in a 22 to 24 hour period to chill around 50 tonnes from 19 deg C to 0 deg C.
Source: EconSearch analysis.

Based on the data and assumptions detailed in the earlier sections, the returns for the small scale investment (Table 5.6) are estimated to be positive at higher level throughput (100t/an) across the range of prices ($1.25/kg to $1.40/kg) but would be negative at the lower level throughput (50t/an).

A similar result was calculated for the large scale investment (Table 5.7), where the returns would be negative at the low price low/throughput scenario but would be positive across the price range for the higher throughput scenario.

It should be noted that the prices used in this analysis are relative to the price received for the alternative market, that being bait. For the year of the economic model (2002/03), the average price received by sardine fishers in South Australia was $0.82/kg. The prices expressed in this analysis are a differential to that price. That is to say $1.25/kg, for example, represents a $0.43/kg premium over the next best alternative.

5.4.3.2 Break-even values

The estimation of a breakeven value enables decision makers to recognise the critical values for key variables. The analysis in the previous section showed that profitability of the investment in post harvest handling equipment is very sensitive to both throughput and price. Breakeven values for these two variables are provided in Tables 5.8 and 5.9, respectively.

The results in Table 5.8 show the breakeven throughput values for small and large scale post harvest investments, given a range of sardine prices. If the beach price for sardines were $1.25/kg, then the fisher who had invested in the small scale equipment would need to market an average of 75 tonnes per annum (for ten years) for the investment to breakeven. Similarly, at that price, the larger scale investor would need to process and market 206 tonnes per annum to achieve a breakeven result. Clearly, a higher price would mean a lower quantity would need to be marketed to break even.

Table 5.8 Breakeven throughput for small and large scale post harvest handling investments

Beach Price Equivalent	Volume Marketed per annum for Breakeven Result	
	Small scale [a](tonnes/an)	Large scale [b](tonnes/an)
$1.25/kg	75	206
$1.40/kg	55	149

[a] DWT-1.30: will produce enough Flo-Ice (at 40 per cent ice concentration) in a 12 to 14 hour period to 'chill' around 5 tonnes of sardines from 19 deg C to 0 deg C.
[b] DWT-4.30: complete with pre-chiller will produce enough Flo-Ice in a 22 to 24 hour period to chill around 50 tonnes from 19 deg C to 0 deg C.
Source: EconSearch analysis.

The results in Table 5.9 show the breakeven prices for small and large scale post harvest investments, given a range of throughput values. If the volume marketed by a fisher who had invested in the small scale equipment were 50 tonnes per annum, the price would need to average $1.46/kg for the investment to breakeven. Similarly, at a throughput of 200 tonnes per annum, the larger scale investor would need a price of $1.26/kg to achieve a breakeven result. Clearly, the higher the volume marketed the lower the price required for the investment to break even.

Table 5.9 Breakeven prices for small and large scale post harvest handling investments

Volume Marketed		Beach Price for Breakeven Result	
Small scale (tonnes/an)	Large scale (tonnes/an)	Small scale ($/kg)	Large scale ($/kg)
50	200	1.46	1.26
100	400	1.15	1.06

[a] DWT-1.30: will produce enough Flo-Ice (at 40 per cent ice concentration) in a 12 to 14 hour period to 'chill' around 5 tonnes of sardines from 19 deg C to 0 deg C.
[b] DWT-4.30: complete with pre-chiller will produce enough Flo-Ice in a 22 to 24 hour period to chill around 50 tonnes from 19 deg C to 0 deg C.
Source: EconSearch analysis.

5.5 Disclaimer

We have prepared the above report exclusively for the use and benefit of our client. Neither the firm nor any employee of the firm undertakes responsibility in any way whatsoever to any person (other than to the above mentioned client) in respect of the report including any errors or omissions therein however caused.

Table 5.10 Economic Evaluation: Examples of Detailed Spreadsheets

Economic evaluation of post harvest handling: small scale

	Present Value	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Base Case											
Benefits ($)											
Fish sales - bait	11,394,445	1,516,180	1,516,180	1,516,180	1,516,180	1,516,180	1,516,180	1,516,180	1,516,180	1,516,180	1,516,180
Fish sales - human consumption	0	0	0	0	0	0	0	0	0	0	0
Total Benefits ($)	**11,394,445**	**1,516,180**	**1,516,180**	**1,516,180**	**1,516,180**	**1,516,180**	**1,516,180**	**1,516,180**	**1,516,180**	**1,516,180**	**1,516,180**
Costs ($)											
Fishing cash costs less interest	6,262,633	833,325	833,325	833,325	833,325	833,325	833,325	833,325	833,325	833,325	833,325
Other costs	0	0	0	0	0	0	0	0	0	0	0
Total Costs ($)	**6,262,633**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**
Post Harvest Handling											
Benefits ($)											
Fish sales - bait	11,127,320	1,516,180	1,475,180	1,475,180	1,475,180	1,475,180	1,475,180	1,475,180	1,475,180	1,475,180	1,475,180
Fish sales - human consumption	456,783	0	70,110	70,110	70,110	70,110	70,110	70,110	70,110	70,110	70,110
Total Benefits ($)	**11,584,103**	**1,516,180**	**1,545,290**	**1,545,290**	**1,545,290**	**1,545,290**	**1,545,290**	**1,545,290**	**1,545,290**	**1,545,290**	**1,545,290**
Costs ($)											
Fishing Costs											
Fishing cash costs less interest	6,262,633	833,325	833,325	833,325	833,325	833,325	833,325	833,325	833,325	833,325	833,325
Other costs	0	0	0	0	0	0	0	0	0	0	0
Total Fishing Costs	**6,262,633**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**
Equipment & installation											
Equipment base cost	77,500	77,500	0	0	0	0	0	0	0	0	0
Ozone system	20,000	20,000	0	0	0	0	0	0	0	0	0
Installation	50,000	50,000	0	0	0	0	0	0	0	0	0
Contingency (@20%)	29,500	29,500	0	0	0	0	0	0	0	0	0
Total Equipment & Installation Cost	**177,000**	**177,000**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Operating Costs											
Operating costs	1,824	0	280	280	280	280	280	280	280	280	280
Maintenance costs	19,546	0	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Other (replacement scapers)	8,654	0	0	3,000	0	3,000	0	3,000	0	3,000	0
Total Operating Costs	**30,024**	**0**	**3,280**	**6,280**	**3,280**	**6,280**	**3,280**	**6,280**	**3,280**	**6,280**	**3,280**
Total Costs ($)	**6,469,657**	**1,010,325**	**836,605**	**839,605**	**836,605**	**839,605**	**836,605**	**839,605**	**836,605**	**839,605**	**836,605**
Incremental Benefits ($)	**189,658**	**0**	**29,110**	**29,110**	**29,110**	**29,110**	**29,110**	**29,110**	**29,110**	**29,110**	**29,110**
Incremental Costs ($)	**207,024**	**177,000**	**3,280**	**6,280**	**3,280**	**6,280**	**3,280**	**6,280**	**3,280**	**6,280**	**3,280**
Net Benefits (NPV) ($)	**-17,366**	**-177,000**	**25,830**	**22,830**	**25,830**	**22,830**	**25,830**	**22,830**	**25,830**	**22,830**	**25,830**
BCR	**0.92**										
IRR (%)	**4.6%**	**Market Price for HC:**		**$1.40 /kg**							
Discount Rate (%)	**7%**	**Quantity processed:**		**50 tonnes/annum**							

Economic evaluation of post harvest handling: large scale

	Present Value	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Base Case											
Benefits ($)											
Fish sales - bait	11,394,445	1,516,180	1,516,180	1,516,180	1,516,180	1,516,180	1,516,180	1,516,180	1,516,180	1,516,180	1,516,180
Fish sales - human consumption	0	0	0	0	0	0	0	0	0	0	0
Total Benefits ($)	**11,394,445**	**1,516,180**	**1,516,180**	**1,516,180**	**1,516,180**	**1,516,180**	**1,516,180**	**1,516,180**	**1,516,180**	**1,516,180**	**1,516,180**
Costs ($)											
Fishing cash costs less interest	6,262,633	833,325	833,325	833,325	833,325	833,325	833,325	833,325	833,325	833,325	833,325
Other costs	0	0	0	0	0	0	0	0	0	0	0
Total Costs ($)	**6,262,633**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**
Post Harvest Handling											
Benefits ($)											
Fish sales - bait	10,325,947	1,516,180	1,352,180	1,352,180	1,352,180	1,352,180	1,352,180	1,352,180	1,352,180	1,352,180	1,352,180
Fish sales - human consumption	1,827,132	0	280,440	280,440	280,440	280,440	280,440	280,440	280,440	280,440	280,440
Total Benefits ($)	**12,153,078**	**1,516,180**	**1,632,620**	**1,632,620**	**1,632,620**	**1,632,620**	**1,632,620**	**1,632,620**	**1,632,620**	**1,632,620**	**1,632,620**
Costs ($)											
Fishing Costs											
Fishing cash costs less interest	6,262,633	833,325	833,325	833,325	833,325	833,325	833,325	833,325	833,325	833,325	833,325
Other costs	0	0	0	0	0	0	0	0	0	0	0
Total Fishing Costs	**6,262,633**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**	**833,325**
Equipment & installation											
Equipment base cost	215,000	215,000	0	0	0	0	0	0	0	0	0
Ozone system	20,000	20,000	0	0	0	0	0	0	0	0	0
Installation	150,000	150,000	0	0	0	0	0	0	0	0	0
Contingency (@20%)	77,000	77,000	0	0	0	0	0	0	0	0	0
Total Equipment & Installation Cost	**462,000**	**462,000**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Operating Costs											
Operating costs	32,837	0	5,040	5,040	5,040	5,040	5,040	5,040	5,040	5,040	5,040
Maintenance costs	32,576	0	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Other (replacement scapers)	43,270	0	0	15,000	0	15,000	0	15,000	0	15,000	0
Total Operating Costs	**108,683**	**0**	**10,040**	**25,040**	**10,040**	**25,040**	**10,040**	**25,040**	**10,040**	**25,040**	**10,040**
Total Costs ($)	**6,833,316**	**1,295,325**	**843,365**	**858,365**	**843,365**	**858,365**	**843,365**	**858,365**	**843,365**	**858,365**	**843,365**
Incremental Benefits ($)	**758,634**	**0**	**116,440**	**116,440**	**116,440**	**116,440**	**116,440**	**116,440**	**116,440**	**116,440**	**116,440**
Incremental Costs ($)	**570,683**	**462,000**	**10,040**	**25,040**	**10,040**	**25,040**	**10,040**	**25,040**	**10,040**	**25,040**	**10,040**
Net Benefits (NPV) ($)	**187,950**	**-462,000**	**106,400**	**91,400**	**106,400**	**91,400**	**106,400**	**91,400**	**106,400**	**91,400**	**106,400**
BCR	**1.33**										
IRR (%)	**15.9%**	**Market Price for HC:**		**$1.40 /kg**							
Discount Rate (%)	**7%**	**Quantity processed:**		**200 tonnes/annum**							

BENEFITS AND ADOPTION

Information on the detrimental consequences of not chilling the fish as quickly as possible after capture, together with an audit of vessel hygiene and operating practices, has been used by industry to improve processes and practices to maintain sardine quality such that several more vessels and value-adding ventures are now operating in Port Lincoln than when the project started. Indications are that these ventures are supplying value-added sardines to the substantial domestic commercial and recreational fishing bait markets and thereby replacing some imported baitfish. The option of being able to value-add to a percentage of the sardine catch is of economic and social benefit to the fishers and factory owners in Port Lincoln.

Results from this project were presented to the 10th Sardine Fishery Working Group Meeting held in Port Lincoln on the 20th of July 2006.

FURTHER DEVELOPMENT

Adoption or development of efficient cooling technologies and training of crews into the necessities of product care throughout the cool-chain are essential to the successful establishment of value-adding. Marketing has also been identified as playing a critical role in securing returns which justify required expenditure on infrastructure, therefore further marketing studies are necessary to develop the value-added component of the sardine industry.

PLANNED OUTCOMES

Local, vertically-integrated, fishing enterprises are now supplying value-added sardines to the substantial domestic commercial and recreational fishing bait markets, thereby replacing some imported baitfish. Several more ventures are now operating than when the project began, with information released to industry during the project contributing to their development. In collaborating with industry this project has contributed to increased product quality and thus value, increasing industry revenue, profitability, and local employment.

CONCLUSION

The Objectives were as follows:

1. To assess current on-board and on-shore processing practices and equipment used by the SA sardine fleet and to determine the capacity for improvement.
2. To assess marketing issues as they relate to the capacity of the industry to develop new processes/products.
3. To investigate biological and ecological factors that affect rates of deterioration in sardine quality in the immediate post-harvest period.
4. To examine and compare the effects of at-sea post-harvest handling procedures on the rates of deterioration in sardine quality.
5. To develop options for alternative handling procedures that optimise sardine quality and economic return
6. To undertake a cost-benefit analysis of the various processing options including any changes in gear requirements and fisheries management requirements.

An audit was carried out to assess on-board and on-shore processing practices and equipment used by the SA sardine fleet in fulfilment of Objective 1. This revealed a number of shortcomings that were likely to contribute to deterioration in product quality. The main issues were related to holding tank hygiene and the effective circulation of refrigerated water in fish filled holds. This information was used by some of the boats to make modifications to holding tank cooling functionality and improvements to holding tank hygiene practices.

Objective 2 was addressed in two parts, firstly a desktop and survey approach was used to identify the nature of the current domestic markets for frozen bait sardines and fresh, frozen and processed sardines for human consumption. Following this status report there was an assessment of where Port Lincoln sardine products could capture some of this market. Short-medium term opportunities were assessed as being in the bait markets and the fresh fish markets in Sydney and Melbourne. The marketing advantages of Port Lincoln sardines as bait would include the ‘clean and green’ perception of the fishery, as well as the perception that this is a ‘natural food’ for the main target species. These advantages, however, will not overcome an inferior quality product or a significant price premium. For the human-consumption market the price premium is guaranteed for fresh product providing the quality is high; however, any further processing to butterfly fillets and/or canned product would require substantial investment in processing technology, and the financial returns may not be justified in the short-medium term.

Objective 3 was addressed by investigating the biological and ecological factors affecting rates of deterioration in sardine quality in the immediate post-harvest period (i.e. net to processing factory) using a quality index (QI) and physico-chemical measurements. One of the major issues to be addressed in the study was post mortem belly burst, thought to result from visceral autolysis accentuated by consumption of particular prey species (i.e. copepods). However, although a degree of visceral post-mortem autolysis was detected very few fish were found with burst bellies therefore it is suggested that this issue is not a major constraint on the progress of value-adding in the fishery. The recorded post-mortem autolysis is likely to have been caused by digestive enzyme activity and contributed to the observed increase in sardine QI with time.

At-sea post-harvest handling procedures were not compared (Objective 4) as all vessels used very similar techniques to harvest and store fish. The effect of stomach purging before transfer to on-board storage tanks was also not investigated as logistical difficulties prevented the launch of the corf to be used in the experiment.

The outputs addressing Objective 5 were in two parts as follows. A QI method was adapted and proved useful in sardine quality assessment, with inclusion of ten of the seventeen parameters suggested in the literature. Four of these (i.e. gill colour, eye clarity, body appearance and body stiffness) accounted for 76% of the overall QI. It was evident that the QI would provide a framework for standardisation of the quality of fish going to market, a necessary in the process of value adding. The setting of the QI acceptability threshold would involve market acceptability trials including taste testing, microbiological studies to determine safe levels of bacteria on/in the product, and work to determine safe rancidity levels and should be included as a essential element of any further value adding work on this species.

Secondly, methods are suggested for maintaining sardine quality through the onboard storage process to allow entry of the product into premium markets. These include more rapid water temperature reduction using more efficient, dedicated, on-board value-adding tanks, and reduction in the quantity of fish loaded into tanks to maintain water circulation and facilitate cooling. The practice of topping up nearly-full, cold tanks with the later shots containing relatively warm fish should be limited as this practice causes a temperature spike and probably accelerates deterioration of fish already in the tank. Fish should also be iced between unloading at the jetty and arrival at the processing factory, and jetty-to-factory transport bins chilled using an efficient cooling medium such as flow ice.

Finally, Objective 6 was addressed by undertaking a cost-benefit analysis of various options including investment in small scale (processing 50 to 100 t/an) and large scale (processing 200 to 400 t/an) equipment for improved post-harvest handling and processing of sardines for the human consumption market. The analysis was conducted from an individual licence holder (single boat) perspective using a model based on financial data provided by all active licence holders.

The results of the analysis showed that investment in post harvest handling equipment can generate positive returns to the fishery. However, the outcomes are sensitive to the premiums available for human consumption sardines, the quantity processed (which will be determined by the volume that the licence holder can market) and the initial cost of the equipment and its installation. For small scale equipment, for example, the prices (landed beach price equivalent) at which the investment would yield a breakeven return ranged from $1.46/kg for 50 t/an throughput down to $1.15/kg for 100t/an throughput. For large scale investment, the breakeven prices ranged from $1.26/kg for 200 t/an throughput down to $1.06/kg for 400t/an throughput.

While the analysis demonstrates the potential returns that can be generated by investment in post harvest handing of sardines, it also highlights the critical role that marketing will play in securing those returns. Successful marketing of the product will be essential to achieve both the price and the volume necessary to generate positive returns to licence holder investment.

REFERENCES

ABARE 2002, Australian Fisheries Statistics 2002, ABARE, Canberra.

Australian Bureau of Statistics (ABS) 2003, Consumer Price Index, Australia, Cat. No. 6401.0.

Baker, D. and B Pierce 1998, Reassessment of the Gross Economic Value of the South Australian Inland Fisheries Harvest, SARDI Aquatic Sciences.

Ban, E. 2001, Category Review – Fish Marketing 2001, Feb 19 – Mar 2, 2001

Bremner, H. A. (1985) A convenient, easy to use system for estimating the quality of chilled seafoods. Fish Processing Bulletin, 7, p 59-70.

Bremner, H.A., Olley, J. and Vail, A.M.A. (1987). Estimating time-temperature effects by a rapid systematic sensory method. In `Advances in Food Research: Seafood Quality Determination'. Eds Kramer D E & Liston J., Elsevier press, pp 413-435

Brown, D. 1997, Australian Fisheries Surveys Report: Physical and Financial Performance in Selected Australian Fisheries 1994-95 to 1996-97, ABARE Report, Canberra.

Careche, M., Garcia, R. and Borderias, J. 2002. Anchovy shelf life as affected by different chilling methods during distribution. Journal of Food Protection 65 (2): 353-361.

Chesson, J. (1978). Measuring preference in selective predation. Ecology 59, 211 – 215.

Chesson, J. (1983). The estimation and analysis of preference and its relationship to foraging models. Ecology 64, 1297 – 1304.

Dalgaard, P. (2002) Modelling and predicting the shelf-life of seafoods. Chapter 12, In: Safety and Quality Issues In Fish Processing. H.A. Bremner. (ed) CRC Press. Woodhead Publishing. Chapter 19, Pgs 191-219.

Davidson, W. 2000, SA Pilchard Industry Feasibility Study, Davidson Enterprises, November 2000.

Dunnoun, G (2003) (Supply chain manager, Sydney Seafood Market), personal communication.

EconSearch 2000, Planning for Primary Industries in the Eyre Peninsula Region, South Australia, a report prepared for PIRSA.

EconSearch 2001, Input-Output Tables for South Australia, 1999/00, a report prepared for the Department of Industry and Trade.

EconSearch Pty Ltd 2003a, Economic Indicators for the South Australian Pilchard Fishery 2001/02, report prepared for Primary Industries and Resources South Australia, October.

EconSearch 2003b, Economic Indicators for the Commercial Fisheries of South Australia, Summary Report, 2002/03, report prepared for Primary Industries and Resources South Australia, Adelaide, November.

Environment, Resources and Development Committee 1999, The Pilchard Fishery, Thirty-third Report of the Committee, Parliament of South Australia, June 1999.

Fitz-Gerald, C. and Bremner, A. (1994) Improving the stability and nutritional value of frozen small fish for tuna feed. Final Report, National Seafood Centre Project 6, International Food Institute of Queensland, Agribusiness Section, Queensland Department of Primary Industries. 36pp.

Garcia, R. and Careche, M. 2002. Influence of chilling methods on the quality of sardines (*Sardina sardineus*) . Journal of Food Protection 65 (6): 1024-1032.

Gaut, A. 1999, Pilchard (*Sardinops sagax*) Mortality Events in Australia and Related World Events, report prepared by PIRSA Fisheries for FRDC, Adelaide.

Gildberg, A. (1978) Proteolytic activity and the frequency of burst bellies in capelin. Journal of Food Technology 13, 409-416.

Gildberg, A. and Raa, J. (1979) Solubility and enzymatic solubilisation of the muscle and skin of capelin (*Mallotus villosus*) at different pH and temperature. Comparative Biochemistry and Physiology 63B, 309-314.

Gildberg, A. and Raa, J. (1980) Tissue degradation and belly bursting in capelin. Advances in fish science and technology: papers presented at the jubilee conference of the Torry Research Station Aberdeen Scotland, 23-27 July 1979. J J Connell (ed) Fishing News Books. Pg 255-258.

Gosbell, A.R. 2003 (Mud crab fisher, Wolvi), personal communication.

Higgs J. B. and McInnes 2001, Department of Primary Industries Queensland, Biennial recreational fishing survey of Queensland residents, Brisbane.

Hobbs, G. (1982) Changes in fish after catching. In: Fish handling and processing 2nd Edition. A. Aitken, I.M. Mackie, J.H. Merritt and M.L. Windsor (eds). Chapter 3, Pgs 20-27.

Holt, K. 2003 (Bait wholesaler/retailer, Brisbane), personal communication.

Huidobro, A. Pastor, A. and Tejada, M. (2000) Quality index method developed for raw gilthead seabream. Journal of Food Science 65, (7), 1202-1205.

Kapoor, B.G., Smit, H., and Verighina, I.A. (1975) The alimentary canal and digestion in teleosts. Advances in Marine Biology 13, 109-239.

Kolakowska, A., Czerniejewska-Surma, B., Gajowiecki, L., Lachowicz, K. and Zienkowicz, L. 1992. Effect of fishing season on shelf life of iced Baltic herring. In “Quality assurance in the fish industry” Eds. Huss et al, Elsevier Science Publishers B.V.pp:81-91.

Jelinek, A, 2002 (Sadine fisher/processor, South Australia), personal communication.

Jones, D. S. and Morgan, G. J. (2002). ‘A field guide to crustaceans of Australian waters.’ (Reed New Holland: Sydney.)

Kewagama Research, National Survey of Bait and Berley Use by Recreational Fishers, Report to Biosecurity Australia, AFFA, Noosa Valley, 2002.

Larsen E., Heldbo, J., Jespersen, C.J., Neilsen, J. (1992) Development of a method for quality assurance of fish for human consumption based on sensory evaluation. In: Quality Assurance in the Fish Industry. H.H. Huss, M. Jacobsen and J. Liston (eds). Elsevier Science Publishers, 351-358.

Lopez-Martinez, J., Nevarez-Martinez, M. O., Molina-Ocampo, R. E. and Manrique-Colchado, F. A. (1999). Overlap in the type and size of the prey that compose the diet of the Pacific sardine *Sardine caeruleus* (Girard, 1856), thread herring *Opisthonema libertate* (Gunther, 1867) and Northern anchovy *Engraulis mordax* (Girard, 1856) in the Gulf of California. Ciencias Marinas 25 (4), 541 – 556.

Louw, G. G., Van der Lingen, C. D. and Gibbons, M. J. (1998). Differential feeding by sardine *Sardinops sagax* and anchovy *Engraulis capensis* recruits in mixed shoals. South African Journal of Marine Science 19, 227 – 232.

Mackie, D.W., 1995, A Management Plan for the Experimental Pilchard Fishery, South Australian Fisheries Management Series – Paper No. 13, prepared for the Pilchard Fishery Working Party, Adelaide.

Marketing Pro 2002, Desktop Marketing Systems Pty Ltd, Victoria.

Martinsdottir, E. (2002) Quality management of stored fish. Chapter 19. Chapter 12, In "Safety and Quality Issues In Fish Processing". Ed H.A. Bremner. CRC Press. Woodhead Publishing. 507pp.

Mason, F. 2003 (Seafood importer and wholesaler, Melbourne), personal communication.

McArdle, P. 2003 (Seafood wholesaler, Brisbane), personal communication.

Molina, R. E. and Manrique, F. A. (1997). Stomach contents of two planktivorous fishes of the Gulf of California during Summer 1991. Ciencias Marinas 23 (2), 163 – 174.

Neilsen, D. (2005) Quality index method provides objective seafood assessment. Global Aquaculture Advocate. p 36-38.

Olafsdottir, G., Nesvadba, P., Di Natale, C., Careche, M., Oehlenschlager, J., Tryggvadottir, S., Schubring, R., Kroeger, M., Heia, K., Esaiassen, M., Macagnano, A. and Jorgensen, B. (2004) Multisensor for fish quality determination. Trends in Food Science and Technology 15. 86-93.

Onley T. (2003). New processes and products for the pilchard industry and the marketing issues involved. Milestone Report, Fisheries Research and Development Corporation Project Number 2002/235, Optimising at-sea post-harvest handling procedures for the pilchard (Sardinops sagax). 29pp.

Ozogul, F, Taylor, K.D.A, Quantick, P. and Ozogul, Y. 2000. Chemical, microbiological and sensory evaluation of Atlantic herring (*Clupia harengus*) stored in ice, modified atmosphere and vacuum pack. *Food Chemistry* 71:267-273.

Philips, M. 2003 (Coles Supermarkets employee, Melbourne) personal communication.

Pineiro, C., Barros-Velazquez, J., Aubourg, S.P. (2004) Effects of newer slurry ice systems on the quality of aquatic food products: a comparative review versus flake-ice chilling methods. Trends in Food Science and Technology 15, 575-582.

QIM Eurofish (2003) QIM – your ideal tool for quality determination of fish freshness. http://www.qim-eurofish.com/index_start.htm

Ritz, D., Swadling, K., Hosie, G., Cazassus, F. (2003) Guide to the zooplankton of south eastern Australia. Fauna of Tasmania Handbook no. 10. Fauna of Tasmania Committee, University of Tasmania. 91pp.

Roach, S.W., Harrison, J.S.M. and Tarr, H.L.A. 1961 Storage and transport of fish in refrigerated sea water. *Bulletin No 126,* Fisheries Research Board of Canada.pp:1-61.

Ruello and Associates 2002, Retail Sale and Consumption of Seafood, Fisheries Research and Development Corporation, Canberra.

Ross, B. 2003 (Seafood manager, Woolworths), personal communication.

Smith, D. L. (1977). 'A guide to marine coastal plankton and marine invertebrate larvae.' (Kendall/ Hunt Publishing Company: Iowa.). 65pp

Smith, J.G.M., Hardy, R, McDonald, Ian and Templeton, J 1980.   The storage of herring (*Clupia harengus*) in ice, refrigerated sea water and at ambient temperature. Chemical and sensory assessment. *J. Sci. Food Agric*. 31:375-385

Sveinsdottir, K., Hyldig, G., Martinsdottir, E., Jorgensen, B., Kristbergsson, K. (2003) Quallity index method (QIM) scheme developed for farmed Atlantic salmon (*Salmo salar*). Food Quality and Preference 14, 237-245.

Theodore, F. 2003 (Manager, De Costi Seafoods), personal communication.

Towers, P. 2002, Category Review – Fish Marketing, Retail World 2002, Feb 4 – Feb 15.

Trade interviews 2002/3, Carried out by Tony Onley in November 2002 and Feb – June 2003.

Triqui, R. and Bouchriti, N. (2003) Freshness assessments of Moroccan sardine (*Sardina sardineus*): comparison of overall sensory changes to instrumentally determined volatiles. Journal of Agricultural Food Chemistry. 51, 7540-7546.

Van der Lingen, C. D. (1994). Effect of particle size and concentration on the feeding behaviour of adult pilchard Sardinops sagax . Marine Ecology Progress Series 109 (1), 1 – 13.

Van der Lingen, C. D. (1998). Gastric evacuation, feeding periodicity and daily ration of sardine *Sardinops sagax* in the southern benguela upwelling ecosystem. South African Journal of Marine Science 19, 305 – 316.

Vaz-Pires, P. and Barbosa, A. (2004) Sensory, microbiological, physical and nutritional properties of iced, whole, common octopus (*Octopus vulgaris*). Food Science and Technology, 37, 105-114.

Ward, T. Craig, N., Feuerhardt, G, Jelenek, A., Sarunic B. (2000) Pilchard Industry feasibility project: Norfishing 2000. In SA Pilchard Industry Feasibility Study Final Report. Prepared by Wendy Davidson Enterprises Pty. Ltd. and United Valuations and consulting Pty. Ltd. Appendix 4, 14 pp.

Watanabe, Y. and Saito, H. (1998). Feeding and growth of early juvenile Japanese sardines in the Pacific waters off central Japan. Journal of Fish Biology 52, 519 – 533.

Wilkinson, C. and Lee, K. (2004). 'Common phytoplankton of Southern Australia.' (SASQAP: South Australia.) 25pp

Windybanks A. 2003 (Retail and wholesale bait suppliers), personal communication.

APPENDIX 1 INTELLECTUAL PROPERTY

There are no intellectual property issues arising out of this project.

APPENDIX 2 STAFF

Dr Richard Musgrove

Dr John Carragher

Coby Mathews

Steven Slattery

Tony Onley

APPENDIX 3 INVERTEBRATE COMPOSITION OF THE SARDINE (*SARDINOPS SAGAX*) STOMACH AND ASSOCIATED WATERS IN THE SOUTH AUSTRALIAN SARDINE FISHERY

Coby Mathews

A3.1 Introduction

Several operators in the South Australian sardine fishery currently target higher value sardine markets such as those for human consumption and recreational bait, as opposed to the tuna feed market. Accessing these more discerning markets will require fish to be in premium condition consistently throughout the year. Any advances in knowledge in post-harvest methodology will assist fishers to obtain an increase in value of their product.

A major factor affecting the deterioration of fish in the Norwegian sprat fishery was the presence/ absence of a plankton in the gut which caused the abdomen wall to burst within a few hours of landing (Ward et al., 2000). The quantity and quality of sprats supplied to processing factories was increased when fishers: 1. learned to determine the presence/ absence of this plankton in the gut of sprat; and 2. began keeping catches of sprats that contained these plankton in holding cages for 24 – 48 hours prior to landing so that the plankton could be purged from the gut.

The main objective of this project component was an investigation of the biological and ecological factors affecting rates of deterioration in sardine quality in the immediate post-harvest period. This information will be used to investigate any correlations with the quality of freshly caught sardines and their stomach contents. This study aimed to document the main invertebrate plankton groups found in sardine stomachs and the surrounding water column, caught in areas of sardine abundance throughout an annual period.

Objectives:

1. Document the major plankton groups and their abundance found in sardine stomachs across an annual period

2. Document the major plankton groups and their abundance found in water samples from commercial sardine fishing areas across an annual period
3. Compare trends in the major plankton groups between sardine and water samples across an annual period
4. Investigate the most appropriate method to preserve sardine stomachs for invertebrate identification

A3.2 Method

A3.2.1 Sardine collection

Sardine stomachs were collected on six different trips; 29/03/03 (0700), 02/04/03 (0100), 14/05/03 (0100), 19/06/03 (0030), 26/11/03 (2030) and 18/12/03 (2100) in 2003 on board Boat A. Immediately after capture, fish were removed from the seine net, measured, sexed and the digestive systems removed and preserved.

A3.2.2 Stomach collection and preservation

To determine the best storage technique for preservation of stomach contents, thirty stomachs were collected from sardines on each of the first two trips; 10 were preserved in 70% alcohol, 10 were preserved in 5% formalin and 10 were frozen to less than –20^{o}C. The plankton within each stomach were sub-sampled and assessed by eye for degree of damage. As freezing produced the most intact specimens this method was used to preserve sardine stomach contents on subsequent trips. The stomach contents from the initial trip were used to familiarise the author with the types of invertebrates, their abundance and the most appropriate sub-sampling methodology for quantification. As such, these samples were not scored accurately and the data have been omitted. For subsequent trips the stomachs of 10 fish were collected and frozen.

A3.2.3 Stomach content identification and quantification

Using a dissecting microscope, material was removed from each frozen stomach and placed in a salt-water suspension (approximately 10 ml) and gently agitated to break the detrital material apart in order to view at higher magnification. When the material was sufficiently suspended and homogenised, a 1 ml random sample was taken with a 3 ml syringe and 0.1 ml placed onto a standard microscope slide, covered with a cover slip and viewed under a compound microscope at 4-20x magnification. All invertebrates under the cover slip were systematically identified and scored using methods outlined in Smith

(1977) and Jones and Morgan (2002). Two additional 0.1 ml samples were scored from the 10 ml suspension for each sample. Representative photos were taken of the groups present (Figures 2, 3 and 4).

A3.2.4 Plankton sample collection and preservation

Plankton samples were collected on five of the six trips on Boat A (excluding 19/06/03 when no water samples were obtained as the plankton net became caught in the fishing gear). The plankton net consisted of paired conical nets, each 1.5 m long of 300 μm mesh size, 240 mm mouth opening and one litre bottles attached to each cod end. The plankton net was deployed from the port side of the fishing vessel when the seine net was being pursed (on the starboard side) and allowed to sink to the sea floor (30-45m) then retrieved to the surface at a constant speed using 1 metre marks on the rope, and a stopwatch. Conditions for each haul were standardised as much as possible in order to allow species comparison between hauls. (sensu Ritz *et al*. 2003).

For the first two trips two plankton tows were undertaken per trip. For each tow the paired cod ends of the plankton net were pooled into a bucket and three random 650 ml sub samples taken from each, one was stored in 5% formalin, one in 70% alcohol and the other frozen. For subsequent trips three plankton tows were undertaken. Each time a sample was taken the paired cod ends of the plankton net were pooled into a bucket and three random 70 ml sub-samples were taken from each, yielding nine sub-samples per trip. The samples were then frozen and returned to the laboratory.

A3.2.5 Plankton sample identification and quantification

Samples were thawed and suspended material allowed to settle out. Excess water was carefully decanted with a fine-tubed syringe to decrease the total volume of the sample to approximately 15 ml. A 1 ml random sample of the resuspended plankton was taken with a 3 ml syringe and 0.1 ml placed onto a standard microscope slide, covered with a cover slip and viewed under a compound microscope at 4-20x magnification. All invertebrates under the cover slip were systematically identified and scored using methods and keys in Smith (1977) and Jones and Morgan (2002). For the first trip two additional 0.1 ml samples were scored from the 15 ml suspension (3 sub-samples in total) for each of the two water samples. For the second trip six sub-samples were enumerated for each of the two water samples. For the remaining three trips one slide was scored for each of 9 sub-samples. Representative photos were taken of the invertebrate groups present (Figures 2, 3 and 4).

A3.2.6 Data Analysis

All data presented in Tables A3.1 – 4 and Figure A3.1 are averages of the number of individuals scored for each particular group, with an associated standard error in brackets. Additionally the mean percentage of the particular group found per sampling event is presented.

To determine if there was any preference by sardines for the invertebrate groups found in the sardine stomachs, an electivity index (ε) was calculated for the groups found in both the water samples and sardine stomachs (Table A3.5). A Manly/ Chesson (α_i) index was calculated as described in Chesson (1978 and 1983):

$$\alpha_i = \frac{r_i / n_i}{\sum_{i=1}^{m} r_i / n_i}, i = 1, \ldots, m$$

where α_i is the preference for prey type *i* ranging from 0 to 1, n_i is the proportion of prey type *i* in the environment, r_i is the proportion of prey type *i* in the fish stomach, and *m* is the number of prey types in the environment.

In order to perform a better comparison, a displayed preference as an electivity index (ε) among prey types was calculated as:

$$\varepsilon_i = \frac{m\alpha_i - 1}{(m-2)\alpha_i + 1}, i = 1,...,m$$

where α_i is the preference value previously calculated and *m* is the number of prey types. The value of ε ranges from –1 to +1, where –1 indicates absence of prey in the stomach, negative values suggest avoidance of those prey types and positive values suggest active selection on those prey types. Zero indicates that selection was at random.

A3.3 Results

A3.3.1 All invertebrates

All invertebrate groups scored in both the sardine stomachs and water samples are presented in Tables A3.1 and A3.2 respectively. There were 13 different taxonomic groups identified from the sardine stomachs and 14 from the water samples, with a total of 17 different groups found overall.

The total number of invertebrates scored from sardine stomachs between trips varied greatly across the year from approximately 6 (May and June), 24 (April), 38 (November) to 51 (December).

Table A3.1 Invertebrate groups scored from sardine stomachs collected on five different sampling events.

Data is mean individuals (± SE) and the average % of the invertebrate group found per sampling event (n = 10).

Invertebrate group	**Number of individuals per sampling event scored from sardine stomachs**				
	02.04.03	**14.05.03**	**19.06.03**	**26.11.03**	**18.12.03**
Copepod	1.6 (0.3) 6.5%	0.8 (0.3) 13.4%	4.3 (1.5) 63.9%	2.2 (0.6) 5.7%	4.4 (0.9) 8.6%
Amphipod	0.1 (0.1) 0.2%	0	0	0	0
Cladocera	0	0.1 (0) 1.2%	0.1 (0) 1.0%	0.1 (0.1) 0.3%	2.5 (0.8) 5.0%
Brachyura larvae	0	0	0	0	0.03 (0) 0.1%
Crustacean nauplius	0.1 (0.1) 0.6%	0.03 (0) 0.6%	0.1 (0.1) 1.5%	0.2 (0.1) 0.4%	0.1 (0) 0.1%
Unidentified crustacean	1.4 (0.5) 5.6%	0.6 (0.1) 9.9%	1.3 (0.2) 18.8%	0.7 (0.3) 1.7%	1.3 (0.4) 2.5%
Bivalve larvae	0	0.03 (0) 0.6%	0	0	0.2 (0.1) 0.3%
Trematode	0.2 (0.1) 0.7%	0.03 (0) 0.6%	0.1 (0.1) 1.5%	0.03 (0) 0.1%	0.03 (0) 0.1%
Nematode	0.03 (0) 0.1%	0	0	0	0
Egg	19.2 (7.2) 80.2%	4.0 (0.7) 70.3%	0.8 (0.2) 11.4%	32.7 (6.4) 85.5%	41.8 (7.3) 82.3%
Egg-like structure	0	0	0	2.2 (0.5) 5.7%	0.5 (0.2) 1.0%
Parasitic spore	0.5 (0.4) 1.9%	0	0	0	0
Unidentified	1.0 (0.3) 4.1%	0.2 (0.1) 3.5%	0.1 (0.1) 2.0%	0.2 (0.1) 0.4%	0
Total	**24.0 (7.2)**	**5.7 (0.9)**	**6.7 (1.9)**	**38.3 (7.1)**	**51.0 (7.7)**

These numbers approximately correlate with varying catch times with the lowest three counts from fish caught between 0030 and 0100 and the highest two counts from fish caught between 2030 and 2100.

The total number of invertebrates scored in water samples between trips varied greatly across the year from 3 (November), 10 (December), 19 (May), 36 (April) to 60 (March).

Table A3.2 Invertebrate groups scored from water samples collected on five different sampling events.

Data is mean individuals (± SE) and the average % of the invertebrate group found per sampling event. On the 29.03.03 and 02.04.03 n = 2 and for remaining water samples n = 3.

Invertebrate Group	**# individuals per sampling event scored from water samples**				
	29.03.03	**02.04.03**	**14.05.03**	**26.11.03**	**18.12.03**
Copepod	35.5 (4.8) 58.8%	27.1 (2.4) 74.9%	17.6 (5.3) 94.0%	0.7 (0.4) 20.7%	2.9 (0.6) 29.9%
Amphipod	0	0.3 (0.1) 0.2%	0	0	0.1 (0.1) 1.1%
Cladocera	3.8 (0.2) 6.4%	1.9 (1.1) 5.3%	0.1 (0.1) 0.6%	1.3 (0.3) 41.4%	5.7 (0.8) 58.6%
Mysid	0	0.1 (0.1) 0.2%	0	0	0.1 (0.1) 1.1%
Shrimp larvae	0.8 (0.5) 1.4%	0.3 (0.3) 0.7%	0	0	0
Brachyura larvae	0.2 (0.2) 0.3%	0.2 (0) 0.5%	0.2 (0.1) 1.2	0	0
Crustacean larvae	0	0	0	0	0.3 (0.2) 3.4%
Crustacean nauplius	0	0.3 (0.1) 0.7%	0	0	0
Crustacean	0	0.3 (0.1) 0.7%	0.1 (0.1) 0.6%	0	0.1 (0.1) 1.1%
Bivalve larvae	0.7 (0) 1.1%	0.5 (0.3) 1.4%	0.3 (0.2) 1.8%	0.1 (0.1) 3.4%	0.3 (0.2) 3.4%
Egg	19.2 (8.5) 31.8%	5.3 (1.3) 14.7%	0.3 (0.3) 1.8%	0	0
Egg-like structure	0	0	0	1.1 (1.1) 34.5%	0.1 (0.1) 1.1%
Brittle star	0.2 (0.2) 0.3%	0	0	0	0
Unidentified	0	0.3 (0.1) 0.7%	0	0	0
Total	**60.0 (3.0)**	**36.2 (4.7)**	**18.7 (5.5)**	**3.2 (1.4)**	**9.7 (0.5)**

These numbers generally follow an opposite trend of that found from sardine stomachs and catch times. The two lowest scores were collected between 2030 and 2100, the next two highest scores at 0100 and the highest score at 0700. One explanation for this could be that the number of planktonconsumed by predators is loweest at dusk , gradually increasingeduring the night. Alternatively, the dawn aggregation of zooplankton may simply be higher than that found at dusk.

A3.3.2 Combined invertebrate groups

Many of the groups were represented by a small number of individuals, so several groups of similar classification were pooled in order to more readily identify trends in the data. The groups which contained large sample sizes on their own were not pooled; copepod and cladocera. The remaining groups were pooled into 'other crustaceans' containing amphipods, mysids, shrimp larvae, brachyura larvae, crustacean larvae (indistinguishable from other crustacean larval groups), crustacean nauplius and unidentified crustaceans; 'worms' containing trematodes and nematodes; 'eggs' containing eggs and egg-like structures; and 'others' containing bivalve larvae, brittle stars, parasitic spores and other unidentified organisms. These data are presented separately for sardine stomach content in Table A3.3 and for water samples in Table A3.4.

Table A3.3 Pooled invertebrate groups scored from sardine stomachs collected on five different sampling events.

Data is mean individuals (± SE) and the average % of the invertebrate group found per sampling event (n = 10).

	# individuals per sampling event scored from sardine stomachs				
	02.04.03	**14.05.03**	**19.06.03**	**26.11.03**	**18.12.03**
Copepod	1.6 (0.3) 6.5%	0.8 (0.3) 13.4%	4.3 (1.5) 63.9%	2.2 (0.6) 5.7%	4.4 (0.9) 8.6%
Cladocera	0	(0) 1.2%	(0) 1.0%	(0.1) 0.3%	2.5 (0.8) 5.0%
Other crustaceans	1.5 (0.5) 6.4%	0.6 (0.1) 10.5%	1.4 (0.2) 20.3%	0.8 (0.3) 2.2%	1.4 (0.4) 2.7%
Worms	0.2 (0.1) 0.8%	0 (0) 0.6%	(0.1) 1.5%	0 (0) 0.1%	0 (0) 0.1%
Eggs	19.2 (7.2) 80.2%	4.0 (0.7) 70.3%	0.8 (0.2) 11.4%	34.9 (6.8) 91.4%	42.3 (7.4) 83.3%
Others	1.5 (0.4) 6.1%	(0.1) 4.1%	(0.1) 2.0%	(0.1) 0.4%	0.2 (0.1) 0.3%
Total	24.0 (7.2)	5.7 (0.9)	6.7 (1.9)	38.3 (7.1)	51.0 (7.7)

Table A3.3 (plotted in Fig A3.1) shows the relatively low number of individuals found across all groups except the egg group. Copepod scores remained low, accounting for a small percentage of the score on all dates except for the 19.06.03 where copepods accounted for greater than half of the count. Cladocera counts and percentage occurrences were low for all dates, with a relative increase in the score from the final sample. Scores from the other crustaceans, worms and others groups were similarly low with no definable trend across the year, with the exception of a slightly higher score in the others group on the 02.04.03. In the egg group the first and last two sample dates contained high counts with averages of 19.2, 34.9 and 42.3. Similarly on these dates the egg group accounted for the most individuals scored on their relative sampling dates with high percentages of 80.2, 91.4 and 83.3% respectively. Similarly on the 14.05.03 a relatively high average of eggs was found for this date with a high percentage occurrence of 70.3%. In general, with the exception of the egg group, the mean number of individuals scored from sardine stomachs from each group did not vary greatly across the year.

In general, scores found in the water samples were of a similar magnitude to those found in the sardine stomachs, with the exception of copepods, as described in Table 4 and Fig A3.1. In the first three trips the average number of copepods was high, as was their percentage occurrence for their sample dates. For the remaining two sample dates the average number of individuals scored was low, although their relative percentage occurrence was higher at 20.7 and 29.9% occurrence respectively. Thus at times of low scores, copepods still accounted for approximately 25 % of the count and between 50 and almost 100% of the count at times of high scores. The mean number of individuals scored for the cladocerans, other crustaceans and others groups remained relatively low across the sample dates, with corresponding low levels of percentage occurrence with the exception of the last two sample dates with cladocerans averaging 50%. The mean number of eggs remained relatively low across the sample dates except for the initial sample on the 29.03.03, accounting for approximately one third of the individuals found on this date. There were no individuals found from the worms group at any of the sample dates, indicating that the worms present in the sardine stomachs were not ingested as prey items from the environment. Consequently this group has been excluded from further prey item analyses.

Table A3.4 Pooled invertebrate groups scored from water samples collected on five different sampling events.

Data is mean individuals (± SE) and the average % of the invertebrate group found per sampling event (n = 2 for the 29.03.03 and 02.04.03 and n = 3 for the 14.05.03, 26.11.03 and 18.12.03).

	# individuals per sampling event scored from water samples				
	29.03.03	**02.04.03**	**14.05.03**	**26.11.03**	**18.12.03**
Copepod	35.5 (4.8) 58.8%	27.1 (2.4) 74.9%	17.6 (5.3) 94.0%	0.7 (0.4) 20.7%	2.9 (0.6) 29.9%
Cladocera	3.8 (0.2) 6.4%	1.9 (1.1) 5.3%	0.1 (0.1) 0.6%	1.3 (0.3) 41.4%	5.7 (0.8) 58.6%
Other crustaceans	1.0 (0.3) 1.7%	1.1 (0.4) 3.0%	0.3 (0.2) 1.8%	0	0.7 (0.2) 6.9%
Worms	0	0	0	0	0
Eggs	19.2 (8.5) 31.8%	5.3 (1.3) 14.7%	0.3 (0.3) 1.8%	1.1 (1.1) 34.5%	0.1 (0.1) 1.1%
Others	0.8 (0.2) 1.4%	0.8 (0.3) 2.1%	(0.2) 1.8%	0.1 (0.1) 3.4%	0.3 (0.2) 3.4%
Total	60.0 (3.0)	36.2 (4.7)	18.7 (5.5)	3.2 (1.4)	9.7 (0.5)

A3.3.3 Sardine stomach content and plankton sample comparison

The mean number of individuals for each invertebrate group were plotted against sample date to investigate trends across time for sardine stomach contents (Table A3.3) and plankton samples (Table A3.4) as previously discussed and to compare the numbers found between sardine and water samples on matching sample dates (there are four pairs of sardine and water data with matching sample dates; 02.04.03, 14.05.03, 26.11.03 and 18.12.03). In the copepod group, the first two water sample scores are much higher than those of the sardine stomachs, but are much closer in the last two samples. In the cladocera group all of the water sample scores are higher than those of the sardine counts with the exception of the sample on the 14.05.03. In the other crustaceans group all four of the water samples are lower than the sardine scores. In the eggs group all four of the water sample scores are lower than the sardine scores, with major differences in the last two samples. Both scores are quite similar in the others group with the exception of the sardine counts which are higher in the first sample.

A3.3.4 *Prey selectivity*

To investigate if there was any selectivity exhibited in prey ingested by sardines, a Manly/ Chesson index was calculated for each of the five prey groups found in both the water and sardine samples, as described in Chesson (1978 and 1983). This index was used to calculate an electivity index (ε), among prey items to describe if a particular organism was being selected for (positive values to +1), avoided (negative values to –1) or at random (zero value), as shown in Table A3.5. The category of worms has been left out of the electivity index in Table A3.5 because these individuals may not have been ingested from the water column as a food source (no worm species found in the water column in any of the sampling events (Table 4).

Table A3.5. Electivity index among prey types for the five ingested invertebrate groups across sample date.

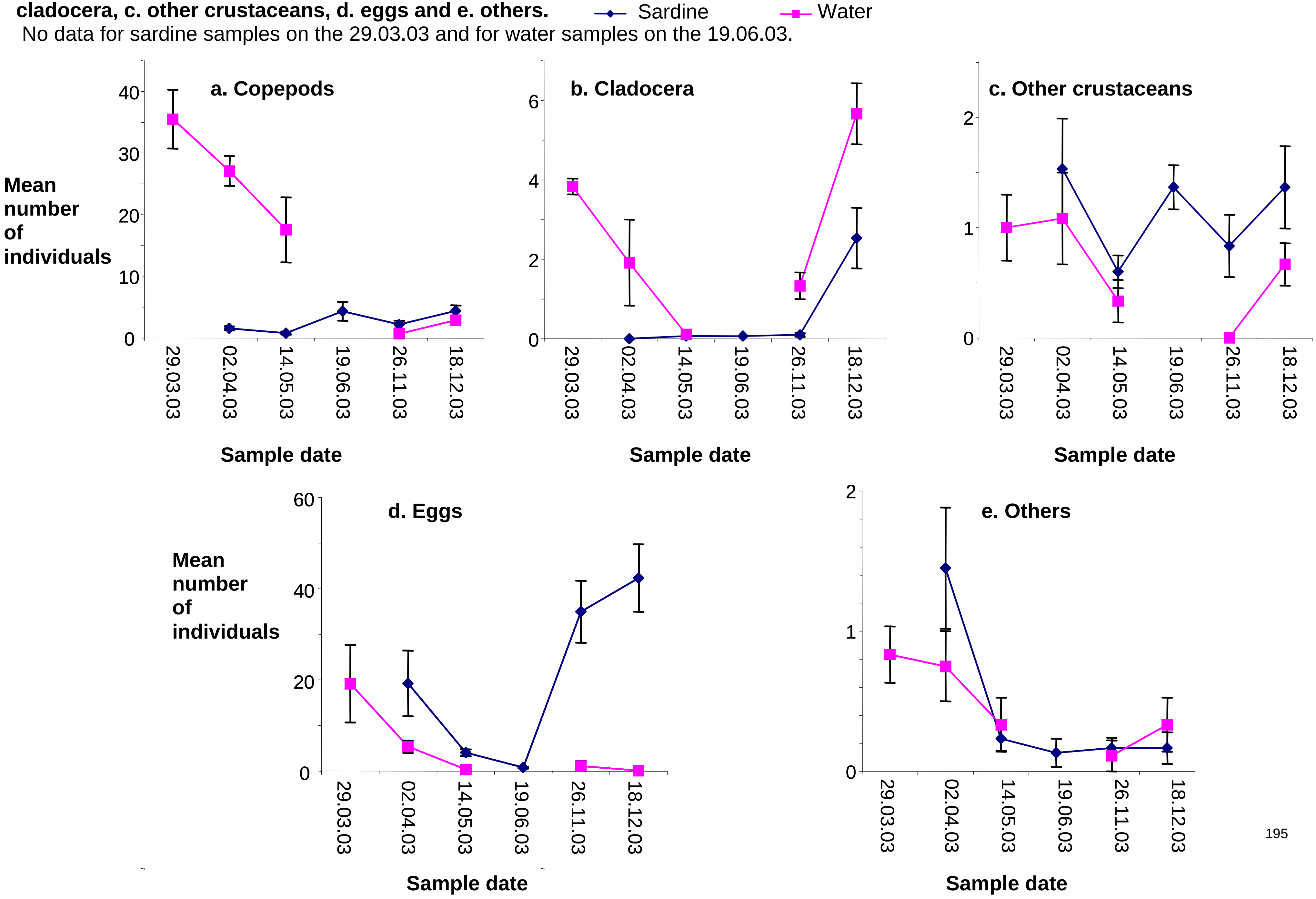
Note, the undefined (U/D) indicates a value which was not able to be calculated due to a zero count in the water sample on this date.

Invertebrate	**Electivity index (ε) for each sample date**			
Groups	**02.04.03**	**14.05.03**	**26.11.03**	**18.12.03**
Copepod	-0.93	-0.98	-0.46	-0.97
Cladocera	-1.00	-0.60	-0.98	-0.99
Other crustaceans	-0.01	-0.31	U/D	-0.96
Eggs	0.63	0.87	0.92	0.99
Others	0.20	-0.72	-0.63	-0.99

On every sample date there was a mix between prey being both selected for, at random or avoided. On the 02.04.03 both copepods and cladocerans were being avoided with values close to –1, whilst eggs and others were being selected for and other crustaceans were being consumed at random. On all other sample dates only the eggs group was being selected for, whilst all other groups were being avoided. Through time, copepods and cladocera were being avoided at every sample point. Other crustaceans were selected at random on the 02.04.03 and were avoided on subsequent dates. Eggs were being selected for at every time point. Others were marginally selected for on the first sample point and avoided on subsequent dates.

Fig. A3.1 Mean number of individuals (±SE) for sardine and water samples per sampling event for; a. copepods, b. cladocera, c. other crustaceans, d. eggs and e. others.

No data for sardine samples on the 29.03.03 and for water samples on the 19.06.03.

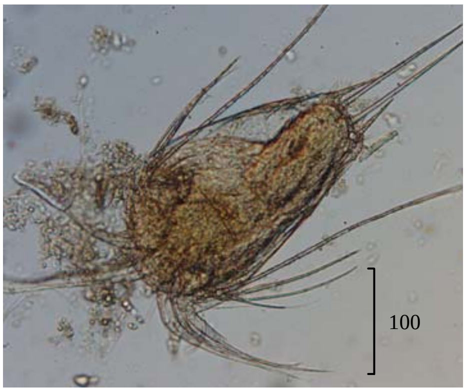


a.

b.

c.

d.

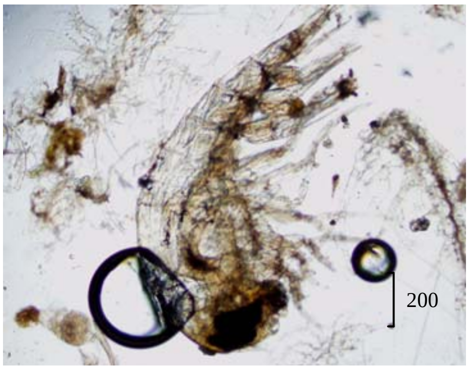


e.

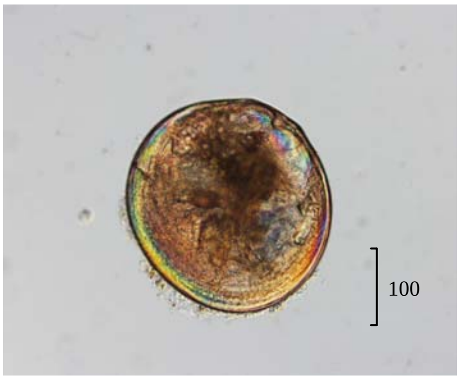
f.

Fig. A3.2 Examples of zooplankters found in the six pooled groups.

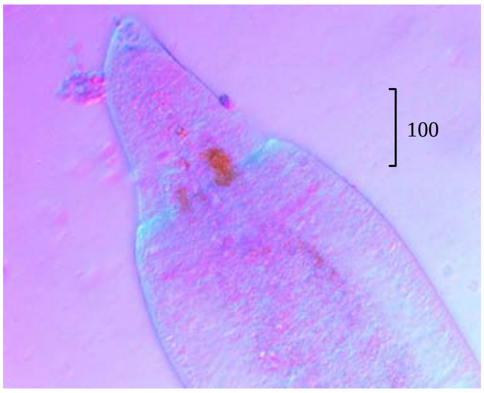
Copepod – a. a copepod and a dinoflagellate from the genus *Ceratium* (10x), **b.** copepod (10x), **c.** copepod (4x), **d.** a copepod and a cladocera (above) (4x), **cladocera – e.** a cladocera (10x), **other crustaceans – f.** a crustacean nauplius (20x). **Scale = micron**



a.

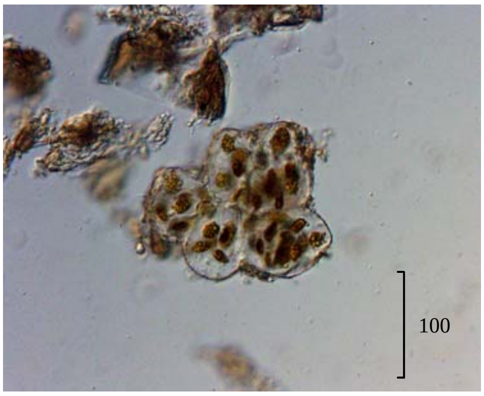


b.



c.

d.

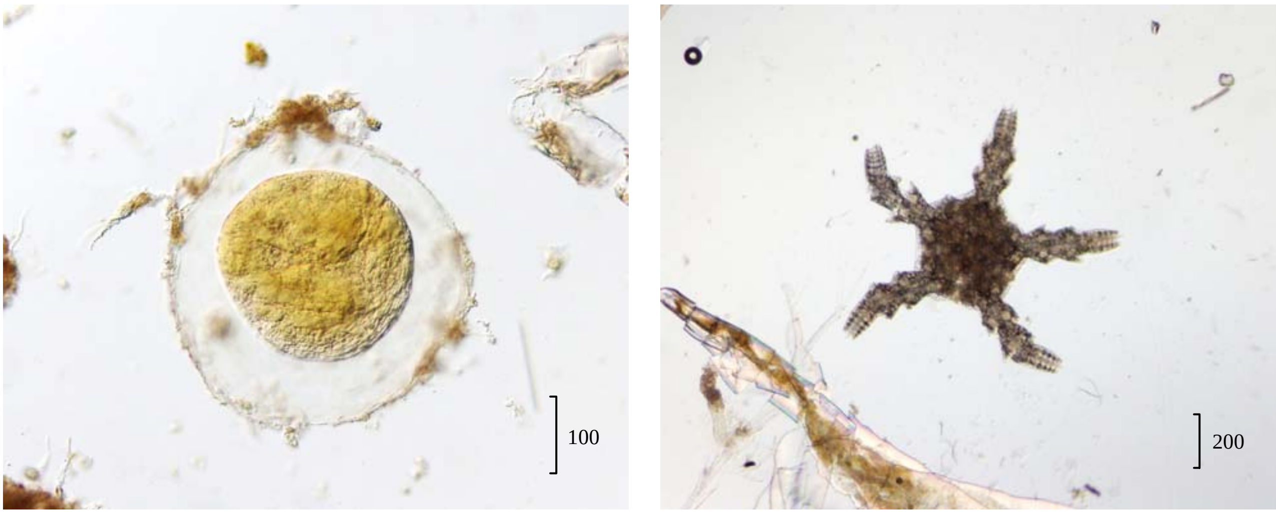


e.

f.

Fig. A3.3 Examples of zooplankters found in the six pooled groups

Other crustaceans – a. a hyperid amphipod (4x), **b.** a bivalve larva (10x), **worms – c.** posterior end of a trematode (10x), **d.** anterior end of a trematode (10x), **eggs – e.** a cluster of eggs (20x), **f.** a fish egg(10x). **Scale = micron**



a. b.

Fig. A3.4 Examples of zooplankters found in the six pooled groups.

Eggs – a. a fish egg (possibly *S. sagax*) (10x), **others – b.** a recently morphosed brittle star (4x). **Scale = micron**

A3.4 Discussion

Three different preservation methods were tested to investigate the most suitable method to preserve the stomach at time of collection, to safely keep the sample until time was available to process the sample. It was found that the stomach was best preserved by freezing and was also the easiest method to employ on a commercial vessel. Both 70% alcohol and 5% formalin tended to dehydrate/damage the specimens and combined with the ease of preservation on a boat freezing was the chosen method for preservation.

The majority of plankton in the stomach was difficult to identify due to several factors which included: 1. presence of detritus and a mucus-like matrix in the sample obscuring some plankton, 2. decomposition of individual plankton and 3. lack of suitable literature for identification. Individual specimens were identified to order or family level, depending on the group. Inconsistency in the quality between specimens made identifying individuals to a higher taxonomic level more difficult. Specimens from the water samples were commonly of better quality than those from the stomach, howeversome individuals still made a higher level of identification difficult and impractical. Near the conclusion of this project Ritz *et al*. (2003) published a comprehensive guide to the zooplankton types found in South-eastern Australia, which would have assisted in early identification in this project. This will be a useful guide for future studies in this area.

The diet of sardines consisted chiefly of copepods, amphipods, cladocerans, several larval crustacean and molluscan species, a variety of eggs from different species and several other minor unidentified species. The stomach also contained various phytoplankton species that were not scored as this was beyond the scope of this project. However, the major species observed in the diatom and dinoflagellate groups were *Ceratium tripos* and *Ceratium spp*, *Dinophysis spp*, *Prorocentrum spp*, and *Pleurosigma spp* (Wilkinson and Lee 2004). The stomach content of sardines described here is consistent with that found in various studies of other clupeoids (Louw *et al*. 1998; Watanabe and Saito 1998; Molina and Manrique 1997; Lopez-Martinez *et al.* 1999). Worms were found only in stomach samples, not in the plankton, suggesting thatthey may have been parasitic rather than prey. . Further work is necessary to support this conclusion.

There appears to be an opposing trend between time of catch and the number of individuals found in the stomach and in water samples. In general, counts in the sardine stomach were high at dusk samples and low for samples taken in the middle of the night, and conversely plankton counts from water samples were low at dusk and progressively higher through the night with the highest count at dawn. All scores are relative only to night hours when the commercial sardine fishery operates.

The most common pattern for zooplankton is to migrate deeper in the water column during daytime and ascend towards the surface at night (diel vertical migration) (Ritz *et al*. 2003). The most likely explanation for this behaviour is to escape predators feeding in the upper lit layers during daytime and to exploit the food sources which are most abundant near the surface when it is too dark for successful capture by visual predators (Ritz *et al*. 2003). The data supports previous findings with the total amounts of plankton being successively higher through the night, with highest scores in the morning. To investigate this trend further, 24 hour sampling would have to be undertaken over a number of days.

Sardines are obligate planktivores, feeding either selectively or non selectively (i.e. 'filter feeding'). When zooplankton densities are low, filter feeding is the major feeding mode for sardines, whereas when zooplankton are highly abundant particulate feeding is more important (Van der Lingen 1994). Further, adult sardines, compared to smaller sized individuals, present very reduced gill raker gaps, indicating that adults are more likely to filter feed as opposed to juveniles who are more likely to particulate feed (Molina and Manrique 1997). Feeding periodicity is size dependent with small fish peaking in feeding activity at or around sunset and larger fish feeding continuously throughout the night (Van der Lingen 1998). In general the peak feeding activity of sardines is associated with dawn and dusk when there is enough light to see, whilst still in the semi cover of darkness to avoid predators. At these times sardines school together to feed on the masses of zooplankton congregations. The data supports this statement, with sardines having more items in their stomach early in the night compared to later, with later caught fish either not feeding as much in the previous few hours, or having had time to purge their stomach contents from an early feeding.

In temperate latitudes, Spring is a time of major primary production in marine systems(Ritz et al. 2003). It follows that zooplankton abundance increases at this time too, with many species timing their reproduction to exploit the bloom conditions. Similarly, Spring usually produces a huge increase in abundance of larval stages in the water (Ritz *et al*. 2003), with many species timing their reproduction to exploit available food. Due to the variability in catch times, it is quite difficult to identify any trends in the data with respect to changes across the seasons in the total numbers of invertebrates found. In general total plankton numbers in sardine stomachs were highest in December (51) and decreased in April (24), May (6) and June (7), increasing again by November (38). Of these counts eggs dominated their diet at all sample dates, except for the June sample where total counts were quite low. The next most abundant food item found in sardine stomachs was copepods, with scores in the vicinity of 10 percent of egg counts. In the water samples the total number of plankton was highest in March (60), followed by April (36), May (19), lowest in November (3) and increasing slightly in December (10). Of these total counts, copepods accounted for the majority of the scores, followed by eggs and cladocerans. Of interest is how species composition changed in each sample over time. To further quantify this variability in species composition in sardine stomachs and water samples, it would be necessary to increase the number of samples taken during a night's fishing, each months and across seasons. Similarly, it is unclear whether the observed zooplankton abundance and composition changes between sample dates are an artefact of time of catch or truly represent the month of sampling.

An electivity index provides information on the extent to which the items in the sardine stomach were being selected from the environment and assists in explaining the trends found in the data. In this data set, copepods were more abundant in plankton samples than in sardine stomachs in April and May and relatively similar in November and December. The largely negative electivity indices suggested they were being avoided as a prey item. Cladocerans were more abundant in plankton samples than in sardine stomachs on all sample dates, with the electivity index displaying largely negative values suggesting they were being avoided as a prey item. The group other crustaceans was marginally more abundant in the sardine stomachs relative to the water samples, with the electivity index displaying close to zero or negatives numbers indicating prey were consumed at random on occasion but were largely being avoided. Eggs were more abundant in the sardine stomachs on all occasions, with major differences in the November and December sample with the electivity index displaying largely positive numbers on all sample dates indicating that eggs are being selected for as a food source. In the others group, total numbers were reasonably similar between sardine stomachs and water samples, with the exception of the initial sample date where there was a slightly higher count in the sardine. The electivity index displayed largely negative numbers on all dates except one which was slightly positive indicating that the individuals in the others group were generally not being selected for.

Being avoided refers to the lack of counts in the stomach and the presence of these individuals in the environment. Due to the difficulty in identifying individuals found in the stomach relative to those from water samples, in general counts from copepods and cladocerans would be down from the actual count. For this reason, some scepticism may be shown to the indication that neither copepod nor cladoceran groups are being selected. The groups contained within the other crustaceans and others groups were more readily identifiable in the sardine stomachs, although scores for these groups were quite low. The individuals in the eggs group were readily identifiable in both the sardine stomachs and water samples, so the indication that they are being selected for at every sample date is quite plausible.

A3.5 Conclusion

The major zooplankton groups identified in sardine stomachs were copepods, amphipods, cladocerans, several larval crustacean and molluscan species, a variety of eggs from different species and several other minor unidentified species. There was an array of unquantified phytoplankton present. In general, the numbers of total plankton in the sardine stomachs is highest in December and decreased throughout the year to a low in May and increased again by November. Of these counts, the eggs group dominated the sardine diet with the next most abundant food item being copepods.

The major zooplankton groups identified in water samples in areas where sardines are commercially fished were copepods, amphipods, cladocerans, several larval crustacean and molluscan species, a variety of eggs from different species and several other minor unidentified species. In the water samples the total number of plankton was highest in

March and decreased linearly to the lowest counts in November and increased slightly in December. Of these total counts, copepods accounted for the majority of the scores, followed by eggs and cladocerans.

Copepods were more abundant in the water compared to sardine stomachs in April and May and relatively similar in November and December - avoided as a prey item. Cladocerans were more abundant in the water compared to sardine stomachs on all sample dates - avoided as a prey item. Other crustaceans were marginally more abundant in sardine stomachs relative to the plankton samples suggesting prey were consumed at random on occasion but were largely being avoided. Eggs were more abundant in the sardine stomachs on all occasions, with major differences in the November and December sample - selected for as a prey item. In the others group, total numbers were reasonably similar between sardine stomachs and water samples – generally avoided as a prey item.

Freezing was the most appropriate method for preserving sardine stomachs and was also the easiest method to employ on a commercial vessel.

A3.6 References

See Pg 176