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Workshop on Shark Interactions with Aquaculture

Proceedings of the Shark Interactions with Aquaculture Workshop
and
Discussion Paper on Great White Sharks

Sue Murray-Jones

Australian Government
Fisheries Research and Development Corporation

Department for environment and heritage

Project Number 2002/040
October 2004

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ISBN 07590 1091 9

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I greatly appreciate all the input from everyone who attended this workshop. Every speaker put in a lot of effort and generously gave their time, and I would like to thank them all. In addition, I would particularly like to thank Barry Bruce (CSIRO) for answering so many queries and providing information; Steven Clarke and Anthony Cheshire (SARDI), and Patrick Hone (FRDC), for assistance and ideas; my own Department (SA Environment and Heritage) for their support; Kate Perkins (Kulu Pty Ltd) for moderating the workshop; Fiona vom Berg (now CALM, WA) for writing the initial draft of the discussion paper, with input from Beth Hammond; Joy McKechnie for assisting on the day and for the horrible task of transcribing the workshop tapes; Carina Cartwright, Helen Croft and Brett Chalmers (PIRSA) for information; Mary Lavelle, DEH for map preparation; John Garvey, AFMA, for data and discussions; Emily Downes of the Finfish Aquaculture CRC, for helping so much with everything; and of course the FRDC for funding the project in the first place.

ACRONYMS

AFFA	Department of Agriculture, Fisheries and Forestry, Australia
AFMA	Australian Fisheries Management Authority
AMCS	Australian Marine Conservation Society
CALM	Department for Conservation and Land Management (WA)
CITES	Convention on International Trade in Endangered Species of Flora and Fauna
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEH	Department for Environment and Heritage (SA)
DPIWE	Department for Primary Industries, Water and the Environment (Tasmania)
EA	Environment Australia (now Commonwealth Dept. of Environment and Heritage)
EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
FAO	Food and Agriculture Organisation, United Nations
FRDC	Fisheries Research and Development Corporation
GAB	Great Australian Bight
IUCN	International Union for the Conservation of Nature
MCCN	Marine and Coastal Community Network
MSF	Marine Scale Fishery
PIRSA	Department for Primary Industries and Resources SA
SARDI	South Australian Research and Development Institute
SBT	Southern Bluefin Tuna
SSF	Southern Shark Fishery
TBOA	Tuna Boat Owners' Association
WSF	Western Shark Fishery
YTK	Yellowtail Kingfish

NON-TECHNICAL SUMMARY

2002/040 Workshop on Shark Interactions with Aquaculture

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Shark Interactions with Aquaculture Workshop

The workshop generated great interest. Numbers were theoretically capped at 50, but over 60 people attended. Speakers from the tuna and yellowtail kingfish aquaculture industry gave their perspectives and experience; researchers gave data on white sharks; and various industry speakers outlined technological solutions. This was followed by small group discussions.

Industry speakers gave details on farm issues for the tuna and yellowtail kingfish aquaculture industries respectively. The main shark interactions for the tuna industry occur in the towing phase and involve mainly bronze whaler sharks and makos, while whalers are a bigger problem for the yellowtail kingfish industry. Industry regards seal/sea lion interactions as a bigger problem than sharks. While white shark interactions are rare, they generate much publicity, and are more difficult to handle because of the protected status of the sharks. Data collected by the kingfish industry suggest patterns in the movements of bronze whalers. The maximum times of interactions in Arno Bay are when the sharks are returning from pupping grounds between March and June. This is a critical period for the kingfish industry; consequently, this period has the highest loss of fish due directly to sharks. There is also a problem with kingfish escaping from cages via the holes created by the sharks. Data on shark numbers and location are recorded using the ISO 14001 management system. Two local commercial fishers then use these data to target and catch sharks at times of increased attacks. This is an issue, given current concerns about the population status of bronze and dusky whalers.

Barry Bruce, CSIRO, outlined what is known about white sharks. He described movement patterns, frequency and duration of visits, and variability in distribution and movements in coastal waters. They are highly mobile, and move to take advantage of different prey. White sharks appear to follow movement pathways, and their behaviour can vary between areas and between sites. While aquaculture operators perceive more problems in winter, the data suggest that there are changes from year to year, and that it is not always true that white sharks are more present in winter. Identifying activities that attract sharks, along with areas more prone to interactions, will enable strategies to be developed to reduce interactions.

The successful release of a white shark from the SARDI research tuna cage was described, including observations on behaviour as well as the methods that were trialled to release the shark.

A representative of the Tuna Boat Owners' Association spoke on effective farm management. The tuna industry has already implemented a number of changes to their operations to minimise interactions. Interactions are most likely with towing cages, and makos and bronze whalers are the species they have most have trouble with. The industry has been through a developmental phase in terms of animal husbandry to reduce the number of mortalities.

Presentations on technological fixes included developments with Shark Shield technology and the use of rigid steel cages. Both technologies have great potential, but also have drawbacks. Both are already being used with success in some sectors and for some applications. Further development needs to be in conjunction with industry partners.

After the presentations by keynote speakers, the workshop participants split into small groups to discuss ideas, information, solutions and research needs. There were some key points for which there was general agreement. These included the following:

- Aquaculture cages do not appear to be attracting sharks to the region.
- Both sharks and pinnipeds (seals and sea lions) can be a problem.
- The main factor triggering attacks is the presence of freshly dead fish in cages - this is a farm husbandry issue.
- We need more information about patterns of shark movements, behaviour, survivorship, and population status for white sharks and bronze whalers.
- We need better records to determine the scale of the problem.
- There is an urgent need for best practice guidelines.
- Interactions with bronze whalers are more frequent than white sharks. Interactions with both species vary with site, season, and operator.

After the workshop, but prior to the completion of this document, two white sharks entered tuna cages near Port Lincoln. Both were successfully released. This is a wonderful outcome, and industry should be congratulated. I believe this result is, in part, due to an increased awareness of the need for conservation of white sharks. I have included a detailed description of the release in Appendix 1 at the end of this report, with the intention of making sure that this successful release method is disseminated as widely as possible.

Discussion Paper on Great White Sharks

The life history characteristics of white sharks (slow growth, delayed maturation, long reproductive cycle, low fecundity and long life span) make this species particularly vulnerable to overfishing. Genetic data suggest that females do not disperse as widely as males. White sharks appear to show some degree of site fidelity, hence are highly vulnerable to over-exploitation or local eradication. The loss of even a few white sharks could have impacts on genetic diversity and local populations. While protected in all states, and federally, there is still considerable mortality of white sharks in southern Australia.

White sharks vary greatly in distribution and behaviour. Segregation by size and by sex is common. White sharks appear to have an age/size preference for certain foods, with juvenile white sharks preferring fish, particularly snapper. As they increase in size, their diet expands to include other sharks, rays, marine reptiles, sea birds and marine mammals. Some larger white sharks may also continue to prey on finfish (e.g. snapper). In general, seals and sea lions appear to be the preferred prey for adult white sharks.

There are some common themes in the number of sharks taken as bycatch. Variability in sightings is high, as is variability in catches, both spatially and temporally. For some reason, this variability is particularly high in the Great Australian Bight. Such differences are possibly due to variations in currents and/or availability of prey species. No data are available on survivorship after entanglement.

Most data highlight a decline in the number of white sharks in Australia over the past 50 years. The greatest risk is from commercial fishing; however, reductions in effort and changes to gear in many fisheries have acted to reduce the number of white sharks caught as bycatch, and also to lessen mortality.

White sharks are sometimes captured in tuna tow and farm cages. Unsubstantiated reports suggest that there may be as many as 10-20 interactions per year; however, records are sparse and often unobtainable. This is an issue that needs to be addressed.

OBJECTIVES

1. To develop a discussion paper to summarise information about interactions between human activities and marine animals in temperate waters and to determine the key issues affecting large marine vertebrates.
2. To hold a workshop to scope effective methods, techniques and technologies to prevent or minimise problems with marine animals in the key areas identified in the discussion paper.

BACKGROUND

As there were considerable concerns in South Australia about interactions with sharks and finfish cages, plus there was considerable interest generated by SARDI's success in freeing a great white shark from an aquaculture cage. Hence it was decided to hold the workshop on the topic of shark interactions with aquaculture. The workshop was piggybacked onto the annual conference of the CRC for Finfish Aquaculture, held in Adelaide in November 2003. The workshop had the aims of developing strategies to reduce shark interactions with finfish farms, and to prevent mortality to trapped animals. For various reasons, not all sections of the original discussion paper and risk assessment were completed. The portion of the discussion paper summarising information on threats and mortality of great white sharks has been included at the end of this document.

NEED

The original proposal took a two-stage approach to the problem of interactions with protected large marine vertebrates due to human use of the environment. The original proposal was entitled "Large Marine Vertebrates due to Human Use of the Marine Environment", and the original needs were:

1. The preparation of a comprehensive discussion paper to outline the key issues. The discussion paper will identify the most important causes of marine animal interactions in South Australia.
2. Based on the conclusions of the discussion paper, a workshop will be held to focus specifically on solutions to the key issues identified. Discussion will centre on avoiding harmful interactions with these species, and/or minimising impacts. This workshop is intended to be very solutions-oriented. To achieve this, the discussion groups need to be small and very tightly focussed.

The decision to narrow the focus of the project was due to a perceived need for some action on the issue of shark interactions with aquaculture; the fact that other groups of animals had become the focus of research efforts elsewhere; and the inability of other agencies represented on the steering committee to complete the components of the discussion paper originally agreed to. Hence the decision was made to hold the workshop on shark interactions with aquaculture in southern Australia, and to confine the discussion paper to species of relevance to aquaculture. This turned out to be mainly white sharks and bronze whalers. As whalers are the focus of a current review of the fishery status for whaler sharks in South Australian and adjacent waters (FRDC 2004/067), it was decided to restrict the focus of the discussion paper to white sharks.

PART 1: SHARK INTERACTIONS WITH AQUACULTURE WORKSHOP

WORKSHOP PROGRAM

The workshop was held on Wednesday 29th October 2003; 1-5 pm at West Lakes Shores, Adelaide, in conjuction with the CRC for Finfish Aquaculture Conference.

Introductory Remarks: Will Zacharin, PIRSA Fisheries

- outline of the problem
- issues in South Australia
- SA policy
- allowed methods for dealing with sharks (protected species, other species)

Farm Issues

Tuna Industry: Brian Jeffries, Tuna Boat Owners' Association. Summary of Information on Shark Interactions

- effect on farm operations - general
- lost production, stress to fish
- disruption of operations
- occupation health and safety
- dealing with media
- types of sharks, seasonality, frequency of interaction
- type and place of interaction (grow out pens; transport pens from the Bight)
- cause of interaction if known
- methods of handling to date

Yellowtail Kingfish Industry: Stephen Bedford-Clarke, General Manager, Clean Seas Aquaculture. Summary of Information on Shark Interactions

- types of sharks, seasonality, frequency of interaction
- type and place of interaction
- cause of interaction if known
- methods of handling to date

Getting In and Getting Out

State of knowledge on Great White Sharks: Barry Bruce, Research Scientist, CSIRO

- movement patterns of white sharks (general overview and state of knowledge in southern Australia)
- frequency and duration of visits by white sharks to specific sites
- interannual variability in distribution and movements in coastal waters - what do white sharks cue their movements to?
- available technology for tracking and monitoring movements of sharks - relevance to the aquaculture industry
- current and proposed research on shark movement patterns

One Success Story: Kate Rodda, SARDI Aquatic Sciences

- case history of release of shark from SARDI small tuna cage

Tea break

Keeping Them Out

Effective Farm Management: David Ellis, Tuna Boat Owners' Association

- solutions already used - effective and otherwise
- what industry does now to minimise risk and address interactions

Technological fixes
(a) Shark Shield ™ Technology. Michael Wescombe-Down, SeaChange Technology
(b) Rigid cages - Scott Hawkins, One Steel

Small group discussions

- discuss guidelines for best farm practice
- stopping &/or managing interactions

General discussion

- synthesis of small group ideas
- where do we go from here
- further research needs

Closing Comments Jon Presser, PIRSA

- summary of key points

Editor's note: I have attempted to meld the transcript tapes with the slide presentations of speakers. Hence this document is a compilation of workshop notes, rather than a formal proceedings, and it has not been peer-reviewed other than the FRDC's review process. All authors have checked their transcripts to ensure accuracy in the transcription process (with the exception of Stephen Bedford-Clarke, who has moved interstate and was not contactable). All graphics in Part 1 are taken from the speakers' PowerPoint presentations.

INTRODUCTORY REMARKS: WILL ZACHARIN

PIRSA Fisheries

- Conference is looking at shark interactions with aquaculture.

AIMS

- Identify some key research directions to improve the management of shark interactions.
- Formulation of best practice guidelines for managing shark interactions in the aquaculture industry. Specifically we need to avoid attracting the sharks in the first place, and then decide how to effectively deal with interactions when they occur.
- Improve our capacity to manage interactions.

BACKGROUND

- White sharks are a protected species under State and Federal legislation - significant fines are imposed for those caught killing them.
- Efforts are made by several commercial fishermen to remove sharks without harm when they get caught in the pens; however, this is not always possible. In the past four years, two white sharks that were trapped in pens had to be destroyed, after exemptions from the Fisheries Act were granted.
- There are strong controls over the shark tourism operators that burley the water (mainly around the Neptune Islands) to attract sharks - it is believed that these operators are not influencing the number of interactions with the aquaculture operators.
- In relation to the destruction of any sharks in SA - PIRSA will only provide exemptions to the Fisheries Act for authorised officers, and then only when someone is in immediate danger.
- The successful release of a white shark from SARDI's research tuna pen illustrates that white sharks can be successfully released without serious harm to the shark or anyone else. This marks the beginning of a new wave of thinking about dealing with large sharks in aquaculture pens, using innovative designs.

FARM ISSUES

(Note: questions held until end of Farm Issues section)

Tuna Industry: Brian Jeffries

Summary of Information on Shark Interactions, Tuna Boat Owners' Association

- From the perspective of the commercial tuna farmers, the issue of shark/tuna farm interactions is an issue of legal protection of the species, the occupational health and safety (OH&S) of staff, and one of balance.

SHARK INTERACTIONS

- The Tuna Boat Owners' Association (TBOA) feels that the level of shark interaction is very limited - a fact confirmed by an independent report (Observer Report, *Rainbow Warrior*, contained in a letter from Greenpeace to TBOA, 16 January 1998).
- Out of the 12 operational farms for Southern Bluefin Tuna (SBT), there are only 1-2 farms that have even limited problems with interactions.
- Interactions are mainly on the tow with makos, not many involving great whites or bronze whalers.
- The interactions with white sharks and bronze whalers tend to be restricted to:
  a) Specific areas and individual farms;
  b) Particular stages in the grow-out cycle - particularly the transfer of the fish from the towing pontoon to the farm pontoon;
  c) Seasonal patterns - white sharks are more abundant during the winter months.

TUNA FARM PARAMETERS

- 150 pontoons (40 m diameter x 16 m depth) around Port Lincoln
- Pontoons are concentrated east of Boston Island (c. 17 km from Dangerous Reef)
- 260,000 SBT are captured in December/March each year in the Great Australian Bight
- There are 38 tows in 40-50 m diameter tow pontoons (with c. 7,000 fish/tow)
- The average tow duration is 17 days (at one knot); average tow mortality is 0.3%
- Marketing: March/August (concentrated July/August)
- Harvesting/shipment includes five freezer boats
- Fish capture weight averages 20 kg

GVP/JOBS

- Gross Value of Production (GVP) exports were worth about $200m in 2003
- About 2,600 jobs are generated in Port Lincoln by this industry
- There is a large research program - Environmental Monitoring Programs, nutrition, fish health, quality
- There may be up to $2.5million worth of SBT in a single pontoon, a factor that must be considered in any interaction

IMPACT OF THESE INTERACTIONS ON TUNA FARMING

- The loss of production as a result of shark attacks is less than 50 fish per annum
- The main cost is probably associated with the increased level of stress to the tuna from these predator attacks. It is important to note that the stress associated with sharks is a comparatively smaller problem than stress from seals and sea lions (which were previously a more common problem around tuna pens).

THE REASON FOR THESE INTERACTIONS - TUNA FARMERS' VIEW

- Sharks are attracted by:
  a) Dead fish left in the pens;
  b) Effluent from the freezer boats associated with fish harvesting.
- Tuna farms themselves do not attract sharks to the region, but inadequate animal husbandry of the tuna leads to increased mortality, which may increase the possibility of interactions with sharks (see Barry Bruce, CSIRO, "*Advertiser*", 8/7/98).

HARVESTING PRACTICES TO MINIMISE/PREVENT INTERACTIONS

Mortality Clearance

- Recovery of dead tuna is fundamental to the problem of sharks - if you do not recover the dead fish you are asking for a problem.

Improving Animal Husbandry

- There has been a general improvement in animal husbandry over the past 10 years. Consequently the total mortality of tuna throughout the tuna farming process is only 2% (a long way below any other fish (or tuna) farming in the world). This is because:
  a) The fish are captured at 20 kg; hence they are strong, robust fish (toughened up in the wild).
  b) We use low stocking densities to reduce stress on fish (i.e. around 2-5 kg/m^3 water in the pontoon, compared with salmon at around 20 kg/m^3).
- Also note that tuna pontoons only have fish in them from 3-6 months in a 12-month production cycle.

Freezer Boat Effluent

- There are strict EPA regulations regarding wastewater from the freezer boats. There should be no wastewater at all. Concerns over the possibility of these boats attracting sharks have been checked out by the EPA.

Improvements

- Improvements include:
  1. Towing the cages at a slower speed;
  2. Increasing the quality of nets - to reduce the chances of sharks getting in;
  3. Relocating the pens - some farms have been moved to locations with a lower frequency of shark interaction;
  4. Major improvements are changes in tow speed and net quality; using bags at the rear of tow nets; and using different tow patterns (i.e.off shelf) [See 2003 AFMA Observer Report for SBT Fishery].

MANAGING INTERACTIONS

- At present the release of trapped sharks is a limited option, realistically.
- Need more research to formulate a method in which human safety is maintained, as well as the health and well being of the shark, and of the tuna (including their commercial value).
- Ideally this method should avoid human entry into the water.

HISTORICAL PERSPECTIVE OF THE TUNA INDUSTRY: IMPACT ON PROBLEM SOLVING

- The tuna industry is a relatively new one (five years old in the commercial sense and 12 years old in the experimental sense).
- The tuna farmers were initially from the 'old school' in which animal husbandry, ethics and protection were not considered an important part of tuna farming.
- However, there has been a huge transition in the way that tuna farmers think - with a shift towards more effective animal husbandry to reduce mortality.
- TBOA and the Australian Seafood Industry Council led the push to protect white sharks, against strong industry and community opposition.
- The industry is now more willing to work with governing bodies to improve the industry.
- The TBOA has an over-riding commitment to avoid interactions. Interactions are bad conservation, bad business and bad ethics.

OH&S ISSUES

- One of the biggest issues surrounding shark interactions is that of the OH&S of the farmers/divers working in and around the cages.
- Since tuna farming commenced in 1991, there have been no shark attacks associated with tuna aquaculture. Prior to 1991 there were numerous interactions with sharks, including one fatality.
- The TBOA is committed to improving its OH&S status by improving pontoon activity for divers and the harvesting processes.

EXPANSION OF SEAL COLONIES AND SHARKS

- The TBOA expresses its concern about the expansion of the fur seal population (15% per annum) and the effect of this in attracting sharks to regional areas such as Port Lincoln.
- There is now a population of seals as close as Donington - which is quite close to the farms and human activity.
- According to the 'Great White Recovery Plan' of 2002 (EA 2002), white sharks are directly associated with seal colonies. This is a significant issue that the TBOA and the community must deal with it. This worries the TBOA most of all.

SUMMARY

- The tuna farmers have an overriding commitment to minimising/avoiding these interactions with sharks because it means good business, good conservation and good ethics.
- Tuna farms do not attract sharks to a region, but inadequate husbandry attracts those in the region to certain farms
- The TBOA is committed to conservation - a fact shown by its active role in the protection of white sharks (although this was against community opinion at the time).
- The TBOA is committed to OH&S - and will not compromise on human safety.
- The TBOA welcomes expert advice in solving even limited interactions, both in terms of prevention and how to deal with trapped sharks.

Yellowtail Kingfish Industry: Stephen Bedford-Clarke

General Manager, Clean Seas Aquaculture. Summary of Information on Shark Interactions

- The purpose of this presentation is to relay the observations made by the farmers about shark interactions with yellowtail kingfish (YTK) and mulloway aquaculture.
- The YTK farms are located at Arno Bay, about half way up Spencer Gulf. The location of these farms may have an impact on the shark species encountered and their behaviour.

AQUACULTURE OPERATION

- Clean Seas Aquaculture (a subsidiary of the Stehr Group) has operated sea cages at Arno Bay for two years.
- The principle business focus is the production of YTK and mulloway via spawning, larval rearing and grow-out of fingerlings in sea cages.
- There are currently 11 YTK cages and 8 mulloway cages (all 25 m in diameter).
- This will be expanding to 32 cages in 2004.
- The Stehr Group is currently applying to have the zoning of these cages changed so that the cages can be spread further across the bay. This may have some important implications for health management of the fish and the level of shark interactions with these operations.
- There is a full time dive team operating on the fish cages on a daily basis (weather permitting).

Figure 1. Location of Arno Bay, South Australia.

OBSERVATIONS OF SHARK INTERACTIONS

- The number one problem in terms of interactions is bronze whalers.
- White shark interactions only tend to occur during the winter months.
- White sharks are typically solitary animals.
- There have only been two reported incidents of white sharks in the cages. The first of these was not actually seen but was assumed to be there because of the presence of an entry and exit hole in the cage (which you don't tend to get with bronze whalers).
- Bronze whalers tend to operate in packs of between 4-14 fish.
- The sharks typically break through the bottom of the nets, although occasionally they have been observed to break through the sidewall.
- In most cases divers find sharks alive in the cage, and generally they are killed instantly, because it is too much of a risk to the divers to have these sharks in the cages.
- A fallacy is that bronze whalers will eat old, dead fish. There was a situation in one of the cages when several thousand dead fish had accumulated at the bottom; however, there were no shark attacks on this cage. Bronze whalers prefer fresh produce.
- In contrast, it has been observed that a single fresh mortality is enough to attract a bronze whaler to break through the bottom of the cage (even when the cage has been cleaned the night before).
- One of the problems associated with Arno Bay is that is quite exposed and weather conditions can sometimes prevent the dive team from cleaning the mortalities from the cages for several days. This presents a problem as the morts attract the sharks.

CAUSE OF INTERACTIONS

- There is only one cause and this is fish deaths in cages.

BRONZE WHALER SHARK MOVEMENTS

- Bronze whalers work their way up the coastline to Franklin Harbour, Cowell, in October-December, where they pup (see Fig. 2).
- During March to June, the sharks move back down the coast - during this phase they are typically hungry after giving birth.
- This period from March to June is a critical period for the aquaculture industry; consequently, this period has the highest loss of fish due directly to sharks. There is also a problem with fish escaping from the cages via the holes created by the sharks.

PREVENTATIVE ACTIONS

Reducing Shark Numbers

- Data on shark numbers and location are recorded using the ISO 14001 management system. This incorporates a daily dive sheet.
- These data are then used by two local commercial fishers to target and catch sharks at times of increased frequency and attacks (generally from March to June). This reduces the number of bronze whalers in the area.

Steel Mesh Cages

- The Stehr Group is the first to trial the steel mesh cages (in conjunction with OneSteel).
- This R&D trial will run over three years (from June 2003) and investigate the operational costs, impacts and life of the material in the water.
- Presently the use of steel cages is three times more expensive than nylon nets, which is a huge issue for YTK aquaculture, which is still a fledgling industry.

- There is still a need to assess the effect of this new technology on the fish and other organisms in surrounding ecosystems.
- Also need to assess the corrosive nature of the material.

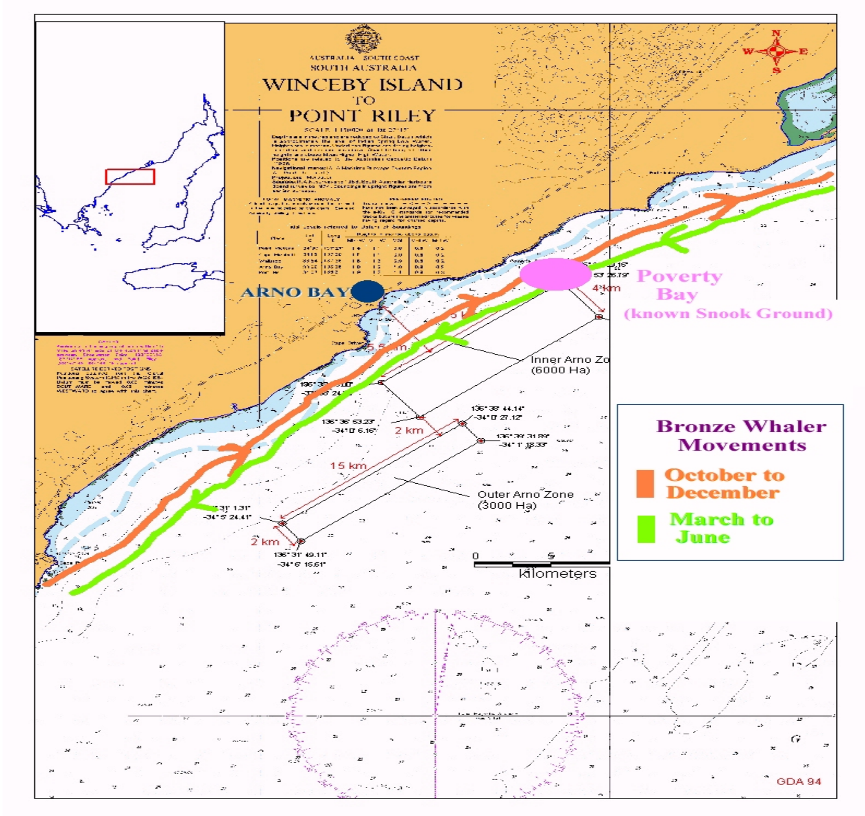

Figure 2. Bronze whaler movements.
Arrows show direction of movement at different times of year. Rectangles are Aquaculture Zones.

Interactions and Mulloway Cages

- An interesting observation made of mulloway cages is that over the past two years there has never been a shark attack on any of them. Divers have observed bronze whalers outside the mulloway cages but they do not attempt to break into the cages. The speaker proposes that this may be explained by the following:
  1. There is a lower incident of mortality in mulloway cages (due to lower number of parasites associated with the fish) as opposed to the yellowfin kingfish cages;
  2. The mulloway tend to sit in a ball at the bottom of the cages (more a benthic fish) where as the YTK school at the top of the cage and are more active - which may preferentially attract the sharks;
  3. There is a very pungent smell associated with mulloway. There might be something in the slime on the fish that deters the sharks.

Research in any one of these areas might uncover a novel approach to reducing the attractiveness of the cages to sharks, hence minimising interactions.

Recommendation

- Currently there is a lack of information regarding the behaviour of these sharks. Hence it is suggested that further research be conducted in the hope that a greater level of understanding of shark behaviour will allow us to deal with the problem of interactions.

Questions for Farm Issues Speakers

(S = Statement, Q = Question, A = Answer)

Kate Rodda (SARDI Aquatic Sciences)
S) The Stehr group is suggesting that dead fish in the cages may be the only factor attracting sharks. Considering that the sharks do not respond to the mulloway cages in the same way as tuna and YTK, there may be scope to investigate this anomaly.

Jon Presser (PIRSA)
Q) How are the bronze whalers destroyed? Does this pose a safety problem?
Stephen Bedford Clarke (Stehr Group)
A) The divers take a powerhead into the cages - they are licensed to do this. The unpredictable nature of the sharks, and the fact that an entry hole is not always noticed, means that the divers do not know what they are going to encounter. Yes, it is an OH&S issue, and one that probably needs to be addressed.

Lindsay Best (DEH)
Q/S) How much mortality can these populations of sharks stand? How robust are the bronze whaler and white shark populations? Where is this mortality coming from? A general statement that we are making is that there is a lot about the general biology of these sharks that we do not understand. What is the relative mortality from other industries compared to aquaculture?
A) No answer given.

Jon Presser (PIRSA)
S) There seems to be an increase in fishing effort on bronze whalers from local fishers.

Keith Jones (SARDI Aquatic Sciences)
S) Following on from Jon's comment, there are indications that the bronze whaler catch and number of days fished by commercial fishers has gone up significantly in Spencer Gulf in the last two years.

Brian Jeffriess (TBOA)
S) Lindsay's question is fundamental. One of the fundamental issues is the population status of the sharks.

Patrick Hone (Aquafin CRC)
S) A population study will give you an indication about where you are in the balance and answer questions about what is the most appropriate catch level.

Lindsay Best (DEH)
S) The management of fish mortality and farm husbandry is clearly an important issue (and common to both speakers so far).

Paul Hastings (AMCS)
Q) Stephen Bedford-Clarke mentioned using a preventative method, namely the use of commercial shark fisherman to remove bronze whalers from the waters surrounding the cages. What effect is this going to have? Based on the lack of information (discussed in the previous questions/statements) surely this should be conducted in a conservative manner. What other preventative methods are being used? What impact will an expansion in the number and area of cages have?

Stephen Bedford-Clarke (Stehr Group)
A) Yes, we are using other preventative methods. There are three other methods that are being trial and developed:

- Steel cages (which will be discussed later).
- Predator nets - which have been useful in reducing sea lion interactions but create problems for dolphins.
- Farm management and husbandry - such as removing mortalities from the cages. But it is important to note that ultimately there are times when you cannot get out to the cages, especially in poor weather, and you can't be out there 24 hours a day - hence you cannot maintain a 100% mortality clearance all the time. To make up for this we are continually looking for new technologies to overcome this.

Will Zacharin (PIRSA)
S) It is PIRSA's understanding that we do not know what the current stock status of sharks is, hence it is suggested that research be conducted in this area.

Paul Hastings
S) This needs to be addressed.

Patrick Hone (Aquafin CRC)
S) There has been a FRDC application from Keith (*Keith Jones, SARDI*) for this year's round, addressing the issue of stock status of whalers for the whole fishery.

Lindsay Best (DEH)
Q) What is the size range of the bronze whalers that get into the cages?

Stephen Bedford-Clarke (Stehr Group)
A) Animals between 2 ft - 8 ft get in. There is no specific size, bronze whalers hunt in schools of mixed sizes.

Brain Jeffriess (TBOA)
S) The problem is that these sharks hunt in packs. When nets are closer to the bottom, sharks don't come up under the cages. With respect to predator nets and dolphins, expert advice really helped i.e. TBOA operators were able to get rid of predator nets when we moved into higher exposure areas.

GETTING IN AND GETTING OUT

State of Knowledge on Great White Sharks: Barry Bruce

Research Scientist, CSIRO

OVERVIEW

- I will discuss white shark movement patterns in the coastal waters of southern Australia, particularly in terms of frequency and duration of visits and how this can change from year to year and from season to season.
- Both Brian and Stephen both mentioned that white sharks are more prevalent in the winter months in SA, but we also see changes from year to year. These may increase or decrease the chances of encounters with these sharks.
- I will also show you some of the technology used to track and monitor shark activity.

TAGGING

- The majority of the information that has been collected comes from tagging data.
- Tags are quite easily applied from the surface. We do not need to get in the water to apply them, white sharks are fairly bold and will come up to the boat.
- There have been a total of 220 white sharks tagged (with various sorts of tags). Many of these were tagged here in South Australia.
- A lot of them are just standard ID tags, of which there have been 11 tag re-captures, ranging from 1 day to 10 years at liberty.
- More recently there has been an increase in the use of electronic tags. These can monitor where the sharks go and what they do. This gives us a lot more information than the point-to-point capture typical of the standard ID tags.

Findings from the Tagging Work

- Most of the captures have been relatively close to where the sharks were tagged. Eight of the captured sharks were caught between 1 and 220 km from the point of tagging; however, three sharks were captured between 600 and 3,800 km from the point of tagging.
- Two of these sharks, tagged in SA, were captured outside SA waters. One was recaptured in New Zealand, the other on the North West Shelf, WA (see Fig. 3). These particular animals were seen regularly at Neptune Island (where they were tagged) and this suggests that white sharks can range far further than simple resighting data suggest.

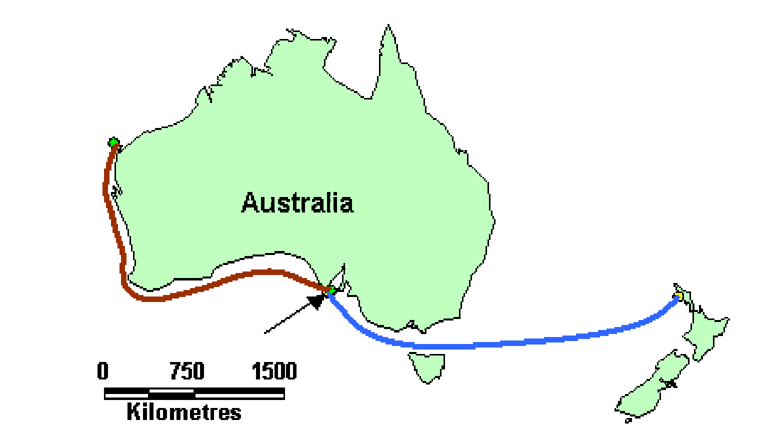

Figure 3. Distances moved by two tagged and recaptured white sharks. ~~Both tagged initially in SA (arrow).~~

MONITORING WORK

- There has also been monitoring of shark behaviour at three different reef systems in South Australia (Dangerous Reef, North Neptune Is and South Neptune Is). These are all seal colony sites (*Editor's note: throughout the presentation, Barry has referred in general to "seal colony sites," however, it may be important to note that the colonies at North and South Neptune Islands are predominantly New Zealand fur seals, which have breeding sites there, while Australian sea lions have breeding sites at Dangerous Reef. There are no breeding sites for NZ Fur seals at Dangerous Reef, and no breeding sites for sea lions at the Neptune Is. This could be important given the different reproductive cycles of seals and sea lions. New Zealand fur seals have an annual breeding cycle, while Australian sea lions pup on an 18 month cycle.*)
- This monitoring program incorporates listening/monitoring devices on the seabed that listen to and record acoustic tags.
- Long life acoustic tags identify each individual shark (see Fig 4). The tags transmit a unique ID code approximately every minute. This code is recorded by listening stations moored on the bottom at study sites. Listening stations record when a tagged shark arrives at a site, the length of time it stays, and when it leaves - this type of data can give insight into the daily patterns of white shark activity, and the frequency at which individuals revisit particular localities.
- The tags last for about two years, and there are currently 30 sharks that have these acoustic tags fitted.
- Listening station arrays (each with three separate stations) have been deployed at three reef systems since April 2001 - North Neptune Island, South Neptune Island and Dangerous Reef (Fig. 5). Unless otherwise stated, the data described below refer to findings at North Neptune Island.

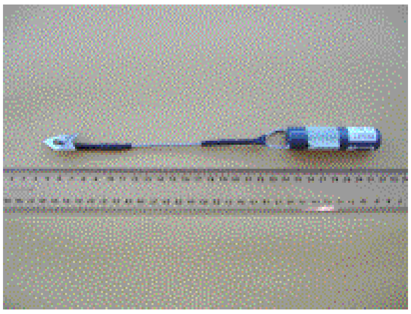

Figure 4. Acoustic tag

Findings of the Acoustic Monitoring Work

- Two listening stations at North Neptune are located inside a small bay where the majority of seals are located, and the other is located approximately 1 km away, outside of the bay on the northern side of the island. We have observed interesting differences between the patterns of listening station records inside and outside the bay at North Neptune, despite their close proximity.

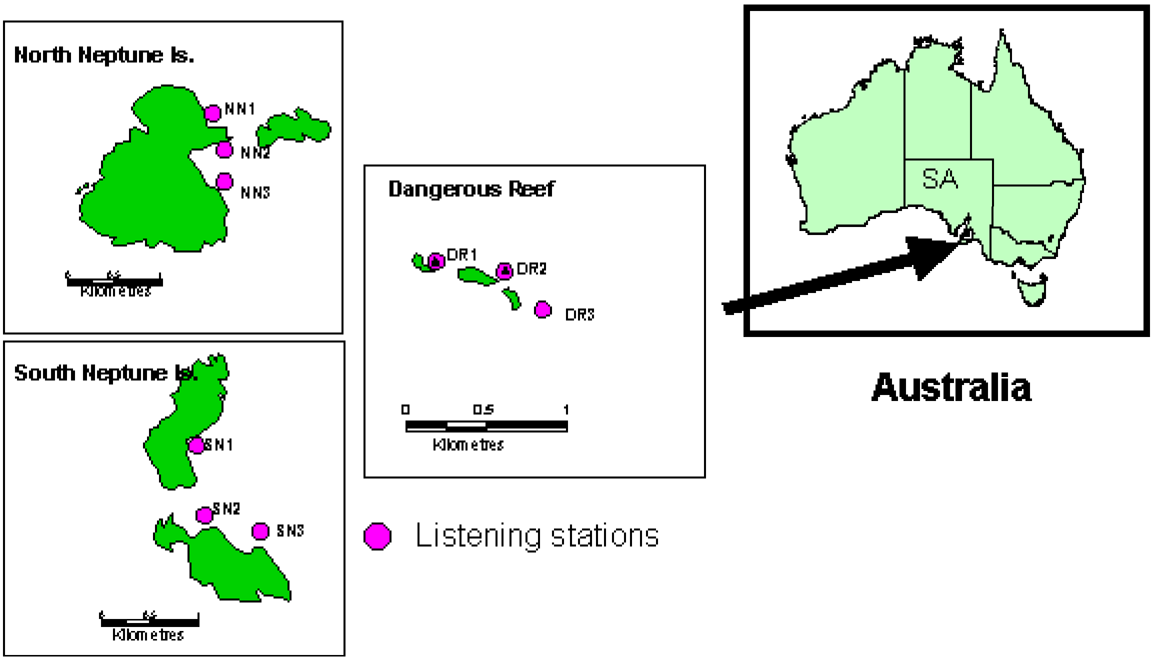

Figure 5. Map of locations of acoustic listening stations for white sharks in SA.

Diurnal Patterns at North Neptune Island

- Inside the bay (where the seal colony is situated), the sharks display a clear diurnal pattern - sharks are more active during the middle of the day (see Fig. 6)
- Outside the bay, the sharks display a more even pattern across the day (Fig. 6).
- Individual sharks can display different behaviours - one shark may peak in its activity at one time and another shark at a slightly different time of the day (see Fig. 7).

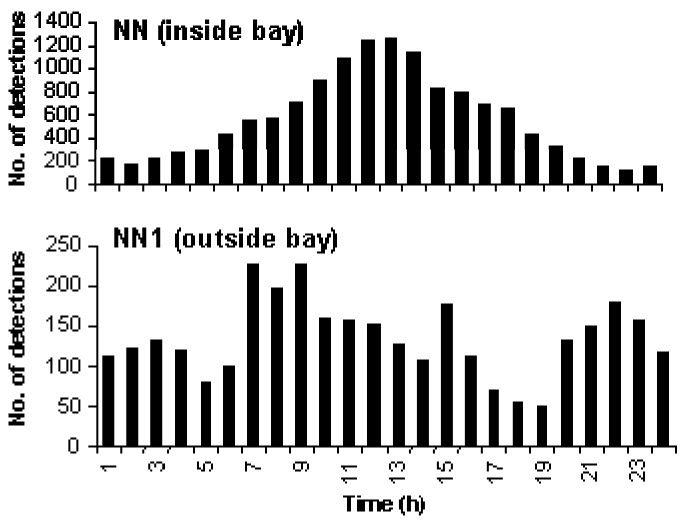

Figure 6. Daily detections, all tagged sharks, N Neptune I (Apr 2001- Sept 2003)

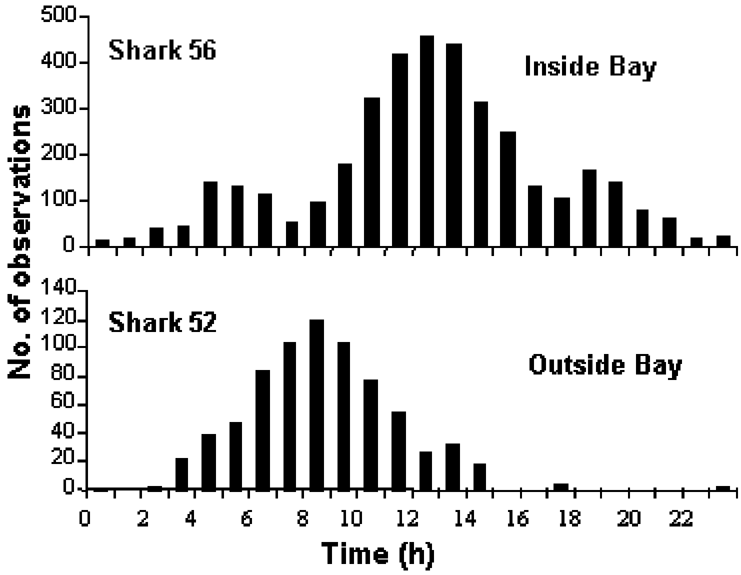

Figure 7. Variability in activity between individual sharks.
Different individuals may show different patterns in the timing of their visits to a site. Data are all records combined for sharks no. 56 and 52 between April 2001 and September 2003.

Duration of Visit Patterns

- From the aquaculture farmers' perspective, one of the important things to know is how long a shark will stay in an area.
- For the listening station data set we have defined the duration of visits as the number of consecutive days over which a shark was detected.
- In general, the sharks' visits were fairly short in duration - a few days; however, there are exceptions to this, with some sharks staying for up to 19-20 consecutive days.
- Some sharks were also observed to display a pattern of intermittent residency, often making multiple visits during a period of residency - they come and go, spend a few days at the site, disappear for a few days, come back and disappear to somewhere else.
- This has also been observed in other species of sharks.
- The average period of residency was 36 days, but can be up to 90 days - coming and going.
- There was no evidence that any individuals were permanent residents of these sites (see Fig. 8). Instead, patterns of site residency for a shorter period of time are observed, during which the sharks are coming and going, and after which they move off to somewhere else.

Seasonal Patterns

- Sharks also show interesting patterns in terms of predictable seasonal visits (see Fig. 9).
- For example Shark 36 was first tagged on 5th September 2001 and was recorded until 18th November 2001 (70 days). It then disappeared from the listening station record and was not heard until the 4th September 2002 (within a day of when it was tagged in the previous year), and was recorded until 2nd November 2002 (Fig. 9).

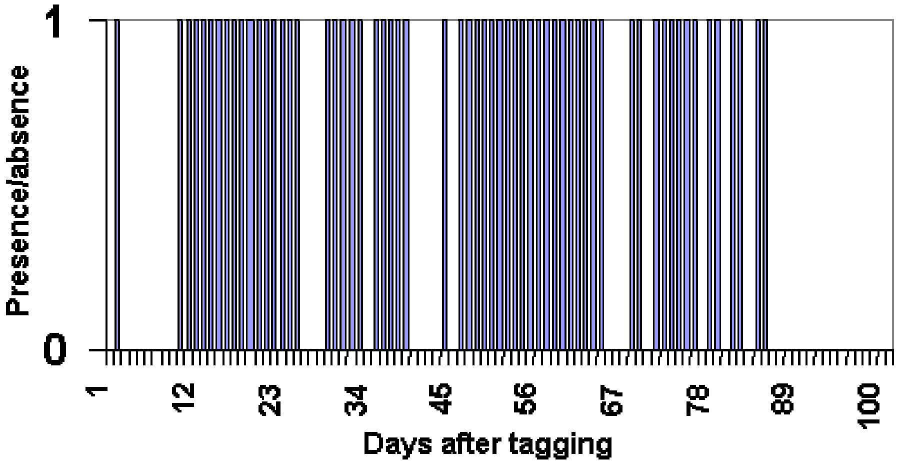

Figure 8. Site residency at North Neptune I.
Multiple visits made by one shark during an 86 day residency period in 2002. Gaps indicate days when the shark was not detected at the site.

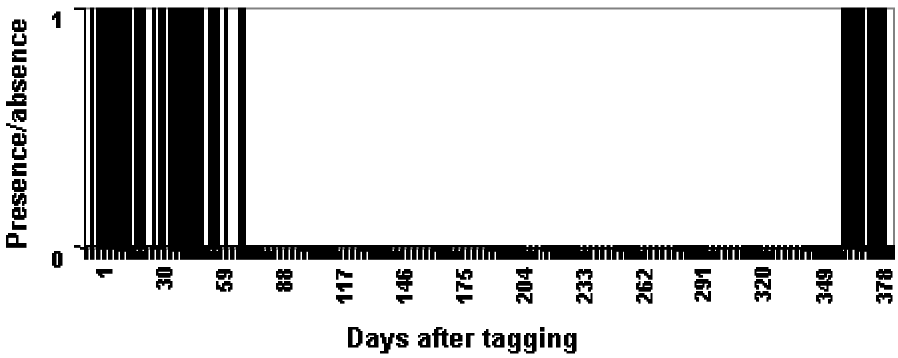

Figure 9. Predictable seasonal visits.
Listening station record for Shark 36. This shark was recorded at North Neptune I from 5/09/01 to 18/11/01, and from 4/09/02 to 2/11/02. Other sharks have shown similar patterns of predictable season visits e.g. Shark 48 (4/04/01 - 29/6/01 and 23/04/02 - 6/06/02).

Multiple Shark Movement Patterns

- Sharks can occur in an area *en mass* - multiple numbers of sharks in the same area.
- There is also evidence to suggest that there are events when sharks leave at the same time e.g. six sharks disappeared from North Neptune Island over a period of two days and did not return for another four or five months (see Fig. 10).
- Although these data do not allow us to suggest that the sharks remain together, it does challenge the preconceived idea that sharks are loners all of the time.
- The big questions that still remain unanswered are;
  1. Why leave an area such as North Neptune Island, which has a stable population of seals (prey item)?
  2. Where do they go?
  3. What implications does this have for understanding the movement patterns of white sharks throughout SA?

DATE	36	43	48	51	52	53	54	56	59	60	62	66	68
	Shark Number												
28/10/2001	35						3				90		
29/10/2001	21	63					5				45		
30/10/2001		129				9					3		
31/10/2001							2						
1/11/2001							1						
2/11/2001		5					3						
3/11/2001		2					1						
4/11/2001	9	15					2						
5/11/2001	6	13					1						
6/11/2001	4												
7/11/2001		21					2						
8/11/2001							4						
9/11/2001		2					3				2		
10/11/2001	1	23									45		
11/11/2001		133					2						
12/11/2001							2						
13/11/2001				81		16	1						
14/11/2001							2	31					
15/11/2001				10		4	2						
16/11/2001	1						2				2		
17/11/2001				19			3				2		
18/11/2001	1										1		
19/11/2001				5			2						
20/11/2001				46							9		
21/11/2001				148			1				4		
22/11/2001			6	107							1		
23/11/2001			48	146							24		
24/11/2001				27							21		
25/11/2001				58			1				1		
26/11/2001			33				1				1		
27/11/2001				3			3						
28/11/2001				2			1				1		
29/11/2001							3	2			9		
30/11/2001				6			2	398					
1/12/2001				8			1	257					
2/12/2001				23			2	198					
3/12/2001				30				47					
4/12/2001				1			2						
5/12/2001				50									
6/12/2001				8			1						
7/12/2001				34				56					
8/12/2001		141		49			2	277					
9/12/2001		109		20			2	44					
10/12/2001		25		87			1	14				1	
11/12/2001		35		15			1	185					
12/12/2001				54				137					
13/12/2001		19		104				525					
14/12/2001				25				337					
15/12/2001				38				548					
16/12/2001		71		241				286					
17/12/2001				37				422	5				
18/12/2001						3	1						
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4/01/2002													
5/01/2002													
6/01/2002													
7/01/2002													

Figure 10. Records of tagged sharks at North Neptune I, 28/10/2001 - 7/01/2002.
Black fill identifies days when a shark was detected; numbers within the black fill are the number of detections of that shark on that specific day. An event appears to have occurred around 16-18 Dec, 2001, that led to the departure from the site of six sharks, numbers 43, 51, 53, 54, 56 and 59.

GENERAL OBSERVATIONS OF SHARK ACTIVITY

Individual and Site Specific Patterns

- Observation of one particular shark, "Grace," revealed that after a couple of weeks in the Neptune Islands, it moved into Spencer Gulf for about a month. This shark was previously thought to be a resident of Neptune Island. It then moved to the head of the Great Australian Bight (see Fig. 11).
- During this period there was large variability in its behaviour.
- During its time around North Neptune it displayed behaviour that is typical of sharks around seal colonies, in which a diurnal signal of swimming depth is observed (see Fig. 12a).
- During the day it was observed in shallow water, hunting seals.
- During the night it swam in deeper water.
- When the shark came into Spencer Gulf it displayed very different patterns of behaviour, and spent a month virtually swimming along the bottom - sometimes in very shallow waters. It was likely to have been feeding on the bottom, targeting rays and fish (see Fig. 12b).
- Most visits were relatively short, < 7 days (see Fig. 13).

Prey Patterns

- There is a general assumption that sharks keep their activities to seals and seal colonies. There is no doubt that you are likely to find sharks around seal colonies, but this is only part of the issue. Sharks also target other prey in other areas, such as snapper in eastern Victoria and South Australia. If you have elevated snapper populations on inshore reefs you can almost guarantee that you will have increased activity of white sharks.
- This suggests that white sharks can switch their behaviour to take advantage of the situation.
- Since factors like snapper population levels are going to change from year to year, there are likely to be changes in the level of white sharks interactions from year to year.

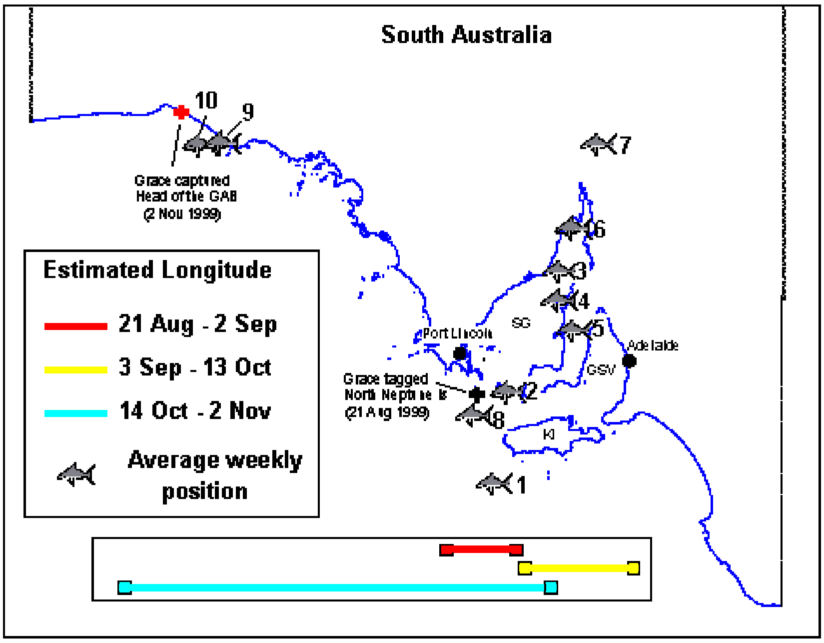

Figure 11. Movement of one individual tagged shark.
"Grace" was tagged at North Neptune I on 21/8/1999, and spent 74 days at large. Crude positions marked on map.

Movement Pathways and Patterns

- The similarity of tracks taken by white sharks in coastal waters suggests that there may be consistent pathways or corridors utilised when swimming between sites.
- Satellite tracking of two separate white sharks, one in 2000 and one in 2001, along the east coast of Australia showed very similar results (Fig. 14). Both sharks travelled at a distance of 5-30 km offshore (mostly between 5-10 km), at depths of 50-100 m.
- Other tracked white sharks have also swum in a restricted depth zone of 50 - 65 m when travelling along the coast - e.g. a 3.0 m female was tracked travelling across the GAB in this depth zone, which represents a region approximately 5-30 km from shore.
- It was suggested that these sharks are following similar environmental cues, or they are following schools of fish that are doing the same thing.
- Identifying these pathways may allow us to minimise interactions with white sharks.

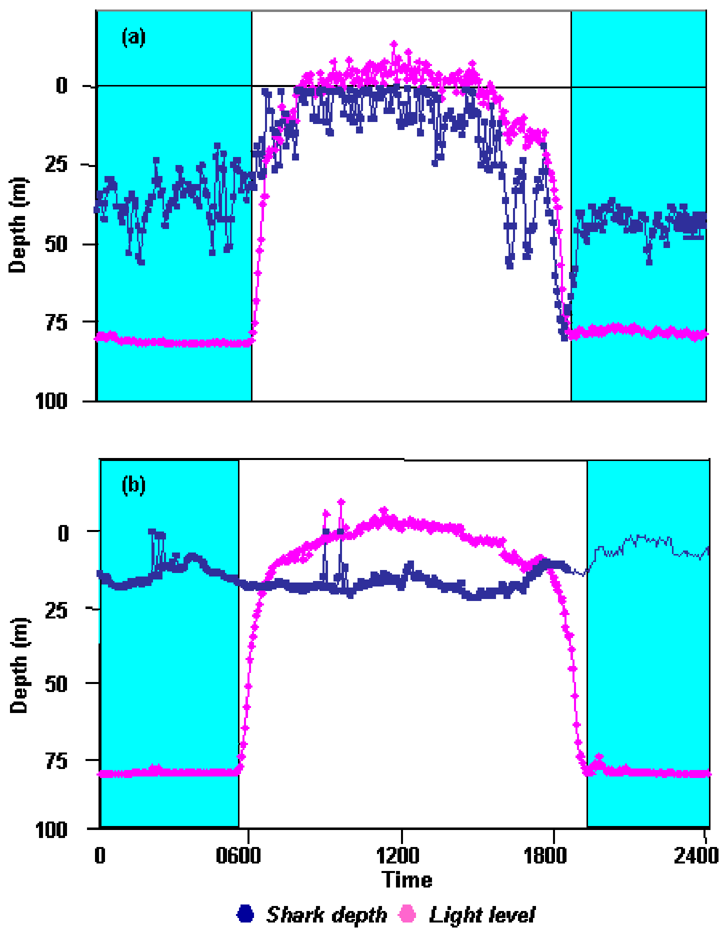

Figure 12. Swimming behaviour of "Grace" (a) North Neptune I (b) in Spencer Gulf. "Grace" was observed around the seal colony at N. Neptune, and was probably feeding on rays and fish in the Gulf. Shaded area denotes period of darkness.

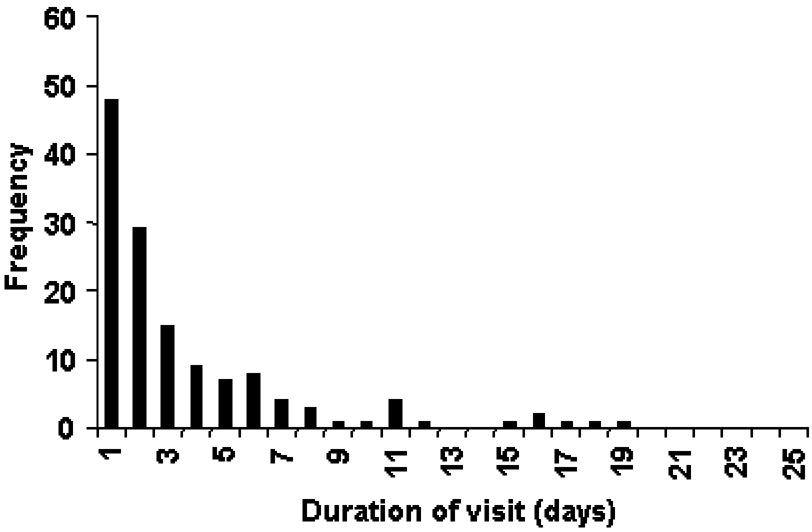

Figure 13. Duration of visits (defined as number of consecutive daily detections).

Conclusion about Where White Sharks Go and Why

- They are highly mobile.
- They are not permanent residents of any particular sites.
- Individuals will come and go during the period that they are around these sites.
- Some show particular daily and seasonal patterns in the timing of their visits.
- Sharks move to take advantage of different prey opportunities.
- They are not restricted to seal colonies, although they are commonly encountered around them. It is important to note that the majority of the work on sharks' predatory behaviour has been based around seal colonies. It is no wonder that the literature is peppered with links to seal colonies - but this is only part of the picture and they do go elsewhere.
- Their movement between areas may be quite directed and rapid.
- They may follow pathways.
- Their behaviour may be very different between areas, and between sites in the same area.

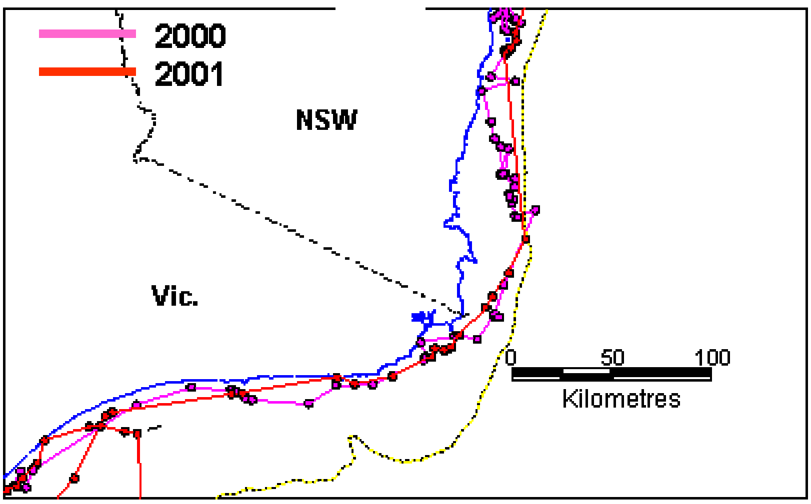

Figure 14. Tracks of two white sharks travelling around Southern Australia.

SHARK ACTIVITY IN COASTAL WATERS

- This project has been monitoring shark activity at North Neptune I for four years. As part of this monitoring program we have been collecting data from the local tourism operators.
- This data is known as the North Neptune Island shark index - the average number of sharks sighted per day by the tourism operators going out to these sites (Fig. 15).

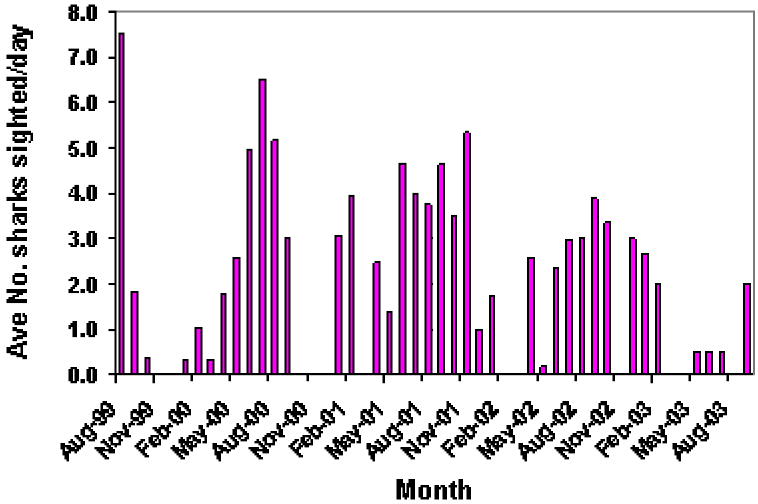

Figure 15. North Neptune shark index. Data from two tourism operators.

Findings of the North Neptune Island Monitoring Program

- There are clear seasonal patterns in shark activity. There is frequently an increase in shark activity during the winter, but these seasonal peaks do not occur every year.
- To further investigate this, the observations have been presented as a monthly anomaly index, which could then be compared over the five years (see Fig. 16). A monthly anomaly index compares the observed index for a particular month with the average index for the same month over the entire observation period (5 years in this case). A positive anomaly means that more sharks were observed than would be expected given the average for that month; a negative anomaly means that fewer sharks were observed than would be expected for that month. This can be a more useful way to identify trends, but can be biased if the time period of observations is short.
- The monthly anomaly index shows the following patterns:
  - 1999 and 2000 showed patterns with less than average shark numbers during spring and summer, and above average during winter (Fig. 16a, b);
  - 2001 showed above average numbers throughout the year; (Fig. 16c);
  - 2002 showed a pattern closer to the long term average (Fig. 16d);
  - 2003 showed below average numbers for winter (Fig. 16e).
- These data demonstrate how shark distributions can change rapidly in coastal waters.
- It is interesting to note that the lower level of shark activity encountered at North Neptune Island in 2003 corresponds directly with an increase in white shark activity at Dangerous Reef over the same period (compare Fig 16e and Fig 17). This suggests that there was a shift in distribution of white sharks into the lower Spencer Gulf regions during this period. This has been seen before, in the early 1990s.
- Abundance in coastal waters can vary seasonally and between years. We believe this is independent of population size and represents a shift in distribution with sharks moving into or out of coastal waters.

(a)
(b)
(c)
(d)
(e)

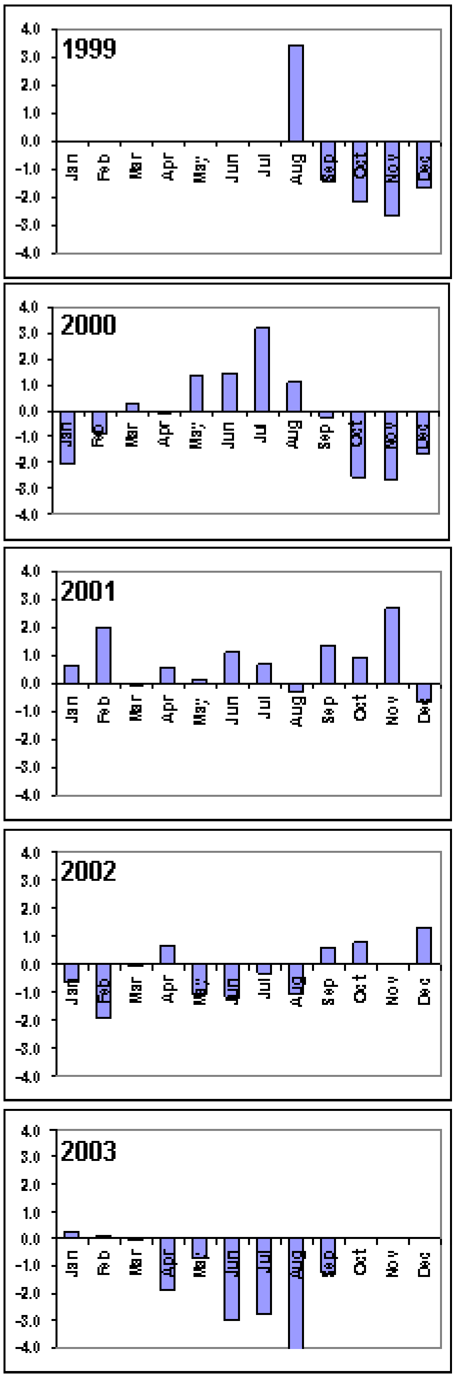

Figure 16. Monthly index anomaly for five years, 1999-2003.
Data compared to overall average for month. Note seasonal differences.

- Does this mean that the risk of interaction also varies between seasons and years?
- This is where researchers needs some help from industry - we would like to ask you to record your observations of white sharks and other species - it would be ideal to get the whole industry (including tuna and abalone) on board to record these sightings so that we can interpret this information.
- Ideally, we hope that this information, combined with the current research, can be used to identify areas that are more prone to shark interactions, and this information can then be used to reduce these interactions.

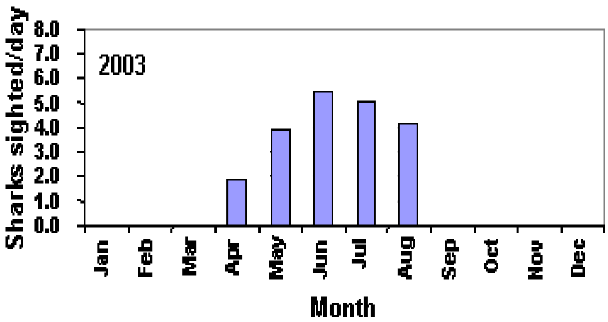

Figure 17. Number of sightings/day at Dangerous Reef, 2003.
Data taken from operators' logbook data. This figure shows that during the same period there was a decrease in shark activity at North Neptune (Fig. 16e), there was an increased level of interaction at Dangerous Reef.

ISSUES FOR THE AQUACULTURE INDUSTRY

- Are white shark interactions sufficiently important to warrant looking for solutions?
- Can the risk of interaction (and their repercussions) be reduced or more effectively managed?
- Public and media perception is probably driving a lot of the angst and concern about this issue. It may be beneficial to give the public more information about what the sharks are really doing in these areas, and what the operators are doing to minimise these interactions.
- Keeping the sharks out, and getting them out once they are in the cages - there are undoubtedly technological and other solutions to these issues (including farm husbandry practices), which farmers should be able to use.
- Can farmers identify and minimise activities that attract sharks, and therefore achieve what we all refer to as best practice?
- Are there areas more prone to interactions (identifiable from defining movement pathways)? If so, can these be identified/predicted, and thus used to interpret interaction frequency and manage or minimise risks?
- If there are interactions of concern then it is important to quantify just how extensive these interactions are, and to identify just what the sharks are doing and what kind of activities they are reacting to (sounds like some industry people are already doing this).
- If there are specific activities that do attract sharks, can they be modified to reduce these interactions and then this information disseminated?
- Just because you cannot see a shark it does not mean that it is not there - we have seen this in our listening station work at Neptune Island, by comparing acoustic tag data with the tourist operators' sighting data.

MINIMISING INTERACTIONS

Need to:

- quantify the extent of interactions
- identify what sharks are doing and what farm activities they are reacting to e.g. harvesting, feeding, presence of fish/cages
- modify specific activities to reduce interactions
- figure out how to monitor to determine whether actions have been effective.

QUESTIONS

** All answers given by Barry Bruce (CSIRO) unless stated.*

Lindsay Best (DEH)
Q) What is the range of the tag or the listening device?
A) The range of these tags and listening devices is about half a kilometre.

Lindsay Best (DEH)
Q) Could you put a listening station inside the tuna cages?
A) Yes, you could. In fact, this would be a useful way of gathering information about what the sharks are doing - how frequently they are visiting cages, and if they are moving from cage to cage - this type of technology would be ideal for this, for both YTK and tuna.

Dos O'Sullivan (Australasian Aquaculture)
Q) There has been about 20 years of salmon farming down in Tasmania now. What do you think we can learn from this aquaculture industry?
A) The shark interaction level down there is remarkably low, but the overall shark population is also a lot lower compared to what you have over here. They do have interactions with seals (similar to what you guys have here). The seal issue is a bigger problem for them - but as far as shark interactions go, the number is fairly low in Tasmania.

Rachel Lawrie (Australian Fishing Enterprises)
Q) Knowing that there have been attacks on the west coast, and that white sharks move along this coast searching for snapper, is there a reason why there are no listening stations on the west coast? They seem to go up the Gulf and along the west coast in winter, following snapper.
A) This was not one of the questions of the original listening station study, but yes, I agree with you. We did see one tagged white shark move up into Spencer Gulf in late Sept-Oct, and up the west coast in Oct-Nov. I think that with a broader tagging program we will start to see much more predictable patterns and pathways to the movement of these sharks than we currently understand. One of the things that we would like to do is to match some of the electronic tracking technology with the experience and observation that industry can make, so that we can get a better handle on where white sharks go - and when - and use this information to identify the pathways and situations that might lead to levels of increased risk to aquaculture operations. Ultimately if we can get to the stage of combining our observations, there is the possibility of predicting future levels based on parameters such as snapper abundance. The way I see it is that we are all trying to strive for the same thing (particularly with the white shark stuff). We are all trying to get a handle on the status of populations and how best to assess them.

Rachel Lawrie (Australian Fishing Enterprises)
Q) Is it true that sharks are intelligent animals that can adapt their behaviour to take advantage of changing circumstances, particularly in terms of prey? They may be smarter than we think.
A) Yes, these sharks do feed on a number of different prey species, such as seal and dolphins (which are relatively intelligent animals). They have evolved a range of strategies to effectively hunt these species. We have definitely seen evidence of this in the tagging work, with sharks rapidly switching their behaviour to target different prey. They have a very complex range of behaviour, which they can call upon.

Tony Flaherty (Marine and Coastal Community Network)
Q) From captures, there seem to be different distribution patterns in term of male and females sharks. Do they use the islands in different ways?
A) Yes, we do see sexual segregation of white sharks (and you also see this in other shark species as well). Interestingly enough we have also observed shifts in the dominant sex at some

sites e.g. Dangerous Reef is currently dominated by females as it was in the early 90s; however, during the 10 year period in-between, there was a shift toward male dominance. At the same time there was a corresponding dominance of females out at Neptune Island. So yes, they do display sexual segregation, but it is quite complex and experiences shifts and flip-flops.

Tony Flaherty (MCCN)
Q) Are there any patterns in shark activity in relation to seal activity? They don't seem to be tied to sites with fur seals (with a regular annual breeding cycle), compared to sea lions with an 18 month breeding cycle.
A) This was one of the purposes of the listening stations, to explore the way that white sharks utilise the sites and specifically whether they were tailoring their visits to particular patterns of seal behaviour (e.g. breeding). To be honest, we have seen no relationship in the movement patterns of white sharks and what the seals are doing. It appears to be more individually based - we have winter-time sharks that turn up at the Neptunes in winter and that you don't see at other times, we have summer-time sharks that only turn up in summer, etc. It is clear that their movement patterns are quite complex, and at times it seems counterintuitive as to which periods you would expect populations of seals or sea lions to be more vulnerable to a white shark attack.

Brain Jeffriess (TBOA)
Q) What are the current stock levels of white sharks? We've got a long way to go if you look at the recovery plan.
A) It is very difficult to assess the current status of white shark populations, and the more we research these animals the more we realise that understanding movement patterns is part of getting a handle on stock levels. For example, if you look at the data from the Neptune Islands you would assume that the population is crashing, but in reality it is not crashing but moving. The white shark population is a very fluid one, and understanding these dynamics is important so that we can put the sighting frequencies into perspective - only then can we put a number on the status of white sharks.

Helen Croft (PIRSA)
S) Difficulties in the detection, prosecution and reporting of illegal catches of white sharks adds uncertainty.
A) We are not sure how to estimate illegal catch. The current estimates of the take of white sharks as bycatch in various fisheries around South Australia is around 200 per year. But this can vary quite dramatically from year to year, which may be in response to these distributional 'flip-flop' in shark numbers that can lead to an increase in the level of interactions. Although 200 are taken, one of the most pleasing things, particularly in the southern shark fishery, is that quite a lot of the operators are releasing white sharks. We can't say how many of these are surviving, but I think around 60% of white sharks were released.

One Success Story: Kate Rodda

Research Scientist, SARDI Aquatic Sciences

OVERVIEW

- On the 19th June 2003, a white shark was found trapped inside a tuna cage near Boston Island, Port Lincoln.
- The shark, a female approximately 4.4 m in length, was in the cage with 80-100 tuna and a New Zealand fur seal.
- The pen was an experimental cage owned by SARDI and at the time it was involved in tuna feeding trials.
- The total duration of the entrapment was 5-6 days.
- This situation, the entrapment of a white shark, offered a unique opportunity to develop a technique that could be used to free sharks in such a situation, but it also gave a rare opportunity to observe a white shark in captivity.

OBJECTIVES OF THE PROJECT

1) Free the shark safely and unharmed.
2) Minimise the loss of tuna.
3) Maintain a safe (OH&S friendly) environment for all personnel.

ENTRAPMENT AND SHARK BEHAVIOUR

- The shark was first observed on the morning of the 19th by research staff - they noticed that the tuna were not feeding normally. They soon saw the tail and dorsal fin of the white shark. They also noticed the NZ fur seal, which appeared to hang around inside the cage for the first day only, after which it wasn't seen again.
- PIRSA Fisheries was contacted and it was decided that every attempt would be made to release the shark without endangering the shark or human life.
- The shark was observed swimming in clockwise direction about 2 m inside of the cage net at a rate of 2 km per hour (it would take three minutes for the shark to do one lap of the 32 m diameter pen).
- The shark appeared relatively relaxed and was swimming quite close to the surface.
- On the remaining days of the entrapment (total duration 5-6 days), she increased her speed to one lap per minute (approximately 6 km per hour).
- We set up a remote camera so that we could observe the shark in terms of the depth of swimming and her behaviour, but also to observe what the tuna were doing.
- This revealed that the majority of her time was spent quite deep (below 12 m), which made a rescue attempt a little more difficult. The rest of her time was spent at or very near to the surface.

OPTIONS AVAILABLE FOR RELEASING THE SHARK

1) We could drop the net (or a proportion of it) to provide a hole in which the shark could swim out. But this method risked losing tuna, and was discounted.
2) Alternatively, we could create a smaller opening that we could direct the shark out through. It was decided that this was the preferable method.

Small Gate Method

- On the second day of entrapment, divers were deployed on the outside of the net to cut open the gate (usually used to transfer tuna). This gate was 5 x 4 m in size, and 1 m below the surface.

- While the shark was below the level of the gate, the gate was kept closed to avoid the loss of tuna.
- While the shark was in the vicinity of the gate, we opened it and placed a bait on the outside of the gate (half a frozen tuna and the guts & gills of a fresh tuna).
- To avoid the loss of tuna when the gate was opened, the tuna were fed small amounts of pilchards on the opposite side of the cage, to try and keep them occupied.
- This did not draw the trapped shark out; however, it did attract another 16 ft white shark! The gate was quickly closed to prevent the other shark from entering.
- The entrapped shark did not attempt to feed.
- It became clear that to get the shark through the gate we needed to bring her near to the surface. Several techniques were tried to bring the shark closer to the surface and the gate:
    1) putting a hookah hose at the bottom of the cage and blowing air through it;
    2) placing a Shark Shield at the opposite side of the cage;
    3) using baits.
- None of these techniques appeared to have any effect on the shark.
- It is important to note that we did not conduct a scientific test of the Shark Shield - its ineffectiveness may have been because it was not set up to produce an optimal effect.
- On the third day the weather was not very good so it was decided that it was too unsafe to be walking around on the pontoon.
- On the fourth day we tried again. We opened up the gate when the shark was at the right level, we tried to prod her in the side to make her veer towards the gate. Unfortunately this caused her to go in the other direction into the centre of the cage and deeper - where she stayed for the rest of the day.
- On the fifth day she was swimming quite close to the surface - so close that dorsal fin kept touching the spider rope (*Spider ropes are the ropes that are placed internally and on the surface that hold the cage in a roughly circular shape. Ed.*).
- To encourage her to stay at the surface we removed all obstacles on the surface such as the spider rope.
- This also gave us the opportunity to estimate her length - 4.4 m.
- Soon after doing this a few boats came along, causing her to dive deep again - this taught us that you really need to remove all obstacles and to reduce all boat traffic in the vicinity.
- After much debate it was decided that the reason she was not going through the gate was because she could not see it (it was only in her peripheral visual field).
- We decided to make the gate more visible by enlarging it and then opening it inward towards the middle on the cage.
- Divers enlarged the gate to a depth of 9 m (see Fig.18), and attached ropes at the top and bottom - these ropes were then extended to the other side of the cage, which would allow for the v-shape tunnel to be opened (i.e. the gate was now 4 m across by 9 m deep).
- In theory, as the shark was swimming around the cage she would come up to this barrier extending 3 m into the cage, sense it as an obstruction, turn, and head out.
- On the morning of the sixth day she was swimming too deep to attempt anything. As soon as she come close to the surface, we opened up the gate, she did two full circuits, avoiding the open gate, and on the third circuit she went straight out, and swam off.
- The cage was then repaired from the inside - this revealed two holes, one about 1 m^2 at 6 m depth, which was assumed to be the entry point of the shark, and a smaller one which was assumed to be the seal's entry point.

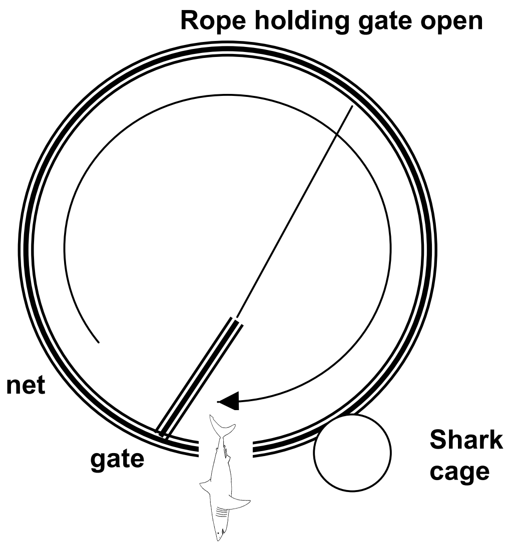

Figure 18. Sketch of gate cut in the SARDI research cage.

CONCLUSIONS

- SARDI would like to thank all of those that were involved in the operation.
- This is believed to be the first successful release of a white shark from entrapment in an aquaculture cage.
- This successful operation has provided new ideas on how to deal with shark entrapment, particularly in terms of the structure of the tuna cages. Perhaps cages could be built to include gates that could be used in the event of shark entrapment.

QUESTIONS

** All answers given by Kate Rodda (SARDI) unless stated*

Brian Jeffriess (TBOA)
Q) Was the movement of the shark around the cage regular - in a circular movement?
A) Yes, very regular - like clockwork. Every minute she would come along moving in the same direction (clockwise). This regularity makes it easier to devise a method of extraction. If she had kept changing direction, the way the gate opened would have had to be different.

Jeff Buchanan (SARDI Aquatic Sciences, tuna research farm manager)
A) She always swam in a right hand circle. At one stage, the fish followed her, then the seal. The seal left after two days.

Barry Bruce (CSIRO)
S) Just to give everyone a comparison of the swimming speed of the entrapped shark versus a wild shark, in the wild the general cruising speed of the white shark is about 3 km/hr, compared to the initial 2 km/hr, and then 6 km/hr in the last 4 days, of the entrapped shark. White sharks are capable of faster bursts. Swimming speed is independent of the size of the shark.

Brian Jeffriess (TBOA)
Q) One of the more radical methods used by one of the tuna operators to keep seals out of the cages was to keep a shark in the cage. Did you find that the shark attacked the tuna?
A) We did notice that one of the tuna was swimming around with a 20 cm chunk out of it and serrations down its side, and it was assumed that it was the shark responsible for this. On conclusion of the operation three more tuna mortalities were observed on the bottom of the cage.

Barry Bruce (CSIRO)
Q) How do you think the shark got into the SARDI cage?
A) Well, it either jumped a 2 m high electric fence (which is unlikely), or it got through the 1 m^2 hole, 6 m down, that was found in the base of the cage. Since a shark that is 4.4 m long is about 1 m in height, this seems quite likely.

Anthony Cheshire (SARDI Aquatic Sciences)
Q) There were reports that, after a few days, the tuna were actually rubbing themselves against the shark's rough skin, scratching themselves. Do you have any comments about this?
A) I guess that is the safest place to be - as far away from its mouth as you can be. Apparently the seal was often found behind the tail of the shark, perhaps for the same reason.
Jeff Buchanan (SARDI Aquatic Sciences, tuna research farm manager)
S) We did see that. As time went on, there seemed to be less interaction. The tuna initially followed closely behind the shark. This would obviously be a problem if the shark had swum out.

KEEPING THEM OUT

Effective Farm Management: David Ellis

Tuna Boat Owners' Association

Basically I will be commenting on my experience on how the tuna industry has evolved over time.

- When the cages are being towed, the majority of interactions (i.e. when a shark gains access to the cage) occur where the mortalities (morts) collect at the back of the tow net. As the cage is being towed (at approximately 1 knot) the morts will naturally collect at the back of the net, which can be at 14-16 m depth during the tow. This is where you get sharks biting through the cage to get at the morts.
- Most of the shark species we have trouble with in the tow phase are makos and bronze whalers, not great whites.
- To get around this we first looked at the shark pod technology. We positioned the sensors so that they produced the greatest electronic field in the area where morts fell; however, the makos bit through the net anyway. The new Shark Shields might be more effective.
- The next method tried was a predator net, which runs over the back of the net. This creates a space between the farm net and the predator net. This distance between the two nets produces a barrier, and this has been a successful deterrent.
- We have also been through a developmental phase in terms of animal husbandry to reduce the number of mortalities. This has reduced the number of shark interactions.
- We are now towing further off the shelf, which has also reduced the number of interactions.
- We have observed that mortalities in the cages increase the number of shark interactions. When tuna die they often get entangled in the net, creating an enticing and easy target for the sharks. Divers used to collect morts and tie them to the handrail, but sharks would come and grab them. Dead fish are pretty easy to spot close up to the net. Also sick fish sometimes struggle upwards, and can get tangled in the net as they die. This makes an easy target.
- How to minimise this is difficult, because you do not know when a fish is going to die. Hence you do not know when to retrieve it.
- So it comes back to good husbandry. There is a flow on-effect where you start looking at total quality management. You need to do the right things through the catching phase, the towing phase, the transfer phase, and use continuously good farm husbandry throughout to minimise the interactions with sharks.

QUESTIONS

** All answers given by David Ellis (TBOA) unless stated*

Rachel Lawrie (Australian Fishing Enterprises)
S) I would like to add that many of the industry representatives are using blood separators which reduce the amount of blood going into the water. Using this type of technology I have observed very minimal levels of interactions with sharks.

David Ellis (TBOA)
S) Yes, what Rachel is saying is true, that we are containing our harvest offal and effluent so that it is kept on the vessel.

Michael Tokley (Abalone Association)
Q) Do you have to dive outside the cage very often?
A) Very rarely do we have to go outside the cage, and if we do we use a shark cage to protect ourselves.

Rebecca Paterson, (Stolt Sea Farm)
S) We have actually been using a ROV (remotely operated vehicle) to assist in retrieving the dead fish from the cages and to assist in cage maintenance.

Patrick Hone (FRDC)
Q) No one has talked about the changing occurrence of sharks with time. You have been in the industry for a while, what are your thoughts/observations of this?
A) I would say that people are observing more whites over time, but how to quantify this I do not know.
Brian Jeffriess (TBOA)
A) There was a reported incident near Port Lincoln jetty the other day, where a seal was attacked just off the jetty. Sharks are less predictable than they used to be. People are relying on them not being around during summer, but this may not be a safe assumption any more.

Jeff Buchanan (SARDI, tuna research farm manager)
S) I would like to add that, in my four years at SARDI, we've only seen one on an underwater video under the cage - otherwise apart from the recent incident we don't see them. During the SARDI entrapment operation, although we knew that there was a shark present in the cage, if you were looking from the surface, the majority of the time you would not know that there was a shark there. This makes the point that although you cannot see a shark it does not mean it is not there, and surface sightings are not a good indicator of the presence of sharks.

Graham Woods (DPIWE, Tasmania)
Q) Are there many school fish aggregating beneath the pens, and is there a chance that the sharks are attracted to these school fish?
A) Yes, we do have small school fish such as tommy ruffs and garfish, but they are generally around the nets during the summer. I have not heard of any white shark sightings during summer, so no, I do not think that the school fish are attracting the sharks.

Technological Fixes: (a) Shark Shield™: Michael Wescombe-Down SeaChange Technology

Background Information

- The Natal Sharks Boards produced the first prototypes of this type of technology. The prototype had a chequered career, which, due to poor design, had a continual problem with the on/off switch often failing. This is one of the reasons that I got involved in this industry.
- The Shark Shield works by acting on the sensitive receptors in the snout of sharks (the Ampullae of Lorenzini), and our tests indicate that this effect is the same on makos and oceanic white tips as for white sharks.
- SeaChange Technology was granted a world wide exclusive license to utilise the unique patented "wave-form" technology
- We have had numerous tests on white sharks, in which they turn away from the Shark Shield unit.
- The old Shark Pods had a significantly lower output than the Shark Shields. This lower output may have been one of the reasons why it did not deter sharks in a cage situation.
- We have found no impact on other marine animals (except crocodiles), which is important if this type of technology is going to be used in an aquaculture situation. We have seen kingfish and other fish feeding quite happily right next to electrodes; however, we are still conducting experiments to make sure that there are no long-term effects.
- We have about 3000 dive units out there, 300 of which are used by abalone divers.
- Recent tests conducted by the Queensland Police and Qld Parks & Wildlife indicated the technology also repels crocodiles, and further tests are being conducted.
- Our first priority has been to develop and distribute a personal range of products, including:
  - DIVE01 - Specialised Diver Unit - for use by divers, spearfishers (Fig. 17a)
  - GPSS01 - General Purpose Unit - divers, snorkellers, spearfishers, kayakers (Fig 17b)
  - PROL01 - ProLine Unit - for use by divers using surface air supply (Fig 17c)
  - BOAT01 - Boating Unit - to be attached to a buoy to protect a small area
- The DIVE01 and GPSS01 units are currently used by divers and other aquaculture staff
- The PROL01 is currently used by aquaculture farms to protect a small area of the net, hence also protecting the diver.

(a)

(b)

(c)

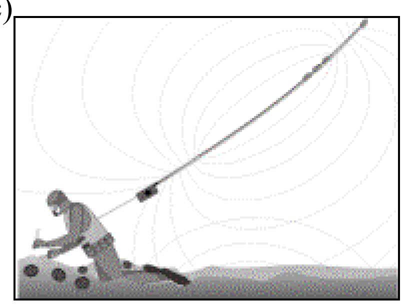

Figure 19. Shark Shield types: (a) DIVE01; (b) GPSS01; (c) PROL01

SHARK SHIELDS AND AQUACULTURE

- Shark Shield products can offer protection to the aquaculture industry in two ways: personal units for staff working on aquaculture farms and commercial units to protect the nets.
- The use of the Shark Shield on tow cages has proven to be a little tricky. I made an initial foray into it about three years ago and built some experimental units. These units did work, but the hydrodynamic forces on the tow nets tore and damaged the cables.
- We have learnt a great deal since those early days, and we shall be revisiting the design of these units to make them more rugged.
- Ideally, we would like to design a high power unit that can be deployed at the rear of the net where the morts usually aggregate (this was the area that the sharks penetrate the nets and cause all the damage, Fig. 20)
- For this unit to work it needs to be extremely tough and create very little drag, in addition it must also require a low level of maintenance for the operator.
- We are now experimenting with flexible stainless steel mesh electrodes, whereas previously they were not flexible.

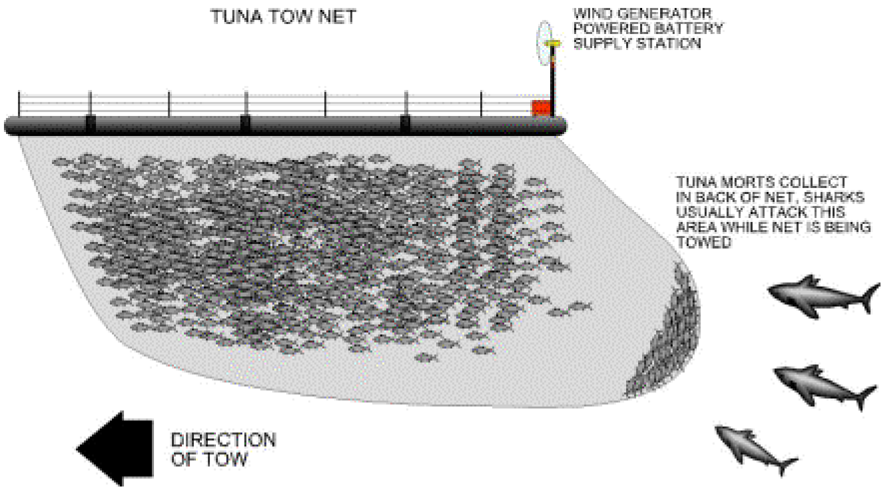

Figure 20. Schematic of towed tuna net showing area of risk.

SUMMARY

- The technology works.
- We are currently able to protect staff working on aquaculture farms (duty of care).
- Early trials of protection of aquaculture stock in towing nets proved initially successful.
- Towing nets considered a priority.
- Aquaculture arrays to be followed by development of beach barriers.

QUESTIONS

** All answers given by Michael Westcombe-Down (SeaChange Technology) unless stated.*

Nigel Preston (CSIRO, Qld)
Q) Would it be possible to have a unit that mediates the amount of charge being emitted, for example if a shark is detected it could switch from low power to high power?
A) It is possible, and probably highly desirable because it would cut the power consumption of the unit considerably. One of the things I would like to do is to work with live sharks and to expose them to different frequencies and charges to determine if there are certain 'sweet spots' that have an optimal effect in deterring sharks (rather than going for excessive amount of charge). We need to find a way of working with white sharks to find out how they react. If we bombard them with too much, their receptors may tune out what's coming in.

Barry Bruce (CSIRO, Tas.)
S) Yes, I do appreciate the difficulties of doing experiments with white sharks; however, perhaps you can undertake these experiments on other species of sharks, even the more benign ones, and at least this would be a starting point. You can use them as a model for the effects these technologies have on sharks.
A). Yes. But we need a third party to do it, to get away from self-promotion.

Technological Fixes:(b) Rigid Cages: Scott Hawkins

One Steel

- OneSteel has developed a new form of steel wiring called MarineMesh® which has an increased level of corrosion protection in the marine environment (Figs. 21, 22)
- The advantages of using MarineMesh are:
  - MarineMesh is comprised of a special galvanised wire with a zinc coating which is some 12 times thicker than conventional chain mesh fencing, and lasts significantly longer.
  - Unlike normal chain mesh, MarineMesh has a double knuckle which gives extra strength, which is critical in terms of the cage holding together and preventing sharks from penetrating the cage.
  - The weight of the MarineMesh makes it very difficult to manipulate. This overcomes the problem of predators pushing the predator nets against the farm nets to get at the fish. They simply cannot do this with MarineMesh.
  - Fish do not get entangled in the nets.
- To date there has been no successful attack on a MarineMesh cage.

TRIAL CAGES

- There is now one trial cage at Arno Bay, SA, plus three totally converted farms:
  - Bathurst Island, Northern Territory;
  - Blue Water Barramundi, Townsville;
  - Van Diemen Aquaculture, Tamar River, Tasmania;

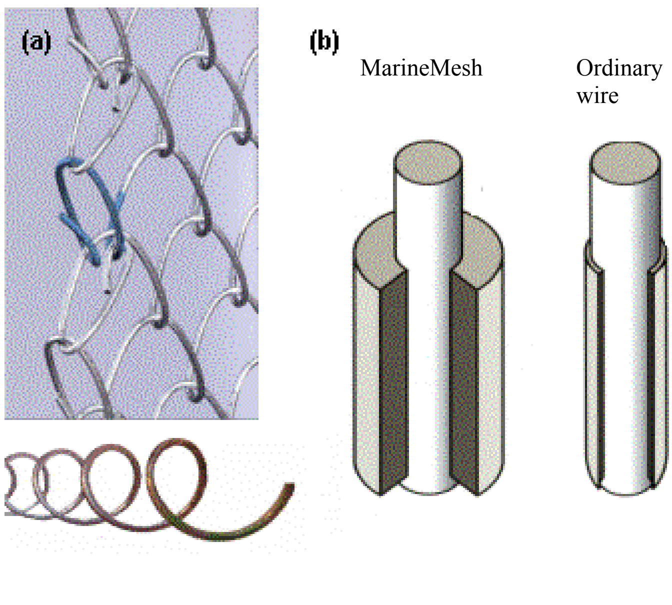

Figure 21. Steel mesh: (a) Double knot construction (b) Steel core with zinc coating.

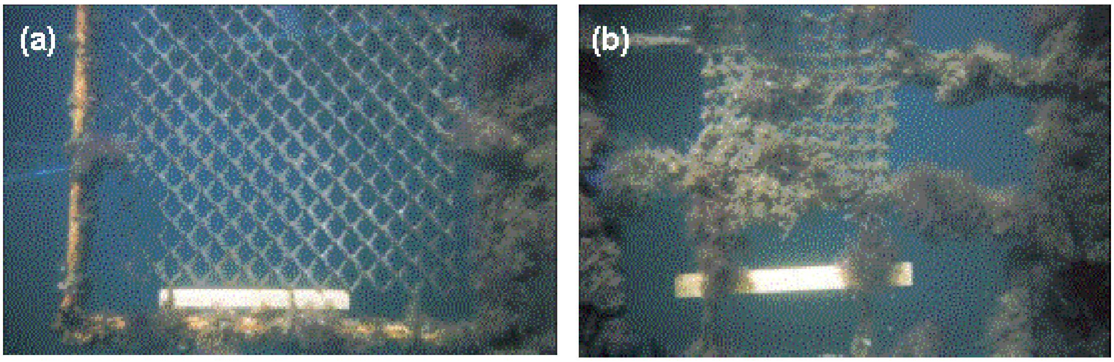

Figure 22. (a) MarineMesh, and (b) Nylon mesh panels.
Both after four months in Botany Bay.

CASE STUDIES

Marine Harvest Bathurst Island, NT. Barramundi Sea Farms.

- Bathurst Island has the longest history of the use of steel cages. In many respects it is a worse case scenario, with very high tides and strong currents, crocodiles, tiger sharks, and very low visibility.
- Within three months of the farming operation commencing (in March 2001), the nets were being breached (a 3.3 m tiger shark penetrated the net in May 2001).
- Entrapment of fish in the nylon nets was perceived to be a major cause of predator attacks.
- The first steel nets were trialled in Sept 2001 with full conversion of the operation by July 2002 (Fig. 23). No predator penetration of the cages has occurred since.
- The other issue for Bathurst Island (given the temperature of the water) was the excessive level of fouling that would occur on the conventional cages - this was such a problem that operators could not keep up with the task of cleaning these cages. The steel cages do not foul at the same rate, and even if anything does adhere, they are relatively easy to clean. So from an economic point of view, this farm is now dependent on the protection offered by MarineMesh nets.

Figure 23. Bathurst I: MarineMesh cages in use
Bathurst I. Marine Harvest farm (barramundi).

Van Diemen Aquaculture, Tamar River, Tasmania. Salmon.

- This salmon farm suffers a little bit because it is located very close (within 8 km) to a seal relocation area. The seals are moved from farms further south.

- The seals were a problem because they tear holes in the net. They can also detect weak points in a net, from the different coloured rope used when repairing the net. Again fish mortalities are a key factor in triggering attacks.
- Productivity is lost through stress to the fish.
- Fish were lost escaping through the holes in the net.
- The steel cages were installed in April 2003 and to date they have not had any seals penetrating the cages.
- Farm entirely converted to steel in October 2003.

Stehr Group, Yellowtail Kingfish. Arno Bay, SA.

- The Stehr group is trialling a steel net in Arno Bay, which is a bold move because it is:
    - the largest cage built to date;
    - constructed on a plastic pontoon; and
    - located in a relatively exposed area.

  None the less, the incidence of predation was such that it was worth trialling these cages.
- The marine mesh is needed as bronze whalers were tearing holes in fibre nets leading to fish escapes.
- The cage was assembled on a wharf in Whyalla and towed to Arno Bay in June 2003.
- This is the first steel net for SA aquaculture, and the first net installed on an 80 m pen.
- Since it was installed (June 2003) there have been no predators breaching this net.
- We are awaiting the outcomes of a longer-term trial.

BENEFITS OF MARINE MESH CAGES

In addition to preventing predator access to the cages, there are other benefits of the steel cages. These are as follows:

- Fouling is significantly reduced. Some parasites that attack fish reside in the fouling, and there have been some reports that there has been a reduction in parasite infestation in the fish with steel cages.
- Improved water flow gives improved fish health.
- Growth rates have been reported to increase because the fish are not stressed by net changes or predator attacks.
- Occupational Health and Safety issues are improved because:
    - farm hands aren't lifting heavy weights on wet moving platforms;
    - divers can dive within the cages and not be exposed to aggressive seals, or dangerous sharks and crocodiles;
- Once predators no longer receive a reward from attacking a net, fewer of them visit the farms.
- The total cost of the system is similar to a fibre net system. A fibre net system requires multiple grower and predator nets, frequent net changes, and is still not predator-proof.
- They are self-weighting and maintain their shape without additional weights. Again the maintenance issues are reduced.
- It is a single net solution (no need for a predator net).

AREAS FOR POTENTIAL INVESTIGATION

- Deployment of these cages on square pens is quite simple and requires little investment.
- The current method for deploying these nets on round cages is more expensive as it requires the use of a large crane.
- One of the areas that we will be investigating is to determine how we can assemble these things on plastic pontoons in the water or on a ramp near the water.

Questions

** All answers given by Scott Hawkins (OneSteel) unless stated.*

Nigel Preston (CSIRO, Qld)
Q) Do you know the reason for the reduced level of fouling in the MarineMesh?
A) No, but I am led to believe that it is because of the thickness of the zinc coating.

Nigel Preston (CSIRO, Qld)
Q) Are there any implications of where the zinc goes - for the fish in the cage or anything outside the cage?
A) Some research was done by NSW Fisheries on the MarineMesh cages that were put into Botany Bay, located near finfish and oyster leases. They found no measurable effect.

Daryl Evans, Marnikol Tuna Farm.
Q) What does the cage in Arno Bay weigh?
A) 4.7 tonnes, hence you need to choose the right pontoon to hang it off.

Bronwyn Gillanders, Adelaide University
Q) How long do the marine mesh cages last, and how does this compare with nylon cages?
A) How long is a piece of string? Up north the water is a lot warmer, salinity is an issue, and the flow rates around the tides are a lot higher. The life of a net is about 19 months to 2 years in the Northern Territory. In southern waters where the waters are colder we have estimated something from 2 ½ to 3 years, based on preliminary results from Tasmanian samples.

Stephen Bedford-Clarke (Clean Seas Aquaculture)
A) The life of nylon nets on the kingfish cages is about 3-4 year (depending on wear and tear), but we are having to change these nets a lot more often.

Tony Flaherty (Marine and Coastal Community Network)
Q) Do you have a problem in currents with the nets lifting or popping?
A) We have not had a problem with this so far because the three installations up north and in Tasmania are in square steel cages, and in Arno Bay there is not a strong current issue. We would be cautious about applying a steel cage to a round pontoon in high current areas; however, having said that, the weight of the steel net is greater than a non-fouled nylon net, but it would be relatively similar in weight (and would create a similar amount of drag) to a fouled nylon net. So the short answer is - if you currently have an installation that is successful in that current we don't foresee any problems with using a steel cage.

Dos O'Sullivan (Australasian Aquaculture)
Q) What are the mesh sizes that are available?
A) The choice of mesh size range is 25, 32, 50, 70 and 100 mm. Your choice of size would be based on the size of your fish or your fingerlings, for example barramundi farms go 25 mm or 32 mm, in other cases when the fish are larger they are opting for 50-75 mm. We would presume that the 100 mm nets would be used purely as a predator net.

SMALL GROUP DISCUSSIONS

Group 1
Jon Presser (PIRSA Fisheries)
Brian Jeffriess (TBOA)
Rachel Lawrie (Australian Fishing Enterprises)
Chris Pitney (Tony's Tuna International)
Paul Hastings (Australian Marine Conservation Society)
Carina Cartwright (PIRSA Aquaculture)
Michael Tokley (Abalone Industry Association)
Rebecca Paterson (Stolt Sea Farm)

Information Learnt
- Didn't know migratory routes and spawning seasons.
- Sharks not attracted to mulloway.

Insights
- Seal colonies are establishing closer to tuna farming zones.
- Seasonality issues.

Issues
- Balancing OH&S and economic issues with conservation.
- Entry routes - studies of species variation in entry.
- Need more information about seasonal patterns etc, and then link them back to aquaculture planning.
- Adaptive farming systems are needed to minimise interactions.

Ideas
- More intensive tagging program needed to determine seasonal distribution and annual migrations (then relate back to planning).
- Need to determine shark feeding regimes.
- Attractants - what attracts? How does it attract? Need this information.

Purpose
- Need to find a balance between conservation/OH&S/economics.
- Find ways to manage - and avoid - interactions.
- Gain further knowledge of seasonal distribution and migratory patterns - relate to aquaculture planning

Input
- Visitations / observations / tagging.
- Behavioural patterns.
- Operators already adopting their own technologies to manage interactions.
- Concerns about expanding populations of seals/sea lions and establishment of colonies closer to tuna farming zones.

Solutions
- Preventative measures important
- Adoption of on-farm technologies that work.
- Adoption of 'continuous improvement' and 'best practices.'

- Rapid expert advice when injury-free removal of sharks is an issue.

Choices

- Some aquaculture operations could be moved on shore (other benefits to this, not just shark interactions)
- Scientific reports giving biologically consistent options for removal should be available when entrapment occurs.
- Behavioural studies (understand the nature of the beast).
- Extension of Barry Bruce's listening station configurations.
- Increase our knowledge of sharks.

<u>Group 2</u>

Helen Croft (PIRSA - Fishwatch)
Serena de Jong (SARDI Aquatic Sciences/Adelaide Uni)
Keith Jones (SARDI Aquatic Sciences)
Mike Westcomb-Down (Sea Change)
Matias Braccini (Adelaide Uni)
Bronwyn Gillanders (Adelaide Uni)

The workshop has raised a number of questions and options. It has focussed on lack of information in data collected e.g. some fishing data available, but none available from aquaculture.

Main Points

- Lack of information - need better data especially:
  - Commercial fishing data
  - Data on all species of sharks
  - The number of interactions, sightings and mortalities

Areas that need to be targeted:

- Northern Spencer Gulf
- Arno Bay
- Port Lincoln
- Fishing industry information separate to aquaculture industry.

- Does the Stehr Group include bronze whaler interactions/dispatches in catch statistics and licence reporting?
- There are concerns about the increased fishing effort of bronze whaler commercial catches on stocks, need to look at this.
- Arno Bay cage relocation from 'snook ground' appears to reduce shark interaction on that cage - supports Barry Bruce's hypothesis about the presence of shark highways.
- Determine migratory patterns of bronze whalers up and down the Gulf.
- FRDC project - collect data on the number of sharks and the level of interactions, data collected from industry (commercial and aquaculture fisheries) - make arrangements with industry to provide this information.
- We must promote a cooperative approach to increase trust/ communication between research / industry / enforcement.

Group 3
Graham Woods (DPIWE, Tasmania)
Kirsten Rough (MG Kalis Group)
Barry Bruce (CSIRO)
David Ellis (TBOA)
Daryl Evans (TBOA)
Kate Rodda (SARDI Aquatic Sciences)
Richard Musgrove (SARDI Aquatic Sciences)
Jason Tanner (SARDI Aquatic Sciences)
Maylene Loo (SARDI Aquatic Sciences)

Prevention/Management

- Interactions with bronze whalers appear to be a bigger issue for industry than white sharks.
- Interactions with white sharks attract a lot more attention, as they are a higher profile species (*Ed. There are also problems because white sharks are listed, and hence protected, under both federal and state legislation. Operators can currently destroy whalers with impunity, but face fines and imprisonment if they do the same to white sharks*).
- Area matters - some areas tend to have a higher level of interaction than other areas - a better understanding of movement may assist in a reduction in interactions.
- Husbandry is an important tool to reduce interactions - appears that most of the industry has adopted protocols to improve husbandry.
    - Net design important
    - Less blood in the water
- The successful release of the shark in the SARDI cages illustrates that the release of entrapped sharks is possible.
    - Incorporating a cage design to aid in these release attempts should be investigated
- It is evident that innovations to cage design (such as steel cages) can reduce/eliminate shark intrusion into the cages.
- Mortalities are a major issue for attracting sharks - need to develop collection cones for removing mortalities (like they use in salmon farms).
- Other cage design features, such as protecting the bottom of the net for YTK operations, may be effective.
- It is important to note that the industry has developed strategies for reducing the number of interactions with sharks - they are on the road to achieving best practice.
- The major issue that keeps being discussed is the lack of information on the status of shark populations. We need to look at:
    - Ways to assess population numbers
    - Implications of increases in fishing effort (capture/kills)
    - Need to keep in perspective/assess across the extraction industries i.e. are deaths from aquaculture significant when put into the bigger picture?
- There is a need for greater information on populations, movements and variations in distribution (across spatial and temporal scales).

<u>Group 4</u>
Daniel Kelleher (Aquafin CRC)
Sue Murray-Jones (DEH)
Patrick Hone (FRDC)
Ian Budge (OneSteel)
Lindsay Best (DEH)
Ross Belcher (DEH)
Timothy Green (UTAS)
Dos O'Sullivan (Australasia Aqua)
Joy McKechnie (Flinders Uni)

Main Points Covered

- Aquaculture cages do not appear to be attracting sharks to the region.
- We need to know to what degree the interactions are occurring.
- The ultimate aim is to not attract the sharks to the aquaculture cages.
- The major trigger attracting sharks are the mortalities in the cages.
- There are two main species of sharks involved (bronze whalers and white sharks):
    - One is protected (white sharks) and the other may become protected on a regional basis in the not too distant future.
    - What is an acceptable level of bycatch of these sharks (based on sustainability)? What is the level of mortality of sharks from aquaculture cf other causes? Need more reporting.
    - What should be an allowable catch? We need trigger levels or some sort of quota system. This is being looked at elsewhere e.g. Neil Gribble's work - for a fisheries situation, there has to be some form of allowable bycatch, even for a protected species (if not, could not fish). However, once this level is reached, fishing stops.
    - How can this be enforced (compliance)?
    - We have concerns about the increased targeting of bronze whalers, especially if it is around breeding areas.
- There are concerns about a lack of knowledge about the biology of these sharks. If we know when they are likely to be around we can take steps to protect cages. Bronze whalers seem to move along pathways in Spencer Gulf ... are these consistent, or do they vary from year to year?
- Need to look at the design of the cages: to improve strength and minimise the level of shark and seal break-ins.
- Can the cages be made of a combination of nylon and steel (to minimise weight and cost, without compromising on the strength)? What about finer steel with a plastic coating?
- Need to look at the placement of the cages (out of shark highways) to minimise the level of interaction.
- Why do tuna operators not use MarineMesh? (suggested answer: they may not be available in large enough configurations)
- Best practices. There is an urgent need for best practice guidelines. These need to include:
    - preventing and managing interactions
    - how to remove trapped sharks
    - mandatory reporting
    - data collection - what is a sustainable take on sharks?
- Planning and good data collection are the key issues:
    - tuna aquaculture has expanded closer to shark and seal habitats. This is a planning issue.
    - need to assess optimal policy for planning
    - is there a better place to locate cages?
    - how can we stop them interacting to the detriment of the sharks?

  - does it matter in terms of shark conservation? Maybe effort is better spent on lowering fishing bycatch? Again, need for better reporting to assess relative risks. Data collection imperative!
  - breakdown of interactions by sector needed e.g. commercial bycatch, tuna operations
  - anecdotal data needs to be considered.
- For individual farms using ISO standards system, good reporting should be built in.
- Tasmania - best practice is removing mortalities.
- Tow cages - perhaps cages should be fitted with a cod end with a gate? (20% of all tows observed some sharks).
- Information on projects funded to date, and results. What is available?
- Should look at salmon/tuna net design, and possibility of stiffening to make break-ins more difficult.
- Need acoustic listening stations around tuna cages.
- Need more information on biology and movement patterns.
- Project - need to pull together best practice guidelines for avoiding shark interactions with aquaculture, and how to deal with these interactions when they occur (when the sharks are caught in the cages).
  - data reporting should be mandatory.
  - advantage of ISO system – farmers committed to ISO have to adopt best practice guidelines where available.
  - how to keep updating best practice? Needs to be updated regularly.
  - should come from a group incorporating representatives from industry, DEH, PIRSA and training provider.
  - FRDC likely to fund, FarmBiz interested in funding training. SeaNet may be interested.
  - more biology/population estimates etc and patterns of use of coast are needed.

Prevention
- barriers
- location
- farm husbandry
- cage design
- new technology

Group 5
Anthony Cheshire (SARDI Aquatic Sciences)
Stephen Bedford-Clark (Stehr Group)
Martin Hernen (SA Maritime Finfish Farmers' Association)
Scott Hawkins (OneSteel)

Information
- Farm husbandry plays a key role.
- Learning shark movements (seasonal migrations) and behaviour are important for understanding the problem.
- Bronze whalers are a bigger problem because they hunt in packs, whereas white sharks are opportunistic (loners).
- There has been a potential increase in the effective fishing effort on bronze whalers - we must question if this will cause problems in the future.
- We need something like an AFMA observer program.
- Mulloway theory (stench).
  - Is the difference in shark response due to the YTK being stressed from disease? The stress response might be the attractor for sharks.

- Is it possible to submerge cages altogether, would this help?
- We must make sure that OH&S is not compromised.
- What are the consequences if a white shark is killed?
- What is the cost of improving sea cage design to reduce interactions?
- Need to resolve dolphin entanglement issues as well.

Issues

- How many bronze whalers are killed?
- Issues related to increased seal populations leading to possible increased interactions with seals.
- Effective husbandry can reduce interactions:
    - Removing mortalities from the cages
    - Develop mechanical techniques to remove mortalities, or alarms to tell when morts are on the bottom of the cage
- Legislation and compliance - need increased requirements for reporting. These need to be enforced.

Information Needed

- Shark movements and behaviour
- What is attracting the sharks to cages: live stock or mortalities?
- Do school fish feeding on waste feed initially attract the sharks?

<u>Short general discussion</u>

Martin Hernen (SA Maritime Finfish Farmers' Association)
It will take years to sort this out, the problem can't be fixed overnight.

Daryl Evans (Marnikol Tuna Farm)
Only 2-3 paragraphs are needed in best practice guidelines.

Tony Flaherty (MCCN)
It's important to look at what else is happening e.g. there's been work on tiger sharks in the tropics, and there are other things happening overseas. We should be talking to people overseas to determine best practice.

CLOSING REMARKS: JON PRESSER

PIRSA Fisheries

- This workshop has provided a lot of insight from industry, and raised (and addressed) many issues.
- The research conducted by Barry Bruce has also provided insight into shark behaviour.
  - It does outline that the more information you gather, the more questions are produced.
  - Ultimately it is hoped that knowledge gained about shark behaviour can be utilised by aquaculture operators to improve the safety of the farms and to minimise impacts to shark populations.
- The process of shark removal is a learning process - a work in progress.
- The ultimate aim is to develop strategies to minimise the level of interactions, and to appropriately deal with these interactions when they occur.
- Getting sharks out of cages is not rocket science, but it's not easy either. We need to keep trying different solutions.
- We should be looking at research in other locations throughout the world, and learning from them - this situation is not exclusive to South Australia.
- Adaptive management is vital. Information changes over time, and operators must be able to pick it up.
- We are grateful to all the speakers, especially industry, for giving their time and their perspectives.

SUMMARY POINTS: SUE MURRAY-JONES

I have attempted to summarise some of the common themes from the small group discussions.

SOME KEY POINTS

- Aquaculture cages do not appear to be attracting sharks to the region.
- Both sharks and pinnipeds can be a problem.
- The main factor triggering attacks is the presence of freshly dead fish in cages - this is a husbandry issue.
- Siting of cages. We need more information about patterns of shark movements in order to minimise interactions, or at least know when the main problems are going to occur. An excellent way of obtaining this would be the installation of listening stations around tuna cages, and fitting sharks with acoustic tags.
- Need for best practice guidelines.
- Interactions with bronze whalers are more frequent than with white sharks. Interactions vary with site, season, and operator.
- More information on shark numbers, distribution and behaviour is urgently needed.
- More data on interactions is needed: reporting needs to be improved.

MAIN CONCERNS RAISED

- What is the impact of professional shark catches on bronze whaler numbers? How many mortalities can shark populations stand? What is the population status of bronze whalers? We don't know.
- How can we encourage the one or two operators with poor husbandry to adopt best practice?
- How do we balance conservation with OH&S and economic concerns?
- More prevention needed, perhaps from looking at:
  - cage design

- shape of cages
- use of steel cages
- predator nets (but note dolphin issue)
- other methods e.g. Shark Shields
- developing remote collection methods for morts, or changes in cage design to make inspection/mort removal easier

THINGS THAT NEED TO HAPPEN

- Urgent need for best practice guidelines - should not be too costly to establish these.
- Industry need get information to public about what they are really doing.
- Joint development/evaluation of management technology needed.
- Information on stock status of bronze whalers and white sharks needed.
- Provision of rapid expert advice on removal when entanglements occur.
- Need better (and faster) reporting of interactions. A valid data set is needed, especially for Northern Spencer Gulf. Information needs to come from fishers and farms. Need to deal with concerns of operators about reporting interactions with wildlife if punitive measures are to be imposed if a protected species is killed.
- Install listening stations around cages to get information on movement patterns.
- Need assessment of risks to bronze whalers and white sharks from all sources e.g. relative risk of aquaculture cf fishing. Does it matter in terms of shark conservation? Maybe effort is better spent on fishing by-catch? Again, need for better reporting to assess relative risks.
- Need more cooperation between industry, researchers and regulators.

RESEARCH PRIORITIES

- Better data on sharks is a priority:
    - Shark populations - how robust are they? What is the population status of bronze whalers? White sharks?
    - What impact do current levels of interactions have on these populations?
    - Determine distribution and movement patterns of both bronze whalers and white sharks. What activities attract sharks? Are there movement pathways? How do they behave around cages?
- Development of best practice guidelines. Need to be developed by industry and non-government organisations, with input from government agencies. Need to have built in ways to evaluate, modify and update them. FRDC have expressed their willingness to consider a funding application for this. Farmbiz expressed interested in funding training in implementing a code. (*In subsequent discussions, Oceanwatch/SeaNet have expressed an interest in taking the lead in writing an application for funding and working with industry to develop such a code.)*
- Independent development/evaluation of shark repellent devices, working with relevant companies and industry.
- Changes in cage design to prevent interactions.
- Changes in cage design to make release efforts easier.

PARTICIPANT LIST

PARTICIPANT	**ORGANISITION**
Anthony Cheshire	SARDI Aquatic Sciences
Barry Bruce	CSIRO
Bob Lester	University of Queensland
Brian Jeffriess	Tuna Boat Owners' Association
Bronwyn Gillanders	Adelaide University
Carina Cartwright	PIRSA Aquaculture
Chris Ball	Conservation Council SA
Chris Pitney	Tony's Tuna Farm (R & D)
Daniel Kelleher	University of Tasmania
Daryl Evans	Marnikol Tuna Farm
David Ellis	Tuna Boat Owners' Association
David Mitchell	Huon Aquaculture
Dos O'Sullivan	Australasian Aquaculture
Graham Woods	DPIWE, Tasmania
Helen Croft	PIRSA Compliance
Helena Wescombe-Down	SeaChange Technology
Ian Budge	OneSteel
Ib Svane	SARDI Aquatic Sciences
Inayah Yasir	Flinders University
Janene Thompson	Flinders University
Jason Tanner	SARDI Aquatic Sciences
Jeff Buchanan	SARDI (tuna research farm)
Jian Qin	Flinders University
Jo Sadler	Consultant
Jon Presser	PIRSA Aquaculture
Joy McKechnie	Flinders University
Kate Miller	Adelaide University
Kate Rodda	SARDI Aquatic Sciences
Keith Jones	SARDI Aquatic Sciences
Ken Sanderson	Flinders University
Kirsten Rough	MG Kalis Group (now TBOA)
Lindsay Best	Natural and Cultural Heritage, DEH
Martin Hernen	SA Marine Finfish Farmers
Marty Deveney	PIRSA Aquaculture
Matias Braccini	Adelaide University
Matt Condon	OneSteel
Matthew Jeffrey	Rural Solutions SA
Maylene Loo	SARDI Aquatic Sciences
Michael Tokley	Abalone Association
Michael Wescombe-Down	SeaChange Technology
Milena Fernandes	SARDI Aquatic Sciences
Nigel Preston	CSIRO
Patrick Hone	FRDC
Paul Hastings	Aust. Marine Conservation Soc.
Peter Montague	Aquafin CRC
Rachel Lawrie	Australian Fishing Enterprises
Rebecca Paterson	Stolt Sea Farm
Richard Musgrove	SARDI Aquatic Sciences
Ross Belcher	Regional Conservation, DEH

Scott Hawkings	OneSteel
Serena de Jong	SARDI Aquatic Sciences
Sharon Drabsch	SARDI Aquatic Sciences
Stephen Bedford-Clarke	Stehr group
Stephen Madigan	PIRSA Aquaculture
Steven Clarke	SARDI Aquatic Sciences
Sue Murray-Jones	Natural and Cultural Heritage, DEH
Tim Green	University of Tasmania
Tom Bayly	Flinders University
Tony Flaherty	Marine & Coastal Community Network
Trent D'Antignana	Flinders University
Wes Ford	Dept. Primary Industries, Water and Environment, Tasmania
Will Zacharin	PIRSA Fisheries

PART 2: DISCUSSION PAPER ON RISKS TO GREAT WHITE SHARKS FROM INTERACTIONS DUE TO HUMAN USE OF THE MARINE ENVIRONMENT

Class	Chondrichthyes (Sharks, Rays and Chimaeras)
Order	Lamniformes
Family name	Lamnidae (Mackerel Sharks)
Scientific name	*Carcharodon carcharias*
Common names	White Shark, Great White, White Pointer

***Editor's note**: A national project (Bruce* et al. *2001) was developed to summarise information and clarify the population status of great white sharks, provide guidelines for conservation and management, collect biological data, etc. The results of this study can be found in Malcolm* et al. *(2001). It is not the intention of this discussion paper to reproduce large amounts of relatively easily accessible material. Hence, other than some basic ecology, only information relevant to threats, likelihood of occurrences in different areas, mortality and entanglements of sharks has been summarised below. The reader is referred to Malcolm* et al. *(2001) and the White Shark Recovery Plan (EA 2002) in particular, for more information, as well as other information sources cited in the reference list.*

ECOLOGY

1.1 Description

The great white shark is in the same family as the mackerel sharks. White sharks have a torpedo-shaped body; and are grey in colour on the upper body and white below. They have large serrated triangular teeth, and a distinctive keel along the body before a crescent shaped tail (EA 2002). White sharks grow to at least 6 m in length, and there are unconfirmed reports of specimens up to 7 m (Mollet *et al.* 2000).

1.2 Reproduction

Female white sharks mature at between 4.5 - 5.0 metres and attain a greater length and weight than males (Francis 1996). Males mature at a smaller size, at around 3.5 - 4 metres, about 12 or 14 years old. Minimum ages at maturity for females and males are estimated to be 18 and 10 years, respectively (Malcolm *et al.* 2001). This age at maturity is high compared to other sharks (Wintner and Cliff 1999). White sharks give birth to live young, which are about 130 cm in length at birth. Litter sizes range from 2-10. Weight at birth is up to 32 kg (Malcolm *et al.* 2001). Size at sexual maturity is known to vary widely (Pratt 1996).

White sharks are naturally low in abundance, have a late age at maturity (18 years for females), and tend to breed only every 2-3 years (Malcolm *et al.* 2001). This means their overall fecundity is relatively low, and they produce relatively few young during their life span. These characteristics, allied to slow growth, make this species particularly susceptible to over-fishing.

1.3 Size/Age

Little is known about age and growth of white sharks. Few sharks are ever caught in the same place (Wintner and Cliff 1999), and the fact that different stocks may grow at different rates adds to uncertainty about age at different sizes. There is considerable variation in length for numbers of growth rings in vertebra (a common method of estimating growth). It is not even clear if growth rings are annual, or instead related to migrations or reproductive stress (Wintner and Cliff 1999). Available data place white sharks into a group of sharks with very slow growth (Wintner and Cliff 1999). While age estimates have not yet been adequately validated, Australian data are consistent with other age and growth studies from California and South Africa (Malcolm *et al.* 2001).

1.4 Distribution

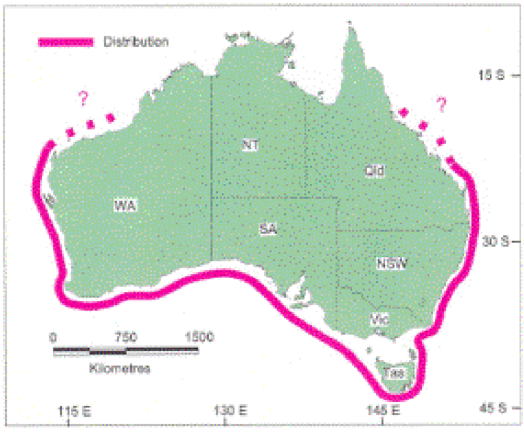

Figure 24. Distribution of white sharks in Australian waters.
From Malcolm et al. *2001.*

White sharks have a worldwide distribution. In Australia they have been recorded from central Queensland to North West Cape in WA (Fig. 24), but are more common in southern waters. They have been recorded from all states except the Northern Territory (Pogonoski *et al.* 2002). They appear to reach their maximum abundance in South Australian waters, but this may be an artefact of sampling effort. White sharks are generally encountered on the continental shelf (often close inshore) but have been recorded down to 1280 m and off oceanic islands (Last and Stevens 1994). They have been recorded well offshore (Anderson and Goldman 1996). White sharks are mainly caught around the southern half of Australia, and there are more captures in SA than other states (Malcolm *et al.* 2001).

In waters along the continental shelf, white sharks generally occur near the surface or at the bottom from 16 to 32 metres depth, rather than mid water depths (Goldman *et al*. 1996).

Studies at pinniped colonies indicate that white sharks appear to be largely transient, with a few longer-term residents (Klimley and Anderson 1996, Strong *et al.* 1992). Individuals are known to return to feeding grounds annually on a seasonal basis. Some populations appear to be small and highly localised, with a high degree of site attachment. For example, in one study in the Spencer Gulf area, 36% of sharks were resighted always in their original location (Strong *et al.* 1992). The resighting of individual white sharks at particular localities is well documented in other areas of the world (Bruce 1995).

White shark populations appear to segregate according to size and gender, and to reproduce. The degree of segregation can fluctuate with location and over time (Strong *et al*. 1996).

There are a number of locations that appear to be seasonally important for juveniles. These tend to be close to shore in the Great Australian Bight; adjacent to Victor Harbor and the Coorong (SA); along Ninety Mile Beach and off Portland in Victoria; and between Newcastle and Port Stephens in NSW (Malcolm *et al.* 2001). The juvenile sharks appear to be associated with seasonal movements of fish.

Sharks from all size classes (small, <250 cm; medium, 250-450 cm; large, >450 cm) were reported from most sites in SA, with the exception of the Neptune Is, The Pages, and the Adelaide area, where small sharks were not reported (Bruce 1992). Small sharks were most common in upper Spencer Gulf and the West Coast (Ceduna, Streaky Bay). Medium sized sharks dominated all reporting sites except Ceduna, where large, usually female, sharks predominated (Bruce 1992). The Nuyts Archipelago has been suggested to be a pupping ground for white sharks, and small specimens are commonly encountered between Streaky Bay and the Head of the Bight (Malcolm *et al.* 2001).

Genetic data suggest that females are less likely to disperse widely than males (Pardini *et al.* 2001).

White sharks cruise at about 3 km per hour, although they can swim much faster for short periods. Tagged individuals have been recaptured up to 1400 km from the point of tagging. Sharks are often resighted at the location where they were tagged; however, their overall movement patterns are still unknown (Malcolm *et al.* 2001).

1.5 Ecosystem Role

White sharks are top predators and hence are presumed to play an important role in the marine ecosystem. This might include keeping the population of their prey in check, and aiding the maintenance of genetic fitness of its prey. It is difficult to predict what impact a continued decline of white sharks could have on the ecosystem. We do know that removing links from the food chain can have enormous consequences that were only predictable with the benefit of hindsight. White sharks have few natural predators.

1.6 Diet

Juvenile white sharks tend to be associated with snapper aggregations off Ninety Mile Beach and Portland in Victoria. Snapper move into this area between October and April. Other juvenile habitat areas may also be associated with abundant fish populations (Malcolm *et al.* 2001). White sharks of all sizes occur in areas where snapper are abundant.

Marine mammals, and other species of Chondrichthyes (rays, sharks and chimeras) predominate in the stomach contents of white sharks (Table 1) (Malcolm *et al*. 2001). Adult white sharks are commonly associated with seal and sea lion breeding sites (known locations of breeding colonies are shown in Fig. 25).

Figure 25. Known seal and sealion breeding sites in South Australia.
Data from DEH files.

Stomach Contents	% of sharks
Marine mammals	46.9
- Dolphins	18.4
- Pinnipeds	28.6
Rays, Sharks and Chimeras	40.8
- other shark species	24.5
- rays	16.3
- chimeras	2.0
Teleosts (bony fish)	28.6
Cephalopods (eg squid, cuttlefish)	14.3
Crustaceans (eg crabs)	4.1
Birds	2.0

Table 1. Stomach contents of white sharks. "% of sharks" is the proportion of sharks which contained the listed prey item. Note that the % column does not add up to 100, as sharks often had more than one prey item in their stomach. Data from 49 sharks, described in Malcolm et al. *2001.*

White sharks do not feed continuously; a large meal such as a seal may last a medium-sized shark for a week (Bruce 1995). White sharks appear to have an age/size preference for certain foods, with juvenile (<2.7 m) sharks preferring fish (Malcolm *et al*. 2001). The diet of larger sharks tends to include other sharks, rays, reptiles, sea birds and marine mammals (EA 2002). Some larger white sharks may also continue to prey on finfish (e.g. snapper). In general, seals and sea lions appear to be the preferred prey for adult white sharks.

Large white sharks will actively hunt small cetaceans, and will scavenge on available carcasses of larger species (Long *et al.* 1996). Scavenging behaviour has been widely observed on Southern Right Whale carcasses in SA. Up to seven white sharks were seen feeding on a dead Right Whale near Victor Harbor in 2002 (pers. obs., SMJ).

Spencer Gulf and Gulf St. Vincent are important feeding grounds for subadult sharks, although large adults and small juveniles also utilise this area. The Gulfs have abundant dolphin and finfish populations (Malcolm *et al.* 2001).

1.7 Protection

In Australia, white sharks are fully protected under Commonwealth legislation. They are listed as Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC). White sharks are also fully protected in the coastal waters of Tasmania, Victoria and WA; protected in the coastal waters of NSW and Queensland with exemptions for beach meshing; and protected in SA apart from an exemption under the Fisheries Act 1982 to take individuals perceived as being dangerous (for details of legislation see EA 2002).

Internationally white sharks are listed as Vulnerable on the IUCN Red List (IUCN 2003) and are protected in various other countries (EA 2002). The assessment of Vulnerable was reached because of this species' biological characteristics (e.g. late maturation, very low fecundity, slow growth) and declining catches in many areas. A global status of Endangered may prove to be more accurate (Pogonoski *et al.* 2002).

White sharks are listed under the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES) in Appendix III. This requires Australia to issue CITES permits to allow trade. This assists in regulating trade in specimens (EA 2001). Other moves to protect sharks generally (and hence white sharks) include the preparation of an International Plan of Action for the Conservation and Management of Sharks, which was adopted by the FAO in 1999. The objective of the plan is to ensure the conservation and management of sharks and their long-term sustainable use (FAO 1999). The plan encourages the adoption of a National Plan of Action by any country where sharks are regularly caught, either in their waters, or by their vessels. Australia released such a plan in May 2004 (Shark Advisory Group and Lack 2004).

In 1994, SA Fisheries removed white sharks from the list that commercial marine scalefishers could take (Presser and Allen 1995).

THREATS

The major threats to white shark populations include:

- incidental catch of white sharks (bycatch);
- overfishing of prey species e.g. snapper;
- shark control programs;
- direct targeting for trophy and parts;
- habitat degradation.

These threats are largely the result of human actions. Although natural fluctuation in prey abundance could be a factor, the species' ability to switch prey items help minimise this threat.

The main risk to white sharks in Australian waters is from commercial fishing, where white sharks are taken as bycatch. Up to 300 sharks per year are thought to be killed in commercial fisheries (National White Shark meeting, 1996, cited in Pogonoski et al. 2002). Additional threats are from shark control programs in NSW and Queensland waters. Recreational fishers occasionally catch this species in all States. They may also be caught in finfish aquaculture cages (both farms and tow cages), as well as in crab traps and rock lobster pots (Malcolm et al. 2001). The degradation of inshore waters used as nursery areas could also have an effect on breeding and/or juvenile survival.

Because white sharks appear to show some degree of site fidelity, the species is highly vulnerable to over-exploitation or local eradication. Evidence suggests they can easily be exploited to the point of extinction, even where relatively few are removed from an environment. For example, research off the Farallon Islands suggested that the removal of just four white sharks greatly reduced, and possibly eliminated, the entire local population (Ainley *et al.,* cited by Cailliet *et al.* 1985). Because of their vulnerable status, even the loss of a few animals, particularly females, may present a serious risk to local populations.

2.1 Commercial Fishing

2.1.1 BYCATCH

Bycatch is generally defined as that part of the catch which is captured incidentally to the species towards which there is directed effort (Saila 1983). White sharks are caught incidentally in fisheries that use longlines, hook-and-line, gillnets, fish traps, and nets of all types. Ten percent of white sharks seen in a SA study were observed bearing short remnants of longlines or gill nets (Strong *et al.* 1996). In lower Spencer Gulf, as many as 30% of white sharks seen had evidence of a previous encounter with commercial fishing gear (Bruce 1992).

In Australia, white sharks are caught as bycatch in a number of fisheries including the Commonwealth Gillnet, Hook and Trap fishery, various longline and set fisheries, the tuna farm industry and the recreational gillnet fishery (Malcolm *et al.* 2001). Catch rates and interactions are highly variable between fishers, regions and years. Catches may exceed 360 in some years. About 40% of captured white sharks are released alive, but post-release survival rates are unknown (Malcolm *et al.* 2001).

In 1990 several fishers reported the capture of large numbers of small white sharks in the Great Australian Bight (GAB) (Malcolm *et al.* 2001). This may be linked to seasonal and inter-annual effects of distribution and abundance of prey such as snapper and marine mammals that are independent of white shark populations. In addition, marine animals are well known to be prone to variation in recruitment, with occasional strong year classes occurring.

There is likely to be considerable error associated with an estimate of annual GW catch for fisheries based on the available data, given the temporal and spatial variability of white shark captures as well as changes in fishing effort, fisher behaviour and experience (Malcolm *et al.* 2001).

There are some common themes. Variability in sightings is high, as in variability in catches, both spatially and temporally. For some reason, variability is particularly high in the GAB e.g. one GAB fisher generally caught one white shark per year but in 1995 caught 6-8 individuals (Malcolm *et al.* 2001). Such differences are possibly due to variations in currents and/or availability of prey species.

2.1.2 COMMONWEALTH FISHERIES

2.1.2a Gillnet, Hook and Trap Fishery

The South East Non-Trawl fisheries are now called the Gillnet, Hook and Trap Fishery (GHTF). The GHTF now incorporates the Southern and Western Shark Fisheries (SSF, WSF).

The majority of recorded catches of white sharks by commercial fishers were from the SSF and WSF. Malcolm *et al.* (2001) estimated that around 74 white sharks per year are caught in the SSF, and 25 in the WSF (note that there are many assumptions in these estimates, and large variances).

Only three captures were reported to Environment Australia between the protection of white sharks under EPBC in 1999, and the review published in 2001 (Malcolm *et al*.). Two were in Commonwealth waters, reported by CSIRO, and the other was captured in a tuna tow cage, reported by PIRSA to Environment Australia (now the Department of Environment and Heritage) (Malcolm *et al*. 2001).

Discussions with fishers indicated that the highest capture rates in both fisheries occurred in the GAB, where catches of 2-5 white sharks per year were reported by most fishers (Malcolm *et al.* 2001). Some fishers working between Streaky Bay and the Head of the Bight reported rates of up to 12 per year. In 1995, one WSF fisher reported catching at least eight, but possibly up to 20 white sharks in the GAB. The majority caught were small juveniles (mean length 2.6 m), which were taken in water less than 60 m depth (Malcolm *et al*. 2001).

Catch rates between Ceduna and Coffin Bay were slightly lower (1-2 per year) than near the Head of the Bight (Malcolm *et al.* 2001). Catch rates from Kangaroo Island to Robe are lower than to the west and highly variable. Juvenile white sharks are caught between Victor Harbour and the Coorong. There were lower catch rates in Victoria and Bass Strait than further west (Malcolm *et al.* 2001).

Release rates appear to have increased since the mid-1990s, and around 50% of white sharks caught in the WSF are released (Malcolm *et al*. 2001).

2.1.2b Australian Fisheries Management Authority (AFMA) data for Commonwealth managed fisheries

Data provided by AFMA for this project provided information on 45 reported interactions between 1998 and 2003 inclusive (Tab. 3, AFMA catch and effort databases). The geographical locations of these interactions are shown in Fig. 26. This map shows where sharks are caught, hence obviously reflects fisher effort as well as giving some indication of the location of white sharks.

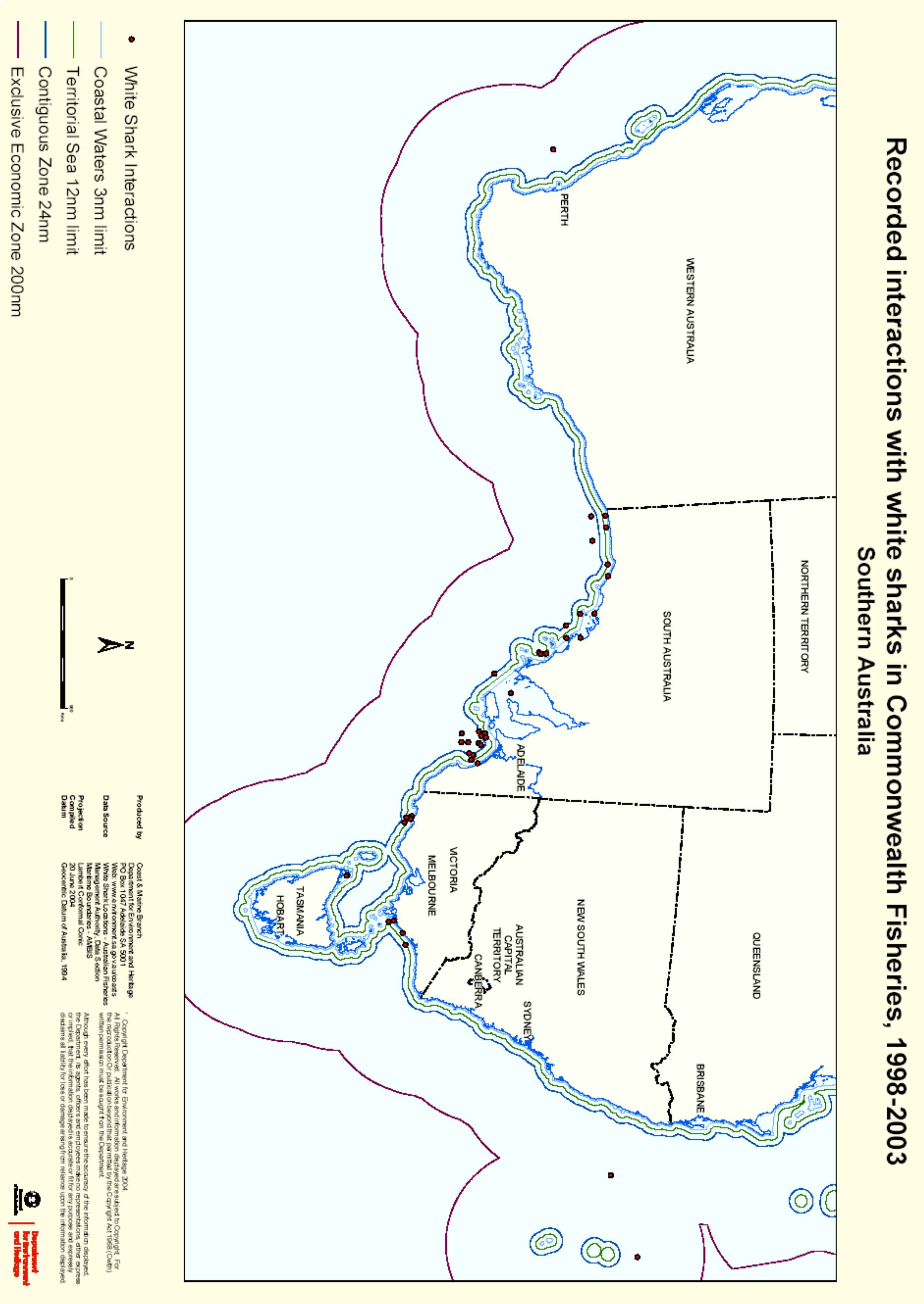

Figure 26. Interactions with white sharks in Commonwealth fisheries, 1998-2003.
Data from AFMA catch and effort databases

Data come from two sources: 1. The compulsory GNO1 logbook filled out by fishers operating in the Commonwealth Gillnet, Hook and Trap Fishery that is under the management of AFMA and joint State jurisdiction. This includes the SSF and WSF. The logbook was modified in July 1999 (GN01A) and now specifically mentions white sharks. Both logbooks contain a specific section for interactions with wildlife. 2. Data on pelagic longline fisheries come from the compulsory AL05 (and previous AL04) logbooks. Both logbooks make provision for the recording of wildlife interactions, with specific reference to white sharks. There are three tuna longline fisheries; the Eastern Tuna and Billfish Fishery; and two that are usually managed together, the Southern and Western Tuna and Billfish Fisheries.

Overall, mortality directly resulting from these interactions over six years was at least 20%, with only nine sharks in 45 recorded interactions being reported as dead (Table 2). No data are available on survivorship. A number of sharks were reported as "being sluggish" when released, and for many no information is given other than being coded as "alive", sometimes with a comment "released alive", or just "released." Mortality is likely to be higher than recorded.

There are variations in interaction rates between years. By far the most interactions were in 1999, when the total of 17 interactions was more than double the number reported in other years. While the introduction of the new GN01A logbook may have been a factor in increased reporting, the majority of interactions were reported before the introduction of the new logbook in the second half of 1999 (J. Garvey, AFMA, pers. comm.). The difference in the interaction rate could be due to a number of causes: increased reporting due to media interest prior to the new logbook; increased numbers of sharks; a change in the numbers of prey species; etc.

		Fishery type			
year	**n**	**GN**	**LLP**	**BL**	**HL**
1998	3(3)	3	0	0	0
1999	17(7)	16	1	0	0
2000	8(1)	6	1	1	0
2001	6(0)	6	0	0	0
2002	5(0)	5	0	0	0
2003	6(1)	3	1	1	1
Totals	45(9)	39(6)	3(2)	2(1)	1(0)

Table 2. Interactions with white sharks in Commonwealth Fisheries between 1998 and 2003. n is the total number of interactions for each year. Fishery types are: GN, gillnet; LLP, pelagic longline; BL, demersal longline; HL, handline. Numbers in brackets are number reported dead. Data from AFMA catch and effort databases.

Of the 45 interactions recorded, by far the majority were caught in gillnets. There were 39 interactions with gillnet fishers, which accounted for 87% of all interactions. Of these, six sharks (15.4%) were reported dead. Pelagic longline fisheries (all for tuna in this data set) accounted for only 6.7% of interactions. Two interactions (4.4%) were reported for demersal longline fisheries while handline fisheries reported a single interaction.

While mortality rates appear highest in the demersal and pelagic longline fisheries, the numbers of interactions are very small, and the differences are unlikely to be significant. Note that over the past two years, wire traces have been banned in the Southern and Western Tuna and Billfish Fisheries. AFMA considers it is unlikely that a white shark would be caught and landed on a longline without wire (Steve Bolton, AFMA, pers. comm.).

2.1.3 South Australian Marine Scalefish Fishery (MSF)

"Bycatch" in South Australian fisheries databases is defined as any catch of species that is not targeted. Hence, data are only collected for other commercial species that are landed and sold, in addition to the targeted catch. Hence no records are collected on other, non-commercial species, including white sharks. This needs to be addressed as a matter of urgency by SA agencies.

2.1.3a Gill Nets

Catches range from negligible to high depending on the fisher and the location fished.

Two MSF fishers without Commonwealth SSF licences operating in the South Australian Gulfs responded to questionnaires. One fisher had caught two white sharks in 32 years (in 1994 and 1995). The other had not caught any (Malcolm *et al.* 2001).

Other gill-net fishers are also known to catch white sharks, e.g. two white sharks were caught near Victor Harbor in 1999 (Malcolm *et al.* 2001). Another fisher in the eastern GAB caught between 12 and 14 white sharks in 1999, although there may have been some intentional targeting (Malcolm *et al.* 2001).

2.1.3b Longlines and Handlines

White sharks have been caught by longliners targeting shark and snapper on the west and southeast coasts of SA, as well as in Gulf St Vincent and Spencer Gulf where they are associated with snapper grounds. Large specimens (>4.5 m) are occasionally taken in the upper gulfs. Catches range from negligible to high depending on the fisher and the location fished.

Rates of catches with handlines have become much smaller since the fishery has changed substantially from longlines to handlines (McGlennon and Jones 1999).

White sharks swimming around snapper boats are unlikely to be caught using handlines, however they may be intentionally shot or hooked with heavy gear. The extent of this is unknown (Malcolm *et al.* 2001); however, they may also be entangled e.g. a 5.35 m shark was entangled and drowned in commercial longlines near Port Germein, SA, in July 1998 (Fig 27a). It was thought to be taking other sharks off the lines, but was obviously also feeding on snapper, as a whole 8 kg snapper fell out of its mouth when being brought ashore (Fig 27b).

Based on estimated catch rates and numbers of longliners in each area, Malcolm *et al.* (2001) estimated that approximately 16 white sharks per year are caught on average. There is high variability in catch rates between fishers, and the overall catch rate could be considerably higher than estimated. A proportion of these sharks either are or could be released, depending on location and method (Malcolm *et al.* 2001). Expected mean catches per year by area are summarised in Table 3.

Area fished	n	Average rate per year (SD)	Expected range
Gulfs			
Upper SG	6	1.00 (1.20)	0- 2.2 pa
Lower SG	3	0.26 (0.26)	0 - 0.5 pa
GSV	1	0.16*	0.16*
West Coast			
Streaky-Ceduna	3	0.16 (0.16)	0 - 0.3 pa
KI - Pages	1	0.30*	*

Table 3. Estimates of longline catch rates in the SA Marine Scalefishery.
*N= no. of fishers. Figures in brackets are standard deviations (SD). SG = Spencer Gulf; GSV = Gulf St Vincent. * average/range not calculated - only 1 record available. After Malcolm* et al. *2001.*

2.1.4 OTHER COMMERCIAL FISHERIES

Charter, hook and longline snapper fishery, Victoria: Juvenile white sharks are associated with snapper grounds from Corner Inlet to Lakes Entrance during the snapper season (October to April). Small white sharks were caught prior to protection, with one fisher reportedly catching 39 white sharks in 11 years (Malcolm *et al.* 2001).

Inshore scalefishery, Tasmania: This fishery includes gillnetting, line fishing and seine netting. Detailed records were available for 13 white sharks caught in this fishery by gillnetting: six were dead on capture, five were killed, and two were released (Malcolm *et al.* 2001). This is unlikely to be an accurate reflection of the numbers caught in this fishery, as only a few catch records are available. Note that the inshore commercial gillnet effort in Tasmania is exceeded by recreational sector (Lyle 2000).

Ocean haul fishery, NSW: Small specimens (1.8 - 2.2m) are occasionally taken although not in all locations or by all fishers. As nets are hauled and not set, it should be possible to release white sharks alive in good condition (Malcolm *et al.* 2001).

Demersal longline and other inshore fisheries, NSW: Lines are set overnight. Captures of white sharks are irregular and total numbers caught are unknown.

Crustacean trap fisheries (all states): There are five records of white sharks being entangled in the float ropes of crab nets and rock lobster pots (Malcolm *et al.* 2001).

Demersal trawling (all states): Small numbers may be caught; however, moves to use seal exclusion devices in many fisheries should minimise entanglements.

Tuna longlining: No white shark captures have been reported by observers on Japanese tuna longline vessels fishing in Australia's Exclusive Economic Zone. Currently there is no observer program on domestic tuna longliners (Malcolm *et al.* 2001).

Set or drum lining (all states): These have been used to target larger sharks for fins, meat, bait or teeth by both commercial and recreational fishers. There have been no reported catches of white sharks. It is usually an incidental and minor part of a fishing operation. However, in some cases this method has been used to target a specific (nuisance) shark. Historically, drum lines have been used in SA to specifically target white sharks and to lessen shark predation on longline catch (Malcolm *et al.* 2001).

Other: Some rock lobster fishers have reportedly set shark lines overnight to capture sharks for bait. The percentage of rock lobster fishers that carry out this practice is unknown. The number of white sharks caught is also unknown (Malcolm *et al.* 2001).

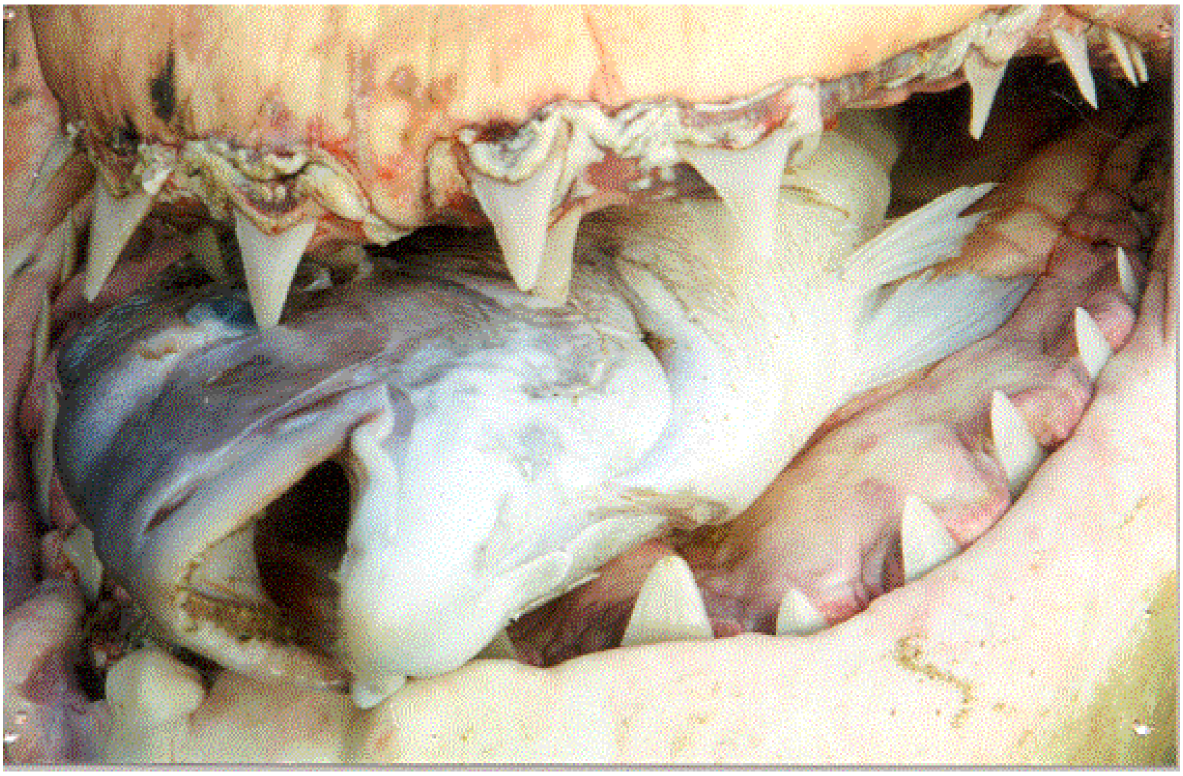

Figure 27. (a) White shark caught by commercial longliners. (b) Last meal: 8 kg snapper. Location: Near Pt Germein, Upper Spencer Gulf. Photos: Aaron Hanson, PIRSA

2.1.5 CHANGES IN COMMERCIAL FISHING PRACTICES

There have been reductions in fishing effort in the commercial shark fishery in southern Australia over the least 15 years, which is likely to have lowered in the number of white sharks taken. There has been a reduction in the amount of net permitted per fishing operation in the SSF. In WA there has been significant reductions in effort during the 1990s through gear reduction (Malcolm *et al.* 2001).

Fishing gear is now made of lighter monofilament polyamide webbing, which can be broken by larger sharks. Mesh size has also decreased since the early 1970s, becoming more selective towards catching smaller sharks (Malcolm *et al.* 2001).

Net height has increased in the SSF, which has had the benefit of separating the head and foot lines. Some fishers believe, however, that increasing the net drop has given the net a bigger "belly" and increased the chance of entanglement. This will depend on how tightly the net is strung onto the head and foot-line and how much floatation is provided to the headrope (Malcolm *et al.* 2001).

Soak times have also decreased in some areas. Commonwealth fishers working out of Robe now usually set for 4-6 hours rather than 8-10 hours. This increases the quality of the target catch as well as ensuring that any white sharks are more likely to by found alive (Malcolm *et al.* 2001).

Changes in the MSF in South Australia have probably also had some benefits. These changes have included reductions in longline and handline effort since the 1980s. In 1987/88, gear restrictions were imposed on the longline fishery with a maximum of 400 hooks per licence being permitted (McGlennon and Jones 1999).

There has been a closure to shark gillnetting and shark long-lining within 3 nm of the Victorian coast in ocean waters since 1988. This closure may provide refuge for small white sharks at a size when they may be most susceptible to capture in nets. This closure also includes areas around seals and sea lion colonies where large white sharks aggregate to feed (Malcolm *et al.* 2001).

A ban on monofilament gillnets in NSW has reduced incidental white shark captures in that state. Shark fishing is prohibited in Western Australia from Shark Bay to NW Cape (Malcolm *et al.* 2001). This was intended to protect breeding stocks of whaler sharks, but incidentally protects white sharks.

2.2 Recreational Fishing

2.2.1 GILL NETTING

Recreational netting is only permitted in Tasmania and WA. Fishers in Tasmania may use two grab-all nets. In 1999, approximately 10,000 recreational fishing licences included an endorsement for at least one net. There is the potential for 370 km of grab net to used on the east coast of Tasmania alone (Lyle 2000).

Over 75% of nets are set and fished overnight, with at least 25% having soak times over 24 hours (Lyle 2000). New management proposals include restrictions on soakage times (DIPWE 2000).

At least 24 white sharks have been reported as caught in recreational nets in Tasmania since the 1950s, although the actual number is expected to be considerably higher (Black 1999, unpublished report, cited in Malcolm *et al.* 2001). Only one shark was reported to have escaped and none were released. In at least five cases the shark was killed, usually by shooting. At the present time, there is no formal requirement to report recreational capture of white sharks other than the fisher surrendering the shark (if dead) to police (Malcolm *et al.* 2001).

Recreational netting is permitted in most marine waters of WA, but must be within 800 m of low water mark. Effort is considerably less than in Tasmania (Malcolm *et al.* 2001).

2.2.2 GAME FISHING

The Game Fishing Association of Australia recorded a total of 183 white sharks caught in NSW between 1960 and 1995 (mainly from the Sydney region). In recent times the number of white sharks captured in NSW has plummeted to an average of about 1.8 per year (Pogonoski *et al.* 2002).

Sport fishing for white sharks was at its height in South Australia during the 1950s. Most sharks were between 50 and 200 kg (Pepperell 1992). Large sharks were captured around pinniped colonies in locations such as the Pages, Dangerous Reef, Sir Joseph Banks Group, Streaky Bay and Ceduna (Bruce 1992). A total of 171 white sharks were landed by the Game Fishing Club of South Australia (GFCSA) from 1938-1990 (Bruce 1992): however, only 45 of these were landed in the period 1961-1990 (Pepperell 1992). The ratio of white sharks to other shark species dropped from 1:22 in 1960 to 1:1651 in the 1980s as white sharks virtually disappeared from game fish records (Pepperell 1992).

Game fish captures of white sharks (prior to protection) declined by 86% in SA between the 1950s and the 1980s, and by 97% in NSW. The numbers caught per year dropped from around 25 pa in the 1950s, to 1.4 pa (Pepperell 1992). Catch rates appear to be relatively stable over the last decade (Malcolm *et al.* 2001).

2.3 Shark Control Programs

Several states have shark control programs. These represent a major threat to white sharks.

In Queensland, 670 white sharks have been caught in the Queensland Shark Control Program since 1962 (Pogonoski *et al.* 2002). During the first 20 years of beach meshing in Queensland an average of about 20 white sharks were caught per year, but this has dropped to an average of about 10 per year over the last 10 years (EA, 2002). The majority of white sharks were caught with drumlines, while the remainder were caught with nets (Pogonoski *et al.* 2002).

In NSW, where beach meshing is employed, 517 white sharks were caught between 1950 and April 2000, averaging 10 per year over the whole period and five per year over the last 20 years (D. Reid, pers. comm.; cited in Pogonoski *et al.* 2002). These have included a number of juvenile white sharks. The size distribution of white sharks caught has shown a shift to smaller sized sharks (<2.25m) in catches over time (Records of the National White Shark meeting, 1996, in Pogonoski *et al.* 2002). Of 227 white sharks for which status was recorded, 105 (46%) were alive when found (Malcolm *et al.* 2001).

Catch rates have declined by approx 75% since the 1960s, and by 50% since the 1950s in the Qld and NSW shark control programs respectively. (Malcolm *et al*. 2001).

2.4 Aquaculture

White sharks are occasionally captured in tuna tow cages and farm cages. For example, there were three confirmed captures and one unconfirmed in 1999 alone (Malcolm *et al*. 2001). In total, there were nine confirmed captures by the tuna farming industry over a period of about five years prior to 2001. In six of these cases the shark was killed. In three cases the shark was already dead (Malcolm *et al*. 2001). Another two white sharks were shot after entering tuna cages in October 2002 and January 2003 (H. Croft, PIRSA, pers.comm.). Malcolm *et al*. (2001) noted that there were unsubstantiated reports of up to 10-20 captures of white sharks by the tuna farm industry prior to the publication of their review, with multiple interactions each year. Interactions are often not reported, despite the legislative requirement to do so. In addition, records do not appear to be kept in any systematic way by PIRSA, and this issue needs to be addressed.

Bruce (1998) suggests that white sharks are the least common of sharks likely to interact with farm operations; however, there was general agreement at the Shark Interactions with Aquaculture Workshop (see proceedings in the first half of this document) that white sharks are the species most likely to cause problems for tuna farms. White sharks are not a major problem for tuna tow cages.

White sharks caught in tuna cages have ranged in length from 3.0 to 5.0 m and have been both male and female. Of the three white sharks known to have entered tuna cages in the past 12 months (one in June 2003 and two in May 2004), all were successfully released (see Appendix 1).

There are other two reports of efforts to release white sharks from inside tuna cages, prior to the SARDI release described in the attached Workshop notes. In one instance (anonymous report) the individual was found lying in poor condition on the bottom of the cage. A rope was tied around its tail and it was hoisted out of the cage where it subsequently sank. Details of the second instance were unavailable (Malcolm *et al.* 2001).

2.5 Tourism and Cage Diving

Five permits for shark cage diving operators have been issued in SA; however, only two are currently operating. The White Shark Cage Dive Operators Association have developed a draft Code of Practice, restricting sites and access times.

Operators anchor on site and attract sharks to their vessel using fish based berley (chum) and baits. Use of mammal products for berley is prohibited. Most effort is concentrated on North Neptune Island.

These operations not directly threaten white sharks but may indirectly limit the recovery of the population. Berleying to attract sharks may induce individuals to remain in an area longer than they normally would, and also encourage them to associate food and boats and humans. It may also result in higher mortalities to adjacent seal/sea lion colonies as a consequence of the increased presence of white sharks.

Tourism may also disturb the interactions between white sharks and their prey behaviour. The effect of boats on sharks and marine mammals needs investigation; however, some cage diving is contributing to data collection for further research (Malcolm *et al.* 2001).

An index of abundance using baiting has been developed and yielded a rate of 0.035 sharks arriving per hour of baiting (Strong *et al*. 1996).

2.6 Intentional Killing

Historically, targeting sharks at whaling stations up till the 1970s was likely to have killed many white sharks.

There are many anecdotal reports of both recreational and commercial fishers catching or shooting white sharks, often because the shark has disrupted fishing either by stealing catch or dispersing the target species. The total number of sharks killed is unknown but the incidence is hopefully decreasing with changing attitudes (Malcolm *et al.* 2001).

There is also anecdotal evidence that, when a white shark attacks a human, "vigilante" action in the local region may be responsible for the deaths of a number of sharks. This was part of the rationale behind allowing an exemption to the Fisheries Act (1982) in SA to allow specified persons to "catch kill or destroy White Pointer

Shark" (*sic*) under specific conditions (unpublished files, SA Dept Envt and Heritage).

2.6.1 Body Part Trade

White shark body parts can be of considerable value. There are reports of up to $5,000 paid for jaws in Australia, and about $500 for single teeth (Malcolm *et al.* 2001).

People can buy and sell white shark parts without requiring access to an intermediate dealer by trading on the Internet. There is a black market trade in white shark parts from sharks captured since protection. A number of fishers agree that illegal jaw selling is still occurring in Australia (Malcolm *et al.* 2001). One fisher reportedly caught 14 to 16 white sharks in South Australia in 1999 and sold their jaws through the Internet. There are other unconfirmed reports of fishers setting drum-lines targeting white sharks for jaws and teeth in southern Australia (Malcolm *et al.* 2001). There is also trade in white shark fins and meat in Asia (EA 2002).

Fishers generally target the larger sharks for their teeth and jaws, which could have a significant impact on population numbers in the long term. As female white sharks reach sexual maturity at approximately 4.5 to 5 metres long, compared to males that reach sexual maturity at smaller sizes, it is the reproductively active females and larger males that are being targeted. This has obvious implications for effective population size, which for this species would be heavily dependant on the number of mature females.

Trade in white shark parts has been regulated under a permit system since the addition of white sharks to CITES Appendix 111 in 2001 (EA 2002). Only one permit has been issued since, in 2002. The permit was for exhibition purposes and included a stuffed shark, jaws and some teeth (Wildlife Management Database; DEH, pers.comm. N. Ellis, 2004)

2.7 Habitat Degradation and Ecosystem Effects

Oceanographic features such as fronts and thermoclines may produce discontinuities. A seasonally dominant frontal zone at the mouth of Spencer Gulf and shelf waters separates inshore and offshore islands. Marked discontinuities in physical (e.g. temperature, salinity and nutrient levels) and biological parameters (e.g. larval recruitment, availability of prey species) occur across this zone and may act to limit movements of white sharks in the area. The reversal of wind stress during autumn and winter, combined with seasonal cooling of Gulf waters, leads to the resumption of water exchange between Gulf and shelf waters (Strong *et al*. 1996).

The pattern of segregation by sex varies in space and time. The gulfs appear to be primary areas for juveniles. Female white sharks were most abundant at "inshore" islands in Spencer Gulf in winter, while males tended to predominate at islands further offshore in summer. Interestingly, with rare exceptions, winter is the only time when mixing of male and female white sharks occurs, which suggests that the frontal zone mentioned above may be a factor (Strong *et al*. 1996).

2.8 Total Abundance and Mortality Estimates

In April 1999, CSIRO Marine Research began a national project on white sharks in Australian waters, funded under the Natural Heritage Trust (NHT). The project had wide reaching aims, including the clarification of the population status of white sharks in Australian waters. This study is described in Bruce *et al.* (2001), and the results given in detail in Malcolm *et al.* (2001).

Data for the NHT project included phone surveys of fishers and fisheries compliance officers, logbooks, shark control programs and capture records, etc. General sighting data from a number of sources were also collected and logged.

Malcolm *et al.* (2001) made some estimates of total mortality, and these have been included in Table 4. These are rough estimates. Note that the number of captures does not equate to total mortality. Approximately 40% of captured white sharks are released. This proportion released varies greatly between fisher, fishing method and fishery. The percentage surviving release is unknown and may be low, especially for sharks released in poor condition.

The relative frequency of shark bites on pinnipeds at haul out sites over 13 years on Kangaroo Island, SA, has also been developed to provide a crude measure of white shark activity and hence abundance (Malcolm *et al.* 2001). Similar data has been used to infer changes in white shark abundance off the Californian coast (Long *et al.* 1996).

In total, an estimated average of 201 white sharks are captured per year in Australian waters (Table 4). However, inter-annual variability is likely to be high and in some years catch rates may be either significantly lower or higher. In high interaction years, the annual catch could be as high as 362 white sharks in Australia (Malcolm *et al.* 2001). Using an estimate of the average release rate of 40%, as many as 217 sharks could die each year (not including those that die post-release) (Malcolm *et al.* 2001).

The estimate of the number of deaths from tuna aquaculture is largely based on anecdotal reports (Malcolm *et al.* 2001), and serves to highlight the need for accurate and credible reporting. The estimate used of 100% mortality also needs to be upgraded due to recent changes in attitude and the success rate of releasing white sharks from tuna cages (100% in the last 12 months).

Source	Estimated av. no. captures per year	Range	Estimated av. annual mortality (%)
NSW Shark Control Program	5	0 - 10	80%
Qld Shark Control Program	10	0 - 20	100%
Game-fishing	2	0 - 5	0%
Recreational fishing	10	1 - 20	50%
SSF	72	12 - 132	51%
WSF	28	0 - 70	50%
SA MSF	30	15 - 40	50%
Vic snapper fishery	5	1 - 10	20%
Other fisheries	>10	5 - 20	50%
Tuna farming	20	2 - >20	100%
Rec netting	4	0 - 10	100%
Illegal targeting	>5	>5	100%
TOTALS	**201**	**46 - 362**	**60%(120)**

Table 4. Capture and mortality estimates per year for white sharks in Australia.
After Malcolm et al. *2001*

I have simplified the data in Table 4, and ranked estimated captures (Table 5). Despite uncertainties in the data, it is very clear that the primary cause of captures, and hence mortality, of white sharks is commercial fishing. All other estimated causes combined account for less than 30% of captures. Estimated deaths from tuna aquaculture are ranked second in these figures (based on Malcolm *et al.* 2001). While numbers are much lower for aquaculture than for commercial fishing, they are still high enough to be a concern, particularly in the light of the low numbers and life history characteristics of this species.

Cause	Estimated av. number pa
Commercial fishing	145
Tuna aquaculture	20
Recreational fishing	16
Shark control programs	15
Illegal targeting	5
Total	**201**

Table 5. Ranked causes of mortality to white sharks.
Numbers are estimated average number of captures per year. Data modified from Malcolm et al. *2001.*

Lack of reporting adds to uncertainly about abundance and catch estimates. There is still confusion among fishers and even some enforcement officers regarding protective legislation for white sharks. The problem is exacerbated by different regulations in Commonwealth waters and for individual States. Information on regulations needs to be more accessible. Reporting requirements, where they exist, are generally not well understood, or are ignored (Malcolm *et al.* 2001). For example, in South Australia documentation is poor. PIRSA and SARDI were unable to provide any formal records for this report, although individual staff were very helpful in providing information on incidents that they knew about. This is an issue that needs addressing.

Sighting and catch data can be difficult to use to interpret abundance, as they are very variable and effort needs to be taken into account. Declines in sighting frequency may be related to changes in distribution and behaviour of white sharks in an area (Presser and Allan 1995). There can also be problems with identification. Any large shark is likely to be assumed to be a white shark.

Neither a stock assessment nor an estimate of population size is yet possible for Australian waters. Future stock assessment work will require a longer time series of catches together with either a trend in relative abundance or at least one estimate of absolute abundance. However, a model using available data was used to estimate the *minimum* population size of female white sharks (age 1 and above) in Australian waters which could support current catches (this makes the vary debatable assumption that these are sustainable). The minimum population size of females, given these parameters, was estimated be within the range of 2,728-13,746 (Malcolm *et al.* 2001).

Currently, available data on absolute or total population numbers for white sharks are extremely limited; however, white sharks appear to be uncommon to rare compared to most sharks (Malcolm *et al.* 2001).

Available data suggest that white sharks have declined in abundance in most areas of Australia within their distribution range. Beach meshing data from NSW show an almost unbroken decline in catches of white sharks since 1974 (Reid and Krogh 1992). Other data indicating declines include beach meshing data from Queensland, game fishing records from NSW and SA, and anecdotal data from tourism operators and divers (Bruce 1995). Other data indicate declines in size in some area (a decline in mean length can be an indication of overfishing).

A number of long-term shark fishers have described an overall decline in sightings and catches over the past three to four decades. During the past decade, catch rates appear to have been relatively stable, although they vary greatly from year to year. Some fishers believe that white sharks numbers are recovering substantially in South

Australia (Malcolm *et al.* 2001). This is quite a common perception and may be true; however, given the population dynamics of white sharks i.e. late onset of maturity and low fecundity, it is important to be aware that population recovery is likely to be very slow. Hence any apparent increases in sightings are more likely to be the result of changes in behaviour, distribution, or local abundance only.

A Recovery Plan has been developed under EPBC (EA 2002). Recovery plans set out the research and management actions necessary to stop the decline of, and support the recovery of, listed threatened species or threatened ecological communities. The aim of a recovery plan is to maximise the long term survival in the wild of a threatened species. It is not just white sharks that are at risk. The biomass of most sharks and rays caught in the South-East trawl fisheries have declined rapidly and are now at very low levels (Graham *et al.* 2001).

ENTANGLEMENT AND RELEASE

There are several forms of interaction:

- Passive or chance encounters. These occur as sharks move through the area.
- Active encounters. These occur when the sharks are attracted by vibrations or smell.

3.1 Entanglement

White sharks will interact with fishing gear by more than just passive or chance encounter. They will swim along or through a net or longline, biting off sharks and other fish that are enmeshed. In general sharks are more likely to be entangled rather than enmeshed (Malcolm *et al.* 2001).

Sharks scavenge from longlines and can be either hooked or entangled. They are most likely to be retained by gear when they are entangled in the mainline. This is most likely to occur when there is slack in the gear and the hooks are close together.

In nets, white sharks are also more likely to be entangled than enmeshed, while white sharks can become entangled in longlines and ropes attached to rock lobster pots (Malcolm *et al.* 2001).

Lighter gear used by some fishers may be more easily bitten through by a white shark, enabling its escape; however, heavier gear can be set more rigidly, which may decrease the chance of entanglement.

At times, a white shark will swim into a net and continue to keep pushing, becoming tightly enmeshed around head. Eventually it will become exhausted and starved of oxygen. It may fall out when the net is hauled. If the bottom is reef, the net is more likely to snag and break (Malcolm *et al.* 2001).

The shark may be only lightly enmeshed, but may break free prior to, or when, then the net is being hauled and under tension. White sharks will in most cases bite or break through the mesh (Malcolm *et al.* 2001).

Occasionally a white shark will follow the net and attack the catch as it is being hauled. They can become momentarily trapped in the body of the net near the roller as the foot-rope and head-rope come together. They usually fall out as it is raised (Malcolm *et al.* 2001).

3.2 Release and Survival

If sharks are alive when nets or lines are retrieved, there area number of outcomes, only one of which is positive. The shark may:

- be killed (now illegal, but still occurs)
- die before being released
- be released alive but still die
- be released alive and survive

The impact of capture stress is not known. Effects will vary depending on factors such as: size; time taken to land: location of hooking (jaw, throat or stomach); type of hook and trace (stainless steel or galvanised); and the way it was 'played'.

Capture may result in subsequent mortality or a range of sub-lethal effects. These may include reduced growth, a temporarily reduced capacity to feed, interrupted reproductive activity, or greater chance of attack from other sharks. Effects may be acute, chronic, or negligible (Malcolm *et al.* 2001).

Release rates vary greatly between fishers (from 0-80%), and depend on the degree of entanglement, the release method, soak times, the size of the shark, and the fisher's experience and attitude (Malcolm *et al.* 2001).

It is not known what proportion of sharks is released alive, nor is the survival rate of released sharks known (Malcolm *et al.* 2001). White sharks need to swim to pass water over their gills and oxygenate their blood. Some of those released alive may be in a critical condition and not recover. For other species post-release mortality rates as high as 35% after gill-netting have been suggested (Malcolm *et al.* 2001). However, white sharks can survive some degree of hypoxia, and release efforts have been successful in the past.

The size range and mean estimated lengths of sharks successfully released are not significantly different to sharks that are already dead (Malcolm *et al.* 2001). Hence size may not have a major influence on release, although handling time may increase with size, and this probably increases mortality. Some white sharks are killed because it is too dangerous for fishers to attempt to release them. Some shark fishers will shoot large sharks prior to bringing them into the boat to reduce the chance of damage to nets and the catch. Other fishers will do everything they can to release the shark (Malcolm *et al.* 2001). White sharks caught on long-lines may continue to get some water movement across the gills because they can still swim to some degree, provided they are not entangled (Malcolm *et al.* 2001).

There are two cases in Australia where white sharks were tagged and released after being entangled, and then recaptured months later (Malcolm *et al.* 2001). Another two small white sharks that had been on set-lines for up to two hours were satellite tagged and tracked for seven and 18 weeks respectively. These sharks were handled very gently post-capture and were also towed prior to release to help re-oxygenate the blood (Malcolm *et al.* 2001).

An archival tag was recovered from a white shark drowned in a net. The depth profile indicated that the shark was in the net for nearly five hours. The fisher reported that the shark was "almost dead" when the net was first pulled, and it had died by the time it was untangled (Malcolm *et al.* 2001).

3.3 Successful Release Methods

- Shaking the net
- Cutting a few meshes where the shark is lightly meshed
- Taking the weight off the net to enable any wrapped rope and net to be cut free
- Turning sharks around if they come to the boat head first (this reduces weight, reduces danger, and gives access to any rope caught around the tail). This requires getting a tail-rope onto the shark (Malcolm *et al.* 2001).

3.4 Minimising Interactions

One Spencer Gulf snapper and shark longliner has changed to heavy mainline (10 mm rope) anchors and chain, high breaking strain stainless steel trace, with about 8 m between each trace. Since changing gear he has not caught any white sharks, and he reports catching fewer large female whaler sharks as well (Malcolm *et al.* 2001).

Fishers that make shorter sets also catch fewer white sharks and are more likely to be able to release them alive. One fisher who only sets during the day, with a three hour maximum set, has never caught a white shark in 40 years (Malcolm *et al.*2001).

White sharks are still hooked on handlines but they generally escape by bending the hook or breaking off. Data available from ten snapper handliners suggest that catch rates are negligible (Malcolm *et al.* 2001). AFMA data appear to support this (Tab. 2).

BENEFITS AND ADOPTION

The aquaculture industry will benefit from this project. A number of outputs and extensions are planned. The most immediate output is be the publication of this discussion paper and workshop proceedings, which will be made freely available and circulated to all participants. This particularly includes detail on recent methods of releasing sharks from aquaculture cages.

Another output will be to identify research needs, such as innovative gear development, and the development of future FRDC proposals. Keith Jones of SARDI has been successful in obtaining FRDC funding to collate existing data for whaler sharks in SA, including shark mortalities associated with sea cage aquaculture and make recommendations regarding the need for biological studies in the future (FRDC 2004/067). While Keith's proposal was not a direct output of this project, the need for research and a risk assessment on whalers was highlighted by this workshop, and supported by participants.

FarmBiz are interested in developing training programs and SeaNet have expressed interest in extension work. The TBOA is currently developing a code of practice for managing and avoiding interactions. The two successful releases post-workshop are an indication that attitudes are changing and methods being adopted to release sharks from cages. PIRSA have also decided to finalise the draft Code of Practice for White Shark Cage Dive Operators.

FURTHER DEVELOPMENT

Further developments needed include:

- the completion of the existing draft White Shark Cage Dive Operators Code of Practice
- the completion of a Code of Practice for reducing and managing interaction with tuna tow and farm cages by the TBOA
- the development of training packages (FarmBiz and SeaNet)
- more stringent reporting requirements on interactions with sharks as part of licensing conditions for both Fisheries and Aquaculture, and the provision of this data in summary form to other agencies
- a change in the definition of "bycatch" in SA catch databases to include species other than those of commercial interest
- a permanent listening station and a program of acoustically tagging sharks around tuna farms, to give information on patterns of visits and behaviour around farms
- the completion of the trial of steel cages for YTK, and reporting back to industry and regulatory bodies on the performance of MarineMesh cages in SA waters
- further development of Shark Shield technology (need for partnerships with industry).

PLANNED OUTCOMES

The planned outcomes in the original grant application were:

> Existing information, both about interactions between human use and marine animals in temperate waters, and information on patterns of use of the marine environment by protected species will be developed and published. Information on effective methods, techniques and technologies to minimise problems with marine animals will be discussed, with an extension program developed to disseminate this information to various industries. It is expected that the discussion paper and workshop will become the basis of a number of codes of practice and government policies, and will inform marine planning and development approval processes. The workshop will bring together key industry players, along with government agencies, technical experts from NGOs and research providers to discuss the relevant issues. This, alone, is a crucial outcome.

These outcomes have been met for the more restricted topic of sharks and aquaculture. The workshop was very successful, with good industry attendance, much open debate and the provision of very useful information on methods, techniques and shark behaviour. FarmBiz are interested in developing training programs and SeaNet have expressed interest in extension work. The TBOA is currently developing a code of practice for managing and avoiding interactions. The two successful releases post-workshop are an indication that attitudes are changing and methods being adopted to release sharks from cages. PIRSA have also decided to finalise the draft Code of Practice for White Shark Cage Dive Operators.

CONCLUSION

The life history characteristics of white sharks (slow growth, delayed maturation, long reproductive cycles, low fecundity and long life spans) make this species particularly vulnerable to overfishing. White sharks appear to show some degree of site fidelity, and are highly vulnerable to over-exploitation or local eradication. They show variation in distribution and behaviour at different spatial and temporal scales, and segregate by size and by sex.

White sharks are highly mobile, and move to take advantage of different prey. They are not restricted to seal/sea lion colonies, although they are commonly encountered around them. They appear to follow movement pathways, and their behaviour can vary between areas and between sites. There are changes in shark activity from year to year. Identifying activities that attract sharks, along with movement pathways and areas more prone to interactions, will enable effective planning to reduce interactions.

The greatest threat to white sharks at present is commercial fishing. The estimated number of captures in all commercial fishing sectors is an order of magnitude higher than for any other cause of capture. The second highest ranked threat is tuna aquaculture; however, in lieu of other data for this sector, mortality and capture estimates are based on anecdotal evidence, because records are sparse and often unobtainable. Recent successes in releasing sharks from cages must certainly contribute to lower mortality estimates; however, accurate records are required to estimate captured numbers more precisely. It is important to remember that the life history characteristics of this species, added to the decline in the population and suggestions from genetic data that females do not disperse widely, mean that the loss of even a few large females can have consequences for the genetic diversity of the species, and affect local abundances. Variability in sightings is high, as in variability in catches, both spatially and temporally. Information is lacking on survivorship after capture. Most data highlight a decline in the number of white sharks in Australia over the past 50 years.

With respect to aquaculture, technological fixes have great potential, but also have drawbacks. Different methods are already being used with success in some sectors and for some applications. It will be interesting to find out how the steel mesh cages perform in SA waters.

The workshop reached general agreement on the following points:

- Aquaculture cages do not appear to be attracting sharks to the region.

- Both sharks and pinnipeds (seals and sea lions) can be a problem.
- The main factor triggering attacks is the presence of freshly dead fish in cages - this is a farm husbandry issue.
- We need more information about patterns of shark movements. An excellent way of obtaining this would be the installation of listening stations around tuna cages, and fitting sharks with acoustic tags.
- There is an urgent need for best practice guidelines for managing interactions.
- Interactions with bronze whalers are more frequent than white sharks. Interactions with both species vary with site, season, and operator.
- We need better (and faster) reporting of interactions, and better communication between industry, researchers and regulators. Concerns of operators about reporting interactions with white sharks (with regard to punitive measures when a shark dies) need to be addressed.
- More research is needed on shark behaviour, stock structure and population status.

Subsequent to the workshop, two white sharks entered tuna cages near Port Lincoln. Both were successfully released with no danger to staff and no loss of tuna. This is a positive outcome, and reflects an increased awareness of the need for conservation of great white sharks.

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APPENDIX 1: SUCCESSFUL RELEASE OF TWO WHITE SHARKS FROM TUNA CAGES

A great white shark was reported in a tuna cage North East of Boston Island on the 14th May 2004. The shark was a female, approximately 4.5 m in length. PIRSA Fisheries took the position that the shark was not to be destroyed under any circumstances.

Farm divers inspected the cage and fixed the hole where the shark had entered, but decided to wait until Sunday 16th of May to try and release the shark, when the weather was expected to improve.

The method that they planned to use was to bunt two tuna cages together and open both transfer gates. They would then string approximately 10 m in length by 2 m depth of mesh net from one side of the gate inwards towards the centre of the tuna farm cage. The idea was that if the shark were swimming around clockwise it would see the mesh net curtain and veer in towards the open transfer gate and into the empty tuna farm. If any tuna followed the shark in they could be harvested. Once the shark was in the empty cage, the tuna farm net would be dropped to release the shark.

When Fisheries Officers arrived at the tuna farm on 16th May, farm divers advised them that another white shark had entered another cage (Cage 5), 20 m north of the cage already holding a shark (Cage 6). The second shark was also female, and was approximately 4.5m in length and had entered the cage overnight (*Note: it is fortunate that the second shark was trapped at the same time. If she had entered the cage a few days later, the assumption might have been made that it was the first shark re-entering - "rogue" behaviour)*

A tuna farm cage was towed up adjacent to Cage 6. A net was put into the empty cage and both transfer gates were opened, then the mesh net curtain was strung across Cage 6.

The shark did not show the same behavior as the one described in the workshop proceedings. She did not always swim clockwise, and for much of the time would swim directly across the cage, then back around one side, sometimes clockwise but at other times anticlockwise. While mostly staying near the surface, she did used deeper water at some times. After approximately 2.5 hours of the shark circling the cage with the transfer gate open, it was decided to drop some of the headline of the cage. This was dropped down directly opposite from the transfer gate. The crew untied approximately 15 m of the headline from the tuna cage ring stanchions and the net was dropped down into the water about 3 m. A mesh net curtain was also put into the cage where the headline was dropped down, to avoid any tuna escaping from the cage. If the shark decided to escape from this area, the curtain could be pulled up immediately to stop any tuna escaping.

The white shark came close a number of times to departing the tuna cage from both opening points. At approximately 1655 hours, the white shark escaped through the opening where the headline was dropped down. No tuna were lost during the release. By this time there was no direct sunlight present. The shark was getting harder to see, and this could be a contributing factor to why the shark exited at this time.

The release of the second white shark was attempted on Wednesday 19th of May. The day was overcast, with no direct sunlight. The second white shark was released using the same method of dropping the headline of the tuna cage. Tuna farm employees dropped two sides of the headline directly opposite each other. It took approximately 1.5 hours for the shark to be released, and no tuna were lost. Video footage was taken of both releases.

Tuna farm operators worked hard to achieve this extremely positive outcome, and their efforts are appreciated. Congratulations to Dinko Tuna Farms staff, especially Michael Vandoorn (Farm Manager), Steve Cowley (Head Diver), and Nick Plucka (Diver).

Based on a report compiled by Fisheries Officers Brett Chalmers, Kane Slater and David Creaser

APPENDIX 2: MARINE MAMMAL INTERACTION PROJECT

The original FRDC project was to develop a discussion paper to summarise information about interactions between human activities and marine animals in temperate waters and to determine the key issues affecting large marine vertebrates. This was later modified to focus on the issue of sharks and aquaculture; however, as part of the original objective, members of the wild harvest fishing industry held a meeting to discuss their main issues with respect to fisheries and interactions between human activities and marine mammals. A brief summary of that meeting is included here. No participant list is available; however, representatives from the abalone, lobster, pilchard, prawn and marine scale fisheries attended.

Marine Mammal Interaction Project

Outcomes from Industry Meeting, Port Lincoln, February 17th 2003

Meeting supported by Seafood Council (SA) Ltd

Report prepared by Roger Edwards, Manger Industry Development
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Summary

Key points

1. The industry has implemented a range of relevant environmental programs
2. Fishing boat numbers are declining
3. Fishing days or time at sea are declining
4. Usage of gear e.g. pot lifts is declining
5. Other non-commercial threats are emerging
6. The debate is not balanced and does not highlight the real reduction in fishing operations and environmental programs in place
7. Industry has demonstrated a willingness to engage in monitoring and data recording but there are strong disincentives to do so across the wider industry
8. An incentive based approach to industry involvement is needed

Background

The fishing industry generally is aware of community concerns about marine mammal interactions with their operations. The practices within the industry have changed dramatically over the last ten years with the heightened understanding of the importance of environmental stewardship, in particular protection of marine mammals.

As well, fishing practices have changed to be more efficient and when combined with ongoing management restrictions, this has lead to substantial reductions in time at sea and therefore the potential for interactions with marine mammals. This is particularly so in the wild harvest sector, however offsetting this is the emergence of the recreational and charter/tourism sectors with thousands of new boats growing the potential for increased interaction.

The seafood industry is committed to minimizing environmental impact and working proactively to deal with issues as they emerge. The industry has a strong track record of investing in new technology and programs to deal with environmental issues and is working to ensure marine mammal interactions are minimized.

The view of the industry is that the impact of the commercial sector is constantly declining through areas such as environmental programs and natural contraction of fishing activities through management.

This report provides a sketch of sector programs and fishing data, and also canvasses future impediments to ongoing commitment to and involvement of the commercial fishing sector in programs aimed at further minimizing marine mammal interactions.

1. Sector environmental programs

The following are examples of sector programs, assessments of activities related to marine mammal interactions.

Sector	***Activities***
Rocklobster (RL)	• Environment Australia assessment conducted and export permits approved • Great Australian Bight voluntary data recording program • Clean Green Environmental Management system (EMS) covering whales, turtles and seals • Uptake of seal protection devices • SeaNet project to remove plastics straps from bait boxes
Prawn	• FRDC-funded EMS under development • EA submission assessed as low risk to seals and dolphins due to the nature of the operations i.e. very low
Pilchards	• Code of Practice under development
Abalone	• Green Chooser program
Aquaculture	• National Aquaculture Council-funded EMS systems completed – oysters, mussels and abalone

2. Contraction of Fishing

The commercial fishing sector has been continuously contracting in South Australia over the last 10-15 years, primarily driven by tighter management arrangement and internal structural adjustment programs. Details for key sectors are provided below:

Sector	***Change***
All licences	1,112 in 1993 down 30% to 778 in 2004
Southern Zone RL	1,645,000 pot lifts prior to quota declined 48% to 854,000 over last 10 years
Northern Zone RL	Peak of 805,000 pot lifts in 1991-92 declined 30% to 571,000 in 2002-3
Prawn	Fishing hours down 38% from 30,559 hours in 1990 to 18,950 in 2003
Abalone	Diving hours down 21% from 10,461 hrs in 1990 to 8,251 in 2003

Sources: PIRSA and SARDI

3. Impediments to industry involvement

While the industry has improved environmental practices across the board over the last ten years, on the matter of marine mammal interactions the perception exists across the industry that government agencies and conservation groups seek a zero impact and or kill. This is viewed as neither realistic nor achievable and this message perpetuates industry reluctance to be involved.

A critical issue for managing marine mammal interactions is that of gathering accurate and timely data. Industry can assist with this and is best placed to do so, but a substantial impediment to industry involvement is the perceived threat of shut downs of industry and fishing grounds in response to information provided by industry.

The shut down of fishing in the Great Australian Bight Marine Park to protect whales is a good example of this. In, particular shut down of sectors that fish when the whales are not present, highlights the inconsistencies, *ad hoc*ism and risks involved in marine management perceived by the industry. With this high profile example in South Australia, the industry questions why it would risk providing more information about whales?

The structure of industry engagement with government with regard to marine mammals is purely punitive e.g. fines where infringements occur. While industry does not condone law breaking, this is seen to be of limited value in environmental management, as the resources have never been sufficient to observe marine mammal interactions at sea in any event.

More importantly the system does not serve in any way to create any incentive to industry to provide data. Until the uncertainty involved in data gathering and reporting is overcome it is suspected that there will be ongoing reluctance collect data and a low likelihood of interactions being reported. It is felt that incentive based arrangements need to be explored and implemented to significantly improve industry engagement over time.

APPENDIX 3: INTELLECTUAL PROPERTY

No patentable inventions or processes were developed as part of this project. The SA Department for Environment and Heritage and the Fisheries Research and Development Corporation retain the right to publish public domain literature from this project.

APPENDIX 4: STAFF

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