Review of the Fishery Status for Whaler Sharks (*Carcharhinus* spp.) in South Australian and adjacent waters

Keith Jones

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Review of the fishery status for whaler sharks in South Australian and adjacent waters.
Final report to the Fisheries Research and Development Corporation.

By: G.Keith Jones

South Australian Research & Development Institute
2 Hamra Ave, West Beach SA 5022

(Current Address:
PIRSA (Fisheries Policy)
GPO Box 1625
Adelaide, SA 5001.

Telephone: 08 82260439
Facsimile: 08 82262434
http://www.pirsa.saugov.sa.gov.au

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Author: Keith Jones
Reviewers: Paul Rogers, Simon Goldsworthy, Greg Ferguson, Shane Roberts, Andrew Sullivan
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LIST OF ABBREVIATIONS

AFFA: Dept. of Agriculture, Fisheries and Forestry, Australia.
AFMA: Australian Fisheries Management Authority.
BRS: Bureau of Rural Resources
CAAB: Codes for Australian Biota.
CCSBT: Commission for the Conservation for southern bluefin tuna.
CPUE: Catch per unit effort
DNA: Dioxyribonucleaic Acid
DL: Drop Line
EEZ: Exclusive Economic Zone
GAB: Great Australian Bight
GABT: Great Australian Bight Trawl Commonwealth Managed Fishery.
GHAT: Gill Net, Hook and Trap Commonwealth Managed Fishery
GSV: Gulf St. Vincent
IFSNA: Indigenous Fishing Survey of north Australia
ITQ: Individual transferable quota
IUCN International Union for the Conservation of Nature
KI: Kangaroo Island
LL: Long Line
MSF: Marine Scalefish fishery (SA managed)
NRIFS National Recreational and Indigenous Fishing Survey
NSW New South Wales
NZ New Zealand
NZRL: Northern Zone Rock Lobster
OCS Offshore Constitutional Settlement
OTC Oxytetracycline
PIRSA: Primary Industries, Resources South Australia
Qld: Queensland
RI: Recruitment Index
RL: Rock Lobster
SA: South Australia
Saf: South Africa
SARDI: South Australian Research & Development Institute.
SE: south-east (SA)
SBT: Southern Bluefin Tuna
SG: Spencer Gulf
SH: Shark Net
SZRL: Southern Zone Rock Lobster
TAC: Total Allowable Catch
TEPS: Threatened, Endangered, Protected or Sensitive species
US: United States of America
VH: Victor Harbor
Vic: Victoria
WA: Western Australia
WC: West Coast (SA)
WSF: Western Shark Commonwealth Managed Fishery
YTK: Yellowtail Kingfish

NON-TECHNICAL SUMMARY

2004 / 067 REVIEW OF THE FISHERY STATUS FOR WHALER SHARKS IN SOUTH AUSTRALIAN AND ADJACENT WATERS.

PRINCIPAL INVESTIGATOR: Dr. G.K. Jones

ADDRESS: PIRSA (Fisheries Policy)
GPO Box 1625
Adelaide South Australia 5001.
Email: jones.keith@saugov.sa.gov.au

OBJECTIVES:

1. To collate the existing biological and fisheries data for whaler sharks in SA waters, including information on mortalities associated with sea cage aquaculture;
2. To analyse these data by undertaking a risk assessment for these species in SA;
3. To develop options for improving the collection and maintenance of catch and effort data;
4. To make recommendations regarding the need for biological studies on the two species in the future; and
5. To provide options for managing the whaler shark resource, where there is sufficient information.

The purpose of reviewing the fishery status of whaler sharks in South Australia (SA) and adjacent waters was to collate and analyse all existing information and data on their biology, fisheries and interactions with aquaculture operations, and to undertake a risk analysis of all activities associated with their capture. By way of this risk analysis process, research and management options could be identified and recommended.

Although most whaler sharks caught in southern Australian waters are reported and marketed as “bronze whaler sharks”, at least two Carcharhinid species (bronze whaler, *Carcharhinus brachyurus*; dusky whaler, *C. obscurus*) have been positively identified in the harvests off South Australia (SA), and a simple morphological method for distinguishing live animals of the two species is presented here.

Biological characters identified as essential for their assessment and management include: geographic distribution, population structure, age and growth rates, reproductive capacity, predator-prey relationships, population trends and the behaviour of sharks in relation to fishing and aquaculture operations. Little published information was available on most of

these characteristics for either species in SA waters. As both species are distributed globally, but with discrete populations, this review includes the biological information on these other sub-populations.

The spatial and temporal distributions of whaler sharks in SA waters was enhanced through the analysis of tag release-recapture data obtained from the Australian Gamefish tagging program (1976 – 2004). Unit stocks for both species exist throughout southern Australian waters. Seasonal movements were inferred from the relatively high numbers of juvenile sharks tagged and recaptured in the warmer gulf waters during Oct – March, with some larger sharks recaptured in the SA offshore or WA waters during the winter months. Other whaler shark populations show similar temperature mediated movements. However, the tagging program was not sufficiently spatially structured to determine whether nursery or breeding areas were either dispersed or discrete. Research on other populations indicates that both species have low growth and reproductive rates and a large size (age) at first sexual maturity. These characters indicate low levels of population productivity, placing both species at a high risk of overfishing and slow rates of recovery if the various impacts are eased.

A total of 11 potential fishery or finfish aquaculture impacts on whaler sharks in SA were identified. These included: a) 8 separately managed harvest fisheries, b) 2 fisheries not permitted to harvest sharks, but known to take them as by-catch and c) aquaculture operations ranching three finfish species in Spencer Gulf, either directly interacting with whaler sharks or through the attraction of sharks to sea pens, thus increasing the catchability of sharks to fishing gear set adjacent to the moored sea pens.

In 2000/01, a total of 213.6 t, live wt of bronze whaler sharks were harvested by up to 8 State and Commonwealth fisheries, with the three most significant being, the SA Marine Scalefish Fishery (MSF) (95.9 t), the SA Recreational Fishery (57.2 t) and the Commonwealth managed Gill Net, Hook and Trap (GHAT) Fishery (43.5 t). The multi-species MSF was the only fishery in which a time series of regional harvest, target effort and CPUE data were available, which initially suggested a rising fishable biomass in most regions of the state. However, these conclusions were confounded because catchability could also have increased, through a number of identified shifts in fishing strategies by MSF fishers. The GHAT Fishery also showed slightly increasing bronze whaler shark harvest. There were little validated data on the mortality levels of whaler sharks taken as by-catch in the 3 fisheries off South Australia, as was the case for the interactions between whaler sharks and moored finfish sea pens.

The prioritisation of research and management of whaler sharks in SA was based on a 2 level semi-quantitative risk assessment by Walker, 2005 and Braccini et al, 2006. At the first level, a total of 8 potential direct and indirect impacts on each fishery were scored (1 – 6) in terms of their spatial and temporal scales, intensity and consequence on the whaler shark population. The potential impacts included: harvest fisheries, cryptic mortality, gear loss, species translocation, catch discarding, provisioning (attracting whaler sharks by bait, berley or seapens), pollution and finally, the ecosystem effects of the removal of whaler sharks. The certainty of consequence levels were scored at two levels depending on the data quality. Five potential impacts were identified: (a) the MSF long-line fishery, (b) the recreational fishery, (c) the Commonwealth gill net fishery, (d) the SBT purse seine fishery and towed cages and (e) the moored sea pens, and these all related to the need for improved monitoring of interactions. Four of these impacts required additional research (ie a,b,d & e) required better information on fishing effort (a), the need for time series of harvest data (b), and(d & e) validated data on the number of interactions. These all relate to the third objective of this study, ie to develop methods to improve the collection and reporting of catch and effort data on whaler sharks in SA. As these impacts are managed by a number of state (Fisheries and Aquaculture) and Commonwealth agencies, it is recommended that there be regular exchange of data between them all.

These five fisheries were then assigned to the 2nd level of assessment. This provided a semi-quantitative score for their respective impact, based on the assessed level of productivity for the whaler shark population and its estimated catch susceptibility (CS). The impact with the highest CS value was the MSF longline fishery with the recreational fisheries and moored sea pens scoring equally second. However, the cumulative effects of all fisheries should not be underestimated (eg the attraction of whaler sharks to sea-pens resulting in increased commercial and recreational fishing effort adjacent to the pens). Research is recommended to achieve a better understanding of the behaviour of whaler sharks, including whether they demonstrate philopatric behaviour to moored seapens or natural breeding or nursery areas.

The second level of risk assessment also signalled key management options required to lower the risk of over-fishing of whaler sharks in SA. In South Australia, with the exception of the prohibition of shark finning at sea, there is currently no management specific to ensuring the sustainability of whaler shark populations and their fisheries. Options used elsewhere included gear regulations, the non-targeting of the species, recreational bag limits, maximum size limits, the closure of breeding grounds to fishing, and the banning of shark finning at sea. However, there is insufficient information on the fishery biology of whaler sharks in SA to develop practical management options. Biological information required for cost-effective management of the whaler shark resource varies according to the management option.

Requirements are as follows:

- At the lowest level of management (ie input controls by jurisdiction), knowledge of the stock boundaries and a fishery status report, using validated catch and effort data for all sectors is necessary. Fishery assessments or stock status reports should be prepared bi-annually to allow adequate monitoring of the resource status.
- Additional management options, such as size limits and the protection of nursery or breeding grounds can only be added if size/age at first sexual maturity for female sharks, the spatial and temporal distribution of key life stages and the gear selection ogives (mesh and hook selectivity) are known.
- Management by output controls (eg TAC's, catch quotas, bag limits) requires detailed assessment of fishable biomass (derived from validated catch and effort data and information on the population biology) and size/age structure of the fished component of the stock.
- In terms of ecosystem management, the effect of removal of whaler sharks and their main prey in SA waters needs to be assessed.

A potential interim approach to the management of whaler sharks in SA is:

- Introduce an industry code of conduct for the release of whaler sharks caught as by-catch in fisheries and finfish aquaculture operations:
- Implementation of release panels / doors to all towed and moored sea pens in the SBT, YTK and Mulloway Aquaculture Industries;
- Improved reporting of catch, target effort, released by-catch for all sectors.
- Set a maximum size limit based on information on the reproductive biology for the SA whaler shark populations. This strategy is supported for public health reasons.

KEYWORDS: Bronze whaler sharks, southern Australia, fishery biology, fisheries, interactions with finfish aquaculture sea pens, risk analysis, research and management prioritisation.

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This report was reviewed by Paul Rogers, Greg Ferguson, Andrew Sullivan and Drs. Simon Goldsworthy, Shane Roberts and approved for release by Dr. Tim Ward. I also acknowledge the valuable comments from an anonymous reviewer, of the draft final report.

CHAPTER 1. INTRODUCTION

1.1. Background

Whaler sharks found in South Australian (SA) waters include bronze whaler (*Carcharhinus brachyurus*), dusky whaler (*C. obscurus*), and a single reported record of the oceanic whitetip whaler (*C. longimanus*) (Gomon et al, 1994). The first two species have been taken in several fisheries, but the catch and effort data are incomplete. In the SA Marine Scalefish (MSF) fishery catches of all species of whaler sharks are recorded as “bronze whaler” sharks, therefore catches of individual species is unknown. There are few data for the recreational fishery. In the Commonwealth managed South-East Gill Net Hook & Trap (GHAT) fishery, that uses drop lines, long lines and gill nets to target sharks, the harvest, by-product and discard levels are recorded in log books provided to AFMA. At the time of commencing this project, there was limited information on discards of whaler sharks from other Commonwealth managed fisheries, including the southern bluefin tuna (SBT) fishery and trawl fishery in the Great Australian Bight.

Although the understanding of total catches of whaler sharks in SA waters is likely to be poor due to un-reported catches in several sectors, there are some indications that the focus on these species has recently increased. In 2002/03, tighter management of the school and gummy shark fishery by Commonwealth and South Australia coincided with a substantial increase in the fishing effort and catch of whaler sharks. For example, the commercial SA MSF Fishery harvest and targeted effort increased respectively by 40 and 111%, above the 10 year average. Additionally, by-catch of whaler sharks by the finfish aquaculture sector may impose additional mortalities. These species may be attracted to the vicinity of sea cages used in aquaculture ventures, where they can die from entanglements or be purposely killed because of the potential danger they pose to divers. The proliferation of sea cage aquaculture in Spencer Gulf for SBT, YTK (*Seriola lalandi*) and more recently mulloway (*Argyrosomus japonicus*) has potentially increased the mortality rate on whaler sharks in this region. The fully protected great white shark (*Carcharodon carcharias*) is currently the only shark species being reported in interactions with these aquaculture operations.

The understanding of the population biology, fishery biology and stock structure of bronze whaler and dusky whaler sharks in SA and adjacent waters is poor. Available data are limited to catch and effort information and there are no data on by-catch of whaler sharks. Consequently, the sustainability of the whaler shark resource is unknown.

This review collates all available information on fishery catches and other mortalities for whaler sharks in SA and adjacent waters. The project establishes the current status of the fishery, and identifies the clear need for a comprehensive biological baseline and fishery assessment study in the near future. A risk analysis was conducted to assess the vulnerability of the populations of dusky and bronze whaler sharks to overexploitation. Recommendations were made to improve data collection and management of the whaler shark fishery.

1.2. Need

The current understanding of the fishery and population biology of whaler sharks in SA and adjacent waters is poor. Consequently, it is not possible to adequately assess the status of the fishery. A key knowledge gap is the lack of comprehensive catch data maintained by different fisheries and management agencies. They may be taken as targeted catch, harvested by-product, or discarded by-catch with differing levels of reporting. Furthermore, this catch and effort information is maintained by different fisheries and management agencies. Thus, it is essential to collate all existing catch and effort information. This may then be used to conduct a risk analysis and a preliminary assessment of the vulnerability of dusky and bronze whaler sharks to over-exploitation.

1.3. Objectives

1. To collate the existing biological and fisheries data for whaler sharks in SA waters, including information on mortalities associated with sea cage aquaculture;
2. To analyse these data by undertaking a risk assessment for these species in SA;
3. To develop options for improving the collection and maintenance of catch and effort data;
4. To make recommendations regarding the need for biological studies on the two species in the future; and
5. To provide options for managing the whaler shark resource, where there is sufficient information.

CHAPTER 2. REVIEW OF THE FISHERY BIOLOGY OF WHALER SHARKS IN SOUTH AUSTRALIAN AND ADJACENT WATERS.

2.1. Introduction.

The Family Carcharhinidae comprise one of the largest and widespread families of sharks, with many species wide-ranging in their global distributions in warm temperate and tropical waters (Compagno, 1984). At least two species occur in coastal SA and adjacent waters (including bronze whaler shark; *C. brachyurus*, and dusky whaler shark, *C. obscurus,* Cappo, 1992a; Kailola et al, 1993). Another, the oceanic whitetip whaler shark (*C. longimanus*) has been reported once in SA waters (Daley et al, 2002), and is abundant in offshore tropical waters (Compagno, 1984). Another oceanic Carchrarinid species (Blue shark, *Prionace glauca*) is commonly found offshore from SA (Daley et al, 2002), but is not included in this review.

This chapter addresses the biological component of objective 1 and identifies knowledge gaps on the fishery biology of *C. brachyurus* and *C. obscurus*. Although the name "bronze whaler shark" has been adopted by CAAB (Codes for Australian Aquatic Biota) as the standard name for both *C. brachyurus* and *C. obscurus*, as both species are used in commercial catch recording (http:www.marine.csiro.au/caab), this report reviews the two species separately. This review includes information on whaler sharks in waters other than SA and also information on other Carcharhinid shark species where relevant.

2.2. Information available and gaps in the knowledge.

2.2.1. Critical scientific documents and relevant reviews.

Identification keys for Carcharhinid sharks using morphological characteristics have been developed by Compagno (1984, 88) who remains the main authority on the identification of whaler sharks. The most recent Southern Australian finfish identification guide (Gomon et al, 1994) refers to this research. *C. brachyurus* and *C. obscurus* have similar body shape and morphometrics (Figure 2.1), but they can be distinguished by the shape of teeth in the upper jaw, fin markings, body colouration, the number of precaudal vertebrae and the presence/absence of an inter-dorsal ridge (see Appendix 3).

Bronze whaler sharks (C. brachyurus)

The most comprehensive biological research on *C. brachyurus*, was undertaken on the eastern South African population (Walter & Ebert, 1991; Cliff & Dudley, 1992). More recently, the reproductive biology of the SW Atlantic population, off Argentina has been reported

(Lucifora *et al*, 2005). No research has been undertaken on the population biology of this species.

The most recent IUCN assessment of the status of *C. brachyurus* lists the species as globally near threatened, however, for the Australian population(s) their status was assessed as Least Concern (Duffy & Gordon, 2003), because of apparently stable catches. Similarly, long term catch rates and average size of *C. brachyurus* caught in protective gill nets off eastern South Africa over the past 20 years were stable (Dudley & Simpfendorfer, 2006).

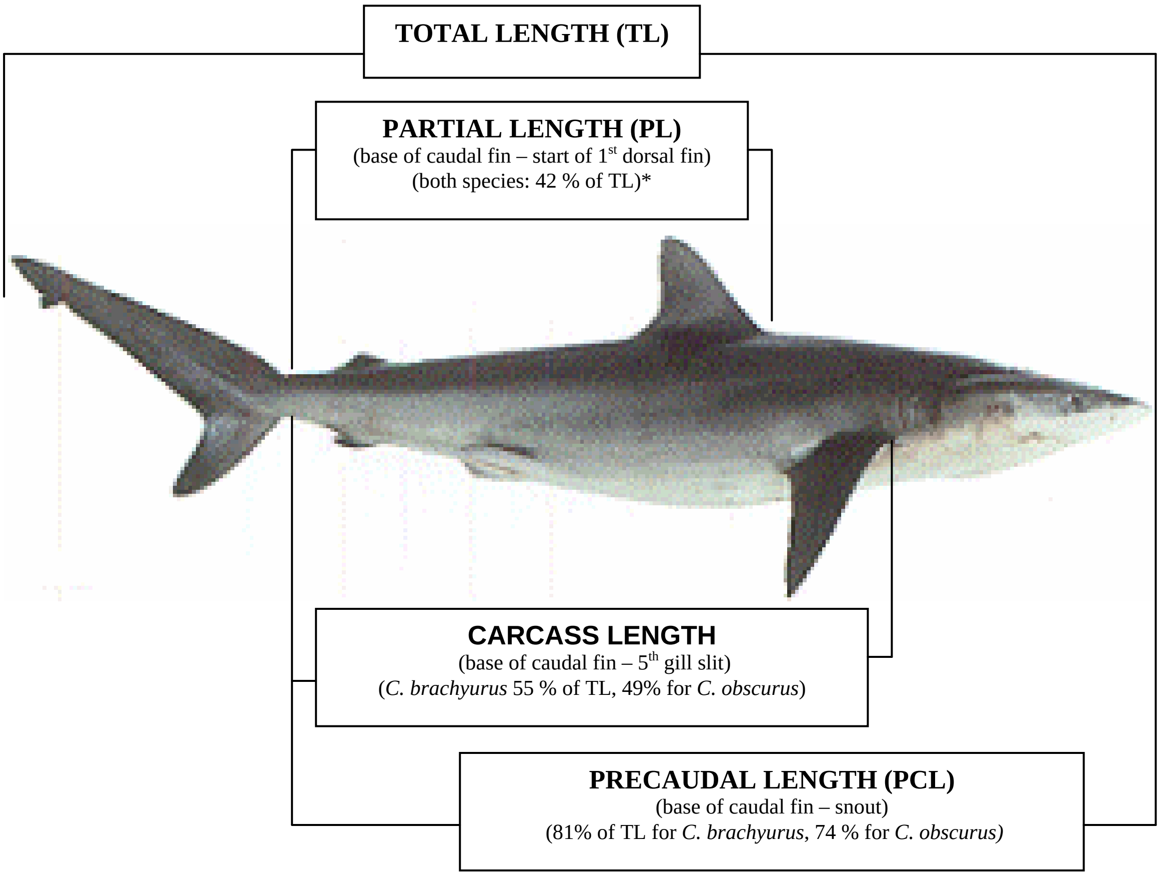


Figure 2.1. Key morphometric dimensions of *C. brachyurus* and *C. obscurus* in relation to the total length of the sharks, adapted from Compagno (1984, 88), Gubanov (1989) & Hancock et al (1977)*
(* bronze whaler sharks reported in WA as several Carcharhinid shark species, including *C. brachyurus* & *C. obscurus*).

Dusky whaler sharks (C. obscurus)

There is a relatively high level of understanding of the fishery biology of two populations of *C. obscurus*. Information is available on the age determination, growth, movements and reproductive biology of the NW Atlantic population (Gulf of Mexico – Eastern US)

(Natanson et al, 1995; Kohler et al, 1998). The biology of the western Australian population has been studied extensively by Simpfendorfer (2000) and Simpfendorfer et al (2001, 2002).

Detailed information is available on the population biology of *C. obscurus* in the NW Atlantic (Musick et al, 1993) and the SW Australian populations (Simpfendorfer, 1999). The species was globally assessed under the IUCN guidelines as Lower Risk, Near Threatened (Camhi et al, 1998), however, the NW Atlantic population was assessed as vulnerable, based on declines in abundance indices (IUCN 1996). A recent report on the state of the dusky whaler shark fishery off the SW WA coast raised increased concern for its status, based on the apparent decline in catch rates of neonates, which suggested a depleted breeding population (Gaughan et al, 2005).

Using information on the age, growth rates and reproductive biology of 26 fished shark species, the rebound potentials of their population growth rates were estimated in response to assumed density dependent responses to hypothetical exposure to fishing mortality. The rebound potential of *C. obscurus* was estimated as one of the lowest of those species of sharks investigated (Smith et al, 1998). Dudley & Simpfendorfer (2006) confirmed the very low rebound potential for *C. obscurus* found along the east coast of South Africa, but also noted the currently stable CPUE and average size of this species caught in the "protective" gill nets over the past 20 years.

2.2.2. Distribution.

C. brachyurus: This species occurs globally in warm temperate waters, usually between 40 & 20^0 latitude in both hemispheres (Table 2.1); however, the global stock structure is unknown. This species is generally coastal in its distribution, and found to depths of 100 m. In SA, both *C. brachyurus* and *C. obscurus* are usually reported by fishers as "bronze whaler" or whaler sharks. Reported captures and sightings of whaler sharks, occur throughout most of SA coastal waters, ranging in habitats from high-energy surf beaches and off coastal rocky headlands to the more sheltered northern gulf waters (Cappo, 1992a). The seasonality in their distributions and movements is discussed in # 2.2.3.

Table 2.1: List of known locations and accompanying references for *Carcharhinus brachyurus.*

Region	**Specific Area**	**Reference**
NE Pacific	Occasionally in southern California	Eschenmeyer & Herald, 1983
SE Pacific	Peru	Compagno, 1984
SW Pacific	Nth Island NZ Eastern Australia (NSW, southern Qld)	Ayling & Cox, 1982, Smith & Benson, 2001, Chan et al, 2003
NE Pacific	China, Japan, the Koreas	Compagno 1984
SE Indian & sthn Australia	SW Western Australia, South Australia & Victoria (occasionally)	Cappo, 1992a, McAuley et al, 2005, this report.
West Indian	Eastern South Africa	Cliff & Dudley, 1992 Smith & Heemstra, 1986
SE Atlantic	Namibia / Angola	Holtzhausen, 2002
NE Atlantic	Sthn Mediterranean, & NW Africa (Morocco, Canary Islands, Guinea)	Hemida et al, 2002, Compagno, 1984
SW Atlantic	Nthn Argentina – Uruguay, southern Brazil	Lucifora et al, 2005, Amorim et al, 1998, Chiaramonte, 1998.

C. obscurus. This species is globally distributed in warm temperate waters. In contrast to *C. brachyurus*, it occurs in both coastal and oceanic waters to depths of at least 200 m (Table 2.2).

Table 2.2: List of known locations and accompanying references for *Carcharhinus obscurus.*

Region	**Specific area**	**Reference**
Eastern Pacific	California, Central America	Eschenmeyer & Herald, 1983 Au, 1991
SW Pacific	NSW Sthn Qld	Chan et al, 2003, Krogh, 1994, Stevens, 1992 Patterson, 1986
East Indian – sthn Australia	WA (Montebello Islands – South Coast WA) South Australia	Simpfendorfer, 1999 Newbound & Knott, 1999 Ward & Curran, 2004 McAuley et al, 2005 Cappo, 1992a
West Indian	East coast South Africa – offshore islands of Indian Ocean	Gubanov, 1988, Romanov, 2002
NW Atlantic	Gulf of Mexico – NE US	Kohler et al, 1998
SW Atlantic	Uruguay – southern Brazil & mid southern Atlantic	Marin et al, 1998, Amorim et al, 1998

2.2.3. Stock structure.

C. brachyurus.

Genetic Studies. Biochemical/genetic (species-specific proteins, allozymes & DNA) profiles have now been developed for most Carcharhinid species in Australian / NZ waters. For example, the phylogenetic relationships for northern Australian Carcharhinid species, derived from allozyme electrophoresis have confirmed the presence or absence of the inter-dorsal ridge as a distinguishing external character (Lavery, 1992). Smith & Benson (2001) and Yearsley et al (1999) used the protein fingerprints of shark fillets and fins taken from commercial landings in NZ and Australia, respectively, to identify a number of shark species, including *C. brachyurus*.

Rapid forensic methods to identify the species-specific DNA of whaler sharks have been developed in the last 7 years, using only small amounts of muscle tissue. Ho (1998), McAuley et al, (2005) and Chan et al, (2003) have successfully used this technique to identify whaler sharks caught in WA fisheries and the NSW shark-meshing program, respectively. Chan et al (2003) identified *C. brachyurus* and *C. obscurus* in NSW waters, and Ho (1998) noted *C. obscurus* in WA waters. McAuley et al (2005) established a secure DNA database on 9 species of sharks (incl. *C. obscurus*) caught in WA shark fisheries to be used for species identification of parts (including fins and carcasses) of sharks landed by fishers, but *C. brachyurus* was not included in this investigation. In addition to the identification of harvested shark species, this technique negates the need to sacrifice the animal, and therefore, has positive implications in collecting species- and stock-identity information for protected shark species (Raloff, 2002; Chan et al, 2003).

A project into the stock sub-structuring of *C. brachyurus* using DNA analyses is currently being conducted by Holtzhausen, (2002) in SE Atlantic waters off Namibia / Angola (see tagging program, below).

Tagging programs. World-wide, several tagging programs have been undertaken, to improve knowledge of the spatial distribution of stocks. Two separate tagging programs on *C. brachyurus* in the eastern and western waters off southern Africa suggest separate stocks exist (Holtzhausen, 2002; Cliff & Dudley, 1992). The Namibian tagging program, which commenced in 1983, found some movement to sthn Angolan waters. The tagging program in eastern South African waters reported extensive movements between Southern Cape and Durban (Cliff & Dudley, 1992). A new tagging program in Namibian and Angolan waters, accompanied by a genetic study (DNA) commenced in 2002, and is aimed at determining and verifying the stock structure of these sharks in these waters (Holtzhausen, 2002).

Endoparasites. Cappo (1992b) explored potential endoparasites suitable for stock discrimination in SA. He considered the intermediary stages of the cestode *Callitetarhynchus speciosis* occurring in Australian salmon (*Arripis truttaceus*) could be used to delineate the origin of schools of salmon as they migrated from SA to WA. The final host of this parasite is suggested to be the bronze whaler shark, and hence could potentially be used as a biological tag for this species (Cappo, 1992b).

C. obscurus.

Genetic studies – *see C. brachyurus.*

Microchemistry of jaw cartilage. Elemental analysis of jaw cartilage in *C. obscurus* in WA suggested spatial separation; however, further research was considered necessary to confirm the usefulness of this technique and to link it with other methods used to discriminate stocks (Simpfendorfer et al, 1999).

Tagging programs.

NW Atlantic stock. Kohler et al (1998) reviewed the mark-recapture data for *C. obscurus* from a cooperative shark-tagging program off eastern USA between 1962 and 1993. This species between New York and the Caribbean Sea, indicating a unit stock.

WA/SA stock. A tagging program commenced on *C. obscurus* in the southern and western waters of WA in 1992, with the aim of determining the geographic extent of this stock in western Australian waters (Simpfendorfer et al, 1999). Preliminary information indicated some movement into SA waters as well as seasonal movements northward and southward along the west coast of WA (Simpfendorfer et al, 1999; McAuley, 2005), thus suggesting a unit stock ranging from the southern Australian coastline to the west coast waters of WA. Some movement of these sharks was reported in waters east of the WA / SA border (long. 129 ^{0} E), with several commercial shark fishers reporting recaptured tagged sharks in the SA gulfs (B. Hay, SA MSF commercial fisher, pers. com.) (see section 2.2.3); patterns of movements for more details). However, research in WA indicated that this species is most abundant in waters between NW WA (Pilbarra) and 120^{0} E on the south coast of WA, and has low abundances in SA, compared with *C. brachyurus* (McAuley, 2005). Monitoring of the species composition of whaler sharks catches in SA using DNA methods on marketed sharks would test this hypothesis.

Ectoparasites. WA/SA stock. Newbound & Knott (1999) investigated the presence of ecto-parasitic copepods in pelagic sharks off the west coast of WA. *C. obscurus* occurred throughout the sampling area between Shark Bay and Montebello Islands, WA. There was no reported diversity of parasites over this range, initially suggesting a unit stock; however, as the same species diversity of copepods were also recorded for *C. obscurus* in NW Atlantic waters (Newbold & Knott, 1999), these parasites may be less useful as biological tags for this species, and studies on the genetic stock structure over a similar spatial scale may be required.

2.2.4. Patterns of migration.

***C. brachyurus*.**

Australia. National tagging data base on whaler sharks in Australia. A National tagging database on whaler sharks is maintained by NSW Fisheries Cronulla as part of the Australian Gamefish voluntary tagging program. Tagging began in 1975 and is conducted mainly by recreational sport fishers in most Australian states and territories (Australian Gamefish Tagging Reports, 1992 – 2001, Murphy et al 2002). The data on releases and recaptures of whaler sharks were kindly provided to the PI for this review. Due to difficulties in identifying live specimens during tag-and-release, uncertainly exists regarding the numbers of each species tagged and released. For some areas (eg East coast and northern Australia) tropical whaler shark species may also have been included in the databases.

Bronze whaler sharks were the most frequently identified species in the SA component of the tagging program, with a relatively small number recorded as whaler sharks (Table 2.3). The majority of these were tagged in the far SE region of the state (off Port MacDonnell).

Table 2. 3. Details of whaler/bronze whaler shark tag release database.

	Bronze whaler releases	**Whaler shark releases**
Duration of tagging program	1978 - 2004	1976 - 2004
Total No. release records	3754	4335
No. releases in SA waters	1220	61

There was strong seasonality in the numbers released and recaptured, with the majority of both occurring during the period October – April (Figures 2.2 – 2.4).

The seasonality of releases and recaptures by location, according to regions of SA and other southern Australian states is shown in Figures 2.3 & 2.4. The majority of whaler sharks were released in SA waters with highest numbers in Gulf St. Vincent (GSV) and the Murray Mouth. The small numbers of whaler sharks recaptured in July – August occurred in WA waters. Also, two bronze whaler sharks tagged in gulf waters of SA in December were recaptured in offshore waters in July & August south of KI and NW of Pearson Island off the west coast in eastern GAB suggesting movement to these warmer waters, relative to those of the inshore SA waters (Figure 2.6); however, additional tagging in these areas are required to test this hypothesis.

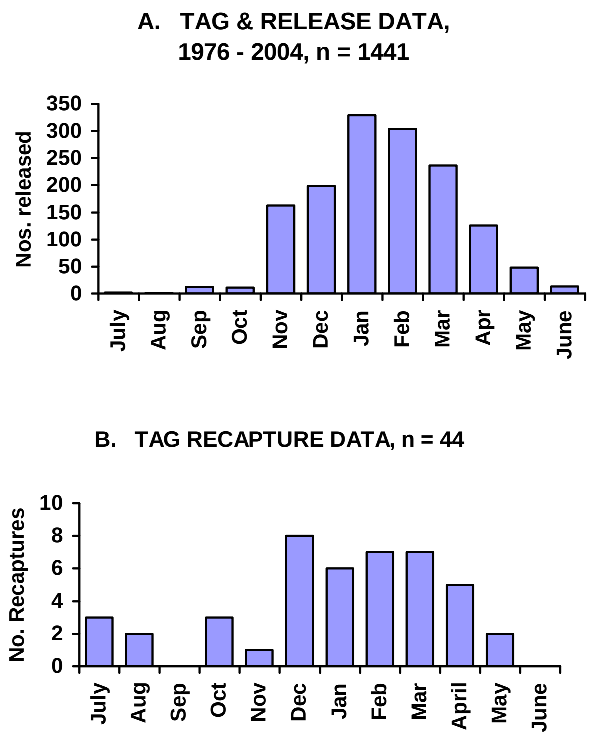


Figure 2.2: No. of tagged whaler/bronze whaler sharks a) released and b) recaptured in southern Australian waters (S of 32^{0} S), but excluding NSW waters.

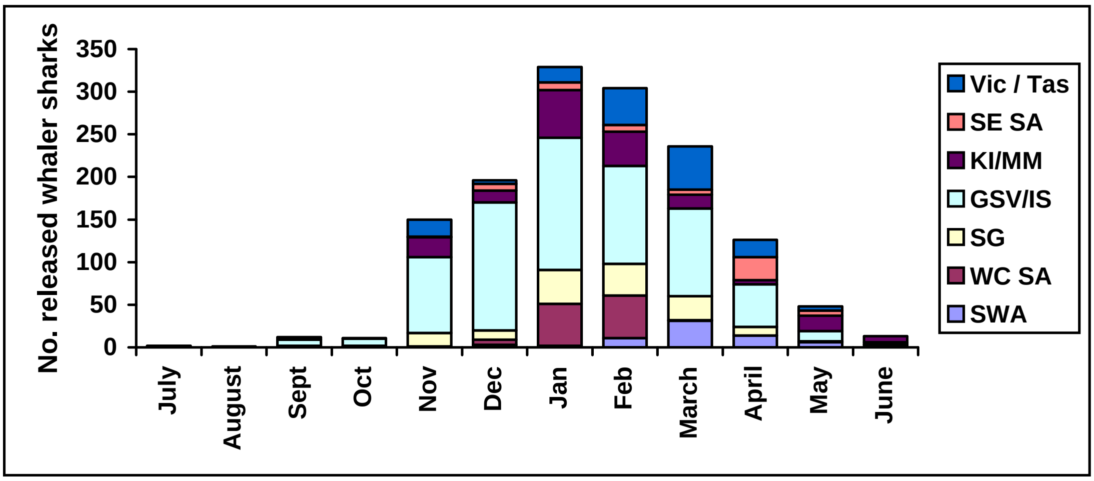


Figure 2.3: Seasonality of released whaler sharks according to locations in Sthn Australian waters between 1976 – 2004 (N released = 1,441)

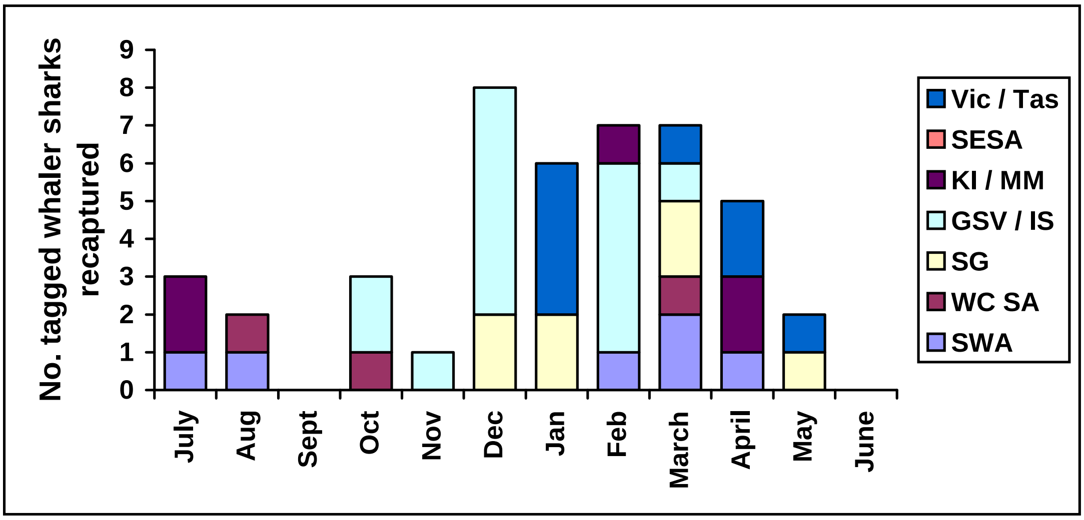


Figure 2.4: Seasonality of tagged whaler shark recaptures, according to locations in southern Australian waters between 1976 – 2004 (N recaptured = 44).

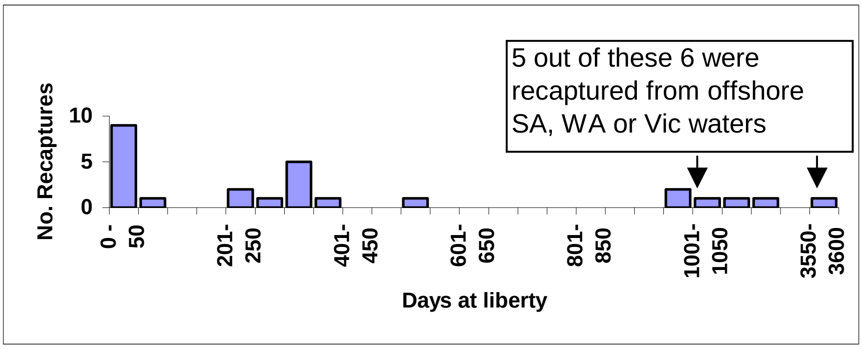


Figure 2.5: Number of tag recaptures of whaler sharks tagged in SA gulfs and other inshore SA waters and recaptured in southern Australian waters, according to days at liberty (N = 26).

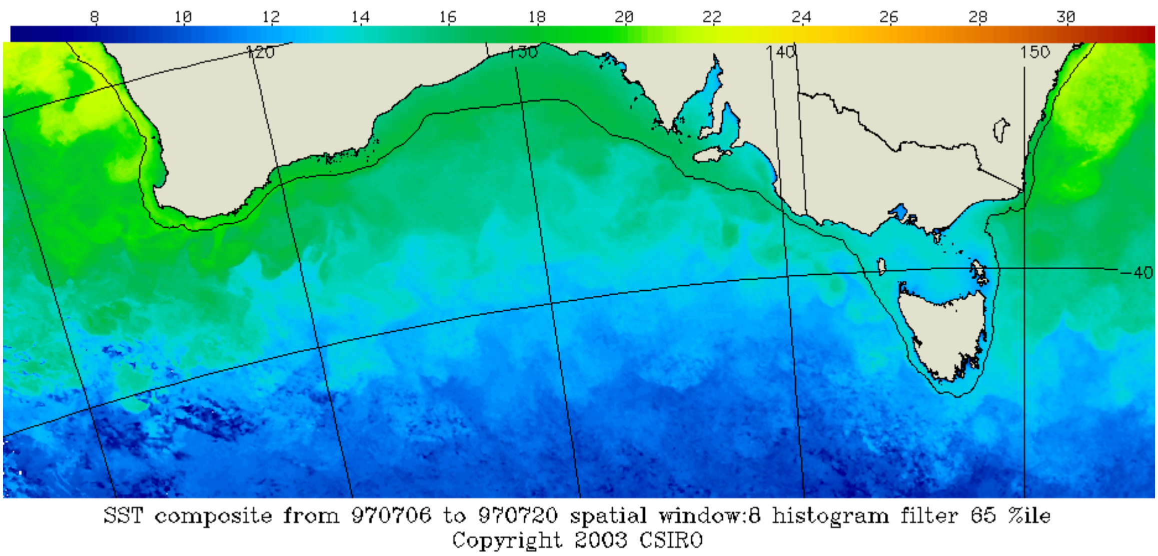
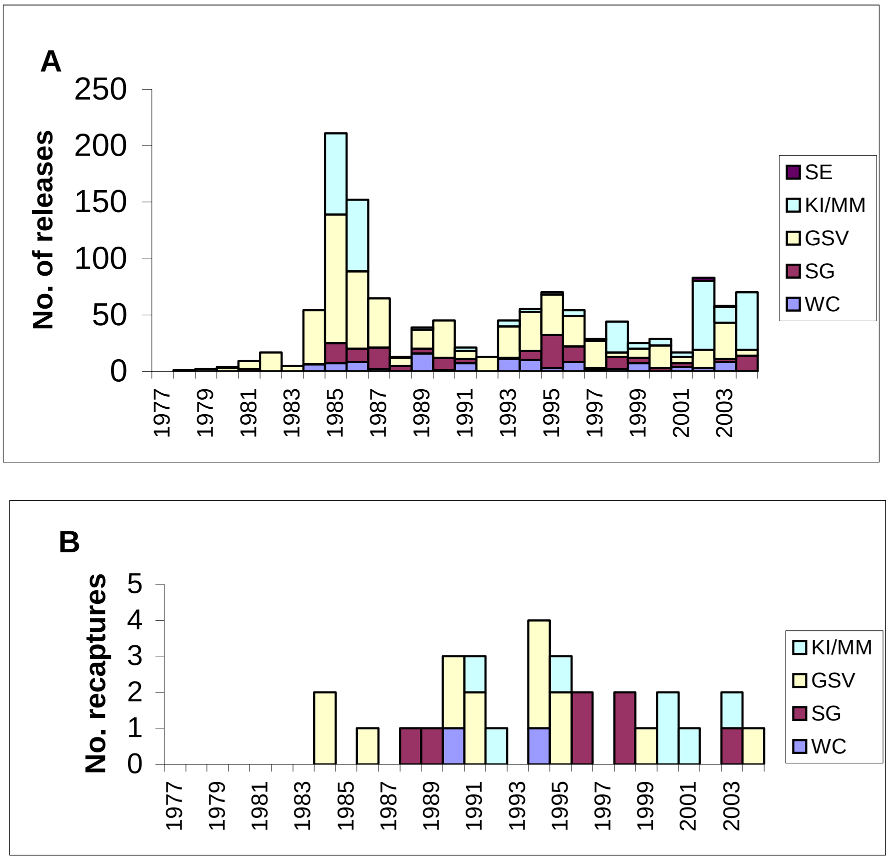


Figure 2. 6: Surface waters temperatures across southern Australia, summarised for period July 6 – July 20, 1997, showing relatively warmer surface water temperatures in offshore waters off SA and the south coast of WA (~17 - 18^0 C) compared with northern Gulf and SE SA inshore waters (~ 12 - 13^0 C).

The overall recapture rate over this period was 3.1%; although the tag-shedding rate is unknown. Figure 2.7 shows a decline in the number of tagged sharks recaptured, over time at liberty. There appears to be pulses of recaptures, again suggesting some seasonality in their catchability, due to movements and /or seasonal variation in fishing effort. Over the duration of the tagging program, most of the tagged whaler sharks were released in GSV or the KI/Murray Mouth regions, with the recent increase in numbers released in the second area (Fig. 2.7a). Similarly, the highest numbers of recaptured tagged sharks occurred in GSV, with similar numbers from the Murray Mouth and thirdly, Spencer Gulf (Fig. 2.7b).

During the tagging program, whaler sharks (40 – 400 cm, TL) were tagged and released, with mostly smaller sharks (< 100 cm TL) released (Fig. 2. 8). Highest numbers of these sharks were released from northern GSV and VH (Murray Mouth)/KI waters. This may be a function of high recreational fishing effort in these areas (see Chapter 3). However, the size structures (Figure 2.8) should be viewed with caution due to the long period (9 years) over which the data were collected.



Figures 2.7 a & b: Time series of a) tag releases and b) tag recaptures of whaler sharks by regions in South Australia between 1977 and 2004.

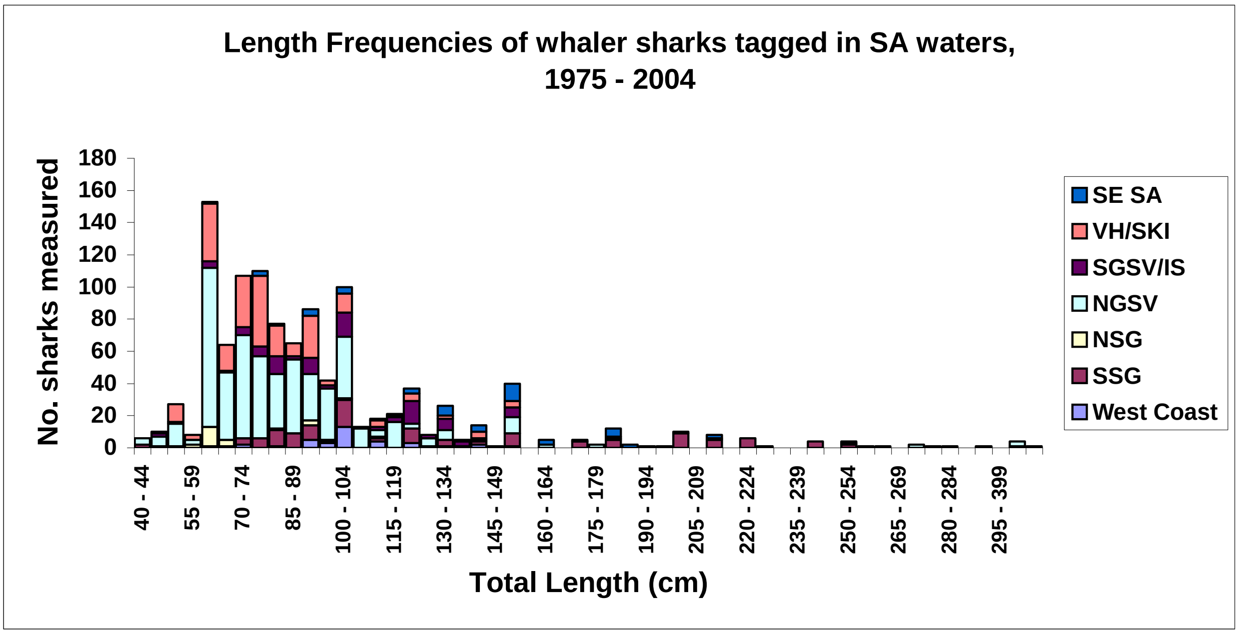


Figure 2.8. Size composition of whaler sharks tagged and released in SA waters, for sub-regions.

In eastern Australian waters, seasonal migratory patterns for *C. brachyurus* are suggested through the seasonalility in catches by recreational sport fishers and those in shark mesh netting operations off the NSW and the Qld coast (Stevens, 1984; Pepperell, 1992; Krogh, 1994 & Patterson 1986, 90). Off the NSW coast, pregnant female sharks are found during the warmer months (Sep – May, with highest numbers caught during Feb – April. Water temperatures during this period ranged between 19.5 and 23^0 C (Stevens, 1984). In southern Qld waters, *C. brachyurus*, and a number of other Carcharhinids, show similar seasonality in their relative abundances (ie high during summer months) (Patterson, 1990). The locations of their wintering area is uncertain, although, preliminary inspection of the NSW gamefish tagging database for whaler sharks for eastern Australia, suggests a northerly movement of at least 500 km for whaler sharks during winter months and vice versa in summer months (Australian Gamefish tagging data set; Jones, unpublished data). However, this information is confounded by the uncertainty in identity of the whaler shark species.

<u>SW Indian and SE Atlantic regions.</u> Critical water temperature thresholds have been suggested as a cue for changes in the spatial distribution and abundance of whaler sharks in these regions. Tag release-recapture programs off the southern and east coasts of S. Africa have shown that individual *C. brachyurus* range widely along the coast from South Cape to the mid east coast (1,320 km) (Cliff & Dudley; 1992). In addition to the distribution of their main prey, the sardine (*Sardinops sagax*), water temperature was believed to play an important role in the distribution of this Carcharhinid shark, with 81% of catches taken in the

temperature range of 19 – 21.9^0 C. Therefore, with these temperature ranges occurring off Durban in winter, but further south in summer, Cliff & Dudley (1992) suggested that sharks found off Durban were the winter migrants from further south.

Cliff & Dudley (1992) measured the seasonal variation in turbidity (silt emanating from river run-off in summer months) in eastern S. African coastal waters, and found that higher abundances of *C. brachyurus* occurred during the winter months, when water clarity was highest (Cliff & Dudley, 1992). However, this direct relationship may just be circumstantial, as *C. brachyurus* in the winter months may more likely be following the sardine aggregations and/or responding to critical temperature ranges (Cliff & Dudley, 1992).

There was no observed westward movement of tagged *C. brachyurus* into the SE Atlantic region, and Holtzhausen (2002) showed there was mixing of tagged sharks between Namibia and Angola, suggesting some population separation between the eastern and western southern Africa.

<u>SW Atlantic region.</u> In similarity with most other regions, population abundance in coastal waters off Argentina is strongly seasonal, with highest abundances occurring during spring (Chiaramonte, 1998) and summer (Lucifora et al, 2005). Movements appear to be related to water temperatures, rather than potential prey, however, the location of wintering areas is unknown.

C. obscurus:

<u>SE Indian and SW Pacific regions</u>. In WA a dusky whaler shark-tagging program has been in place since 1992. Until 1996, a total of 2,155 sharks were tagged, predominantly juveniles and adjacent to the SW WA coastline. Between 1992 and 1996, a total of 442 recaptures were reported (Simpfendorfer et al, 1999), with periods at liberty recorded up to 1,706 days. Movement of tagged sharks occurred between the west and south coasts of WA, and the longest distance recorded was 2,205 km. Eight recaptures were made east of the WA/SA border (Fig. 5.25 in Simpfendorfer et al, 1999). There is no direct (tagging) evidence for the timing of natal migration in WA. Rather, this has been inferred from their distributions, size compositions and reproductive data (Simpfendorfer et al, 1999). Patterns of movement were highly seasonal, with sharks mating during winter on the North West Shelf, then migrating southwards to give birth to their pups in SW WA waters during the following autumn (McAuley, 2005). The juveniles inhabit the waters off the SW and south coast of WA, occasionally moving long distances into South Australia and possibly Victoria, before joining the mature stock off the western and northern WA coastline (Borg & McAuley, 2004).

In Eastern Australia, Stevens (1984), Pepperell (1992) and Krogh (1994) noted the presence of *C. obscurus* in recreational sport fishing catches and mesh netting operations along the NSW coast, and similar to *C. brachyurus*, reported pregnant females during the warmer months, when water temperatures reached 19.5 – 23^0 C. The whaler sharks tagged in eastern Australian waters (Australian Gamefish tagging database, (of which *C. obscurus* was one of the Carcharhinid sharks tagged), showed similar seasonal movements (Jones, unpubl. data).

NW Atlantic region. Tagging studies on *C. obscurus* in NW Atlantic waters demonstrated that a single population existed between the Gulf of Mexico and the NE coast of USA (Kohler et al (1998). In these waters, the species undertakes long temperature related movements, with northward migrations during summer months and a southward retreat as water temperatures decline. Recently, philopatric behaviour (ie tendency to return to a home area, birthplace or other adopted locality) has been suggested for *C. obscurus* and other Carcharhinid sharks occurring off Florida (Hueter et al, 2005).

2.2.5. Ecological Interactions.

Globally, Carcharhinid sharks are high level consumers within pelagic fish assemblages, often naturally aggregating in waters of enhanced productivity due to localised upwelling or over seamounts (Klimley & Butler, 1988, & Table 2.4). The implications to the rest of the food web when these predators are removed, or, the effects on these sharks when the lower trophic levels are impacted by fishing or other causes are only just beginning to be understood; however, there remains a paucity of data on the long-term abundances at the different trophic levels (see review in Stevens et al, 2000). Because of their predatory and scavenging behaviour, Carcharhinid sharks are often associated with schooling pelagic species, such as tunas, Australian salmon and sardine. From observer records of yellowfin tuna (*Thunnus alalunga*) fishing operations in the eastern tropical Pacific, Au (1991) reported silky (*C. falciformis*), whitetip (*C. longimanus*) and dusky (*C. obscurus*) whaler sharks most commonly associated with the tuna, when the latter occurred with flotsam (floating logs). Flotsam is known to aggregate both prey and predators, and man-made flotsam (floating fish aggregation devices - FADs) have successfully been used to enhance fisheries for pelagic species (Preston, 1991). However, this whaler shark/tuna association diminished when the tuna schooled or when dolphins were associated with the tuna aggregations (Au, 1991). Similarly, in the western Indian Ocean, Romanov (2002) found the by-catch of Carcharhinid sharks (including *C. obscurus*) in tuna fisheries was higher when the tuna were associated with flotsam and whale aggregations than when the tuna were free schooling.

Table 2.4: Review of the diets of *C. brachyurus* and *C. obscurus*

Species	**Position in food chain & Diet**	**Reference**
C. brachyurus (S. Aust)	Secondary carnivore: Associated with schooling *A. truttacea* in high-energy coastal areas. (Based on presence of stages of cestode parasites, and personal observations for aerial surveys of salmon schools)	Cappo, 1992a,b
C. brachyurus (S. Aust gulfs.)	Secondary carnivore, feeding on rock flathead and snook (*Sphyraena novaehollandiae*). (adult stages of cestode parasites in *C. brachyurus* and intermediate stages of parasite occurring in flathead and snook)	Campbell & Beveridge 1987
C. brachyurus (Eastern S. Africa)	Mainly sardines (*Sardinops ocellata**), also cephalopods (*Loligo*) and marine mammals (possibly scavenged)	Cliff & Dudley, 1992; Smale, 1991
C. obscurus (WA)	Diet of pelagic fish (*Sardinops sagax*) and cephalopods (Octopus & squid). With increasing size of sharks, increased presence of elasmobranches – ie cannibalistic	Simpfendorfer et al, 2001
C. obscurus (NW Atlantic)	Juveniles generalist predators of demersal and pelagic teleosts, demersal elasmobranchs and crusteans.	Gelsleichter et al, 1999
C. obscurus (Eastern S. Africa)	Cephalopods (*Loligo*) & pilchards (*Sardinops ocellata**) in juvenile sharks	Smale, 1991

*: Since 1998, Genus *Sardinops* is considered to be monospecific, ie *Sardinops sagax*)

2.2.6. Reproductive biology and breeding areas.

There is no information on the reproductive biology nor breeding areas for *C. brachyurus* in SA waters. Elsewhere, information on the reproductive biology of *C. brachyurus* has been obtained from sampling of recreational catches (Lucifora et al, 2005) and shark meshing programs (Cliff & Dudley, 1992) and for *C. obscurus* from commercial fisheries (Simpfendorfer et al, 2002; McAuley, 2005). Most studies have covered a large size/age range of sharks, and were able to estimate size/age at first maturity for both sexes, sex ratio of fished component of the population, number of embryos:female size/age relationship. Sexes of mature male sharks were identified according to presence / absence of calcified claspers, and for mature females, the presence of widened uteri and yolked oocytes were used.

The following information for both species is shown in Table 2.5. For both species, males become mature at a shorter length and younger age than females. For *C. obscurus*, there are slight intra-specific differences, with both genders becoming reproductively mature at slightly younger ages in the NW Atlantic population compared with the Indian Ocean population. There are insufficient data to determine if these differences are genetic or the result of fishing (Cope, 2006).

Table 2.5 : Review of the reproductive biology of *C. brachyurus* and *C. obscurus.*

Species	Male size/age at 1st maturity	Females size /age at 1st maturity	Female fecundity	Sex ratio of fished population	Reference
C. brachyurus (South Africa)	Commences at 2 m, (13 yrs)	Commences at 2.29 m, (20 yrs)	n/a	1.2 males: 1 female	Walter & Ebert, 1991
C. brachyurus (South Africa)	L 50 181 cm (PCL)	L 50 191 cm (PCL)	Average 15, related to size of mother.	Embryos 1:1	Cliff & Dudley, 1992. Dudley & Simpfendorfer, 2006.
C. brachyurus (SW Atlantic)	2.16 m. (TL)	2.22 m.(TL)	16	Adults: usually close to 1:1	Lucifora et al, 2005
C. obscurus (WA) (Indian Ocean)	20 yrs	27 – 32 yrs (median 30 yrs) 24 yrs	3 – 14 every 2nd – 3rd yr.		Simpfendorfer 2002; McAuley 2005 Cope 2006
C. obscurus NW Atlantic)	19 yrs	2.8 m 21 yrs			Natanson et al, 1995 Cope 2006
C. obscurus (sthn Indian Ocean)			Embryo number related to size of mother.	Spatial variation in sex ratio	Gubanov, 1988

2.2.7. Early Life History and nursery areas.

C. brachyurus

All Carcharhinid shark species bear live young with attached yolk sacs. Their length at birth ranges between 59 and 74 cm (Compagno, 1984, Walter & Ebert, 1991). Newly born sharks with open umbilical scars (ie neonates) are often referred to as "pups".

Shark nursery areas are defined here, as areas where neonates or young-of-the-year are : a) more commonly in the area than other areas, b) that shark fidelity is relatively high, and c) the area or habitat is repeatedly used across years (Heupel et al, 2007). Hence, the commonly used term "pupping areas" is included in this definition of a shark nursery area. There is no information on the distribution of *C. brachyurus* nursery areas in South Australia have been undertaken. Tagging information on whaler sharks in SA, indicates relatively high numbers of juveniles occurring in northern GSV and around the mouth of the Murray River, but little tagging was conducted elsewhere.

The SW Atlantic and SW Indian populations, pupping time occurs from October – December (Lucifora *et al*, 2005; Cliff & Dudley, 1992), however, the locations of their pupping areas are again poorly understood.

C. obscurus

Observer surveys on gill net vessels fishing off the south and west coast of WA between 1994 - 97, collected catch rate data of neonates to develop a recruitment index (RI). The main pupping area was in waters off Cape Leeuwin in autumn. There was a poor relationship between RI and the commercial CPUE, indicating that additional factors including environmental variability were required to develop the RI (Simpfendorfer et al, 1999).

2.2.8. Age and Growth.

a. Methods of age and growth determination. Table 2.6 lists the published information on the age determination and growth rates estimated for the two species. In most cases, ages were determined by analysis of annual rings in vertebrae, with validation of ages undertaken by oxytetracycline (OTC) injection of tagged sharks occurring only on one occasion (Simpfendorfer, 2000; 2002).

Table 2.6: Published information on the methods of age determination and growth rates of *C. brachyurus* & *C. obscurus*, and showing the geographic area of the stock.

Species of shark (Genus Carcharhinus).	Method of determination of age and growth and geographical region of stock.	Reference
C. brachyurus	Vertebral ring counts. Not validated. (East Coast South Africa)	Walter & Ebert, 1991
C. obscurus	Vertebra ring counts. Validated from OTC tagged animals. (WA) Juvenile growth determined from tagging expts.	Simpfendorfer et al, 2002; Simpfendorfer, 2000.
C. obscurus	SW Indian and NW Atlantic	Natanson & Kohler, 1996; Schwartz, 1983.

b. Von Bertalanffy Growth equations, and estimates of T_{max}, L_{∞}, k, t_o.

C. brachyurus.

There is only one set of information on growth parameters for this species. Based on 52 specimens from the SW Indian Ocean population, the non-validated ages were estimated from vertebral ring counts, $L_{\infty} = 384$ cm TL, $k = 0.0385$ yr^{-1}, $t_0 = -5.57$ yrs. The theoretical age at zero length age (t_0) is not biologically sensible, and the growth equation has been adjusted, for use in future modelling or stock assessments. A form of the von Bertalanffy (VB) equation has been used in estimating growth rates for *C. obscurus* (Simpfendorfer et al, 2002), ensuring that the growth curve passes though the known size at birth:

$$L(t) = L(t_0) + [(L_{\infty} - L(t_0))(1 - e^{-kt})]$$

For the SW Indian Ocean population of *C. brachyurus,* the back-calculated size at birth was estimated at 41 cm TL, but the size at birth was known to be approximately 74 cm TL (Walter

& Ebert, 1991). Using this known size at birth and the other parameters for *C. brachyurus*, reported above, the growth curve for this sub-population is depicted in Fig. 2.9.

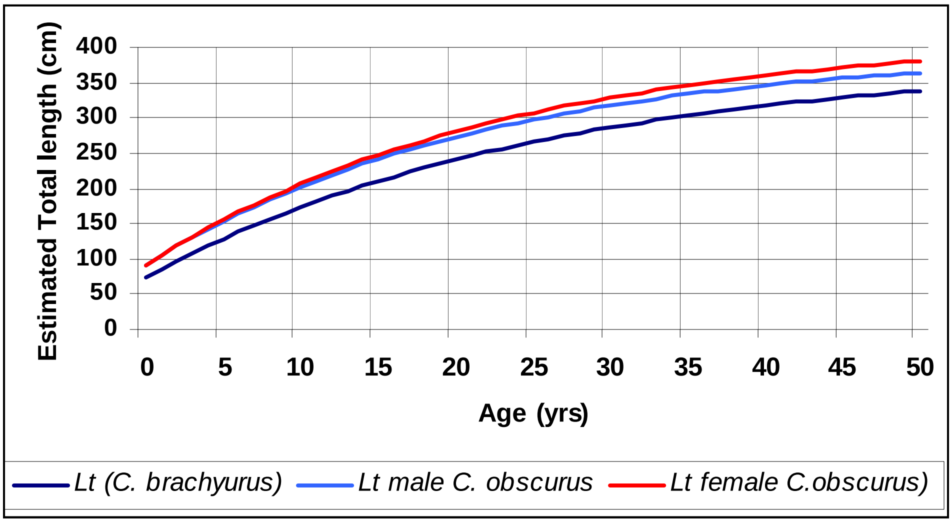


Figure 2.9: Growth curves for E South African sub-population of *C. brachyurus* (combined sexes), and male and female *C. obscurus* from WA, using growth equation developed by Simpfendorfer et al (2002), ensuring that curves passed through known size at birth (74 cm, TL for *C. brachyurus* and 92.1 cm TL for *C. obscurus*).

The growth curve has been extended beyond the theoretical maximum age of 30 estimated from the VB growth equation, as only sharks up to 287 cm, TL were aged, but longer have been reported (see this Chapter).

C. obscurus.

Simpfendorfer (2000) & Simpfendorfer et al (2002) provided validated length / age relationship information for the WA population of *C. obscurus*. Ages were validated from OTC marked tagged and recaptured juvenile sharks over a two-year period. Other sharks were aged from vertebral counts. Females mature between 27 and 32 years (median 30 yrs), which is higher than that estimated for overseas populations, and the maximum size/age of *C. obscurus* in WA is believed to be as high as 431 cm TL and 55 yrs resp. (McAuley, 2005). The von Bertallanffy growth parameters have been estimated at L_∞ (females): 419 cm TL, k = 0.043 per yr, L_∞ (males): 397 cm TL, k = 0.045 per yr and size at birth was 92.1 cm TL for both sexes (Simpfendorfer et al, 2002; Fig. 2.9). The maximum ages for the SW Indian population are 32 yrs (females), 25 yrs (males) (Natanson & Kohler, 1996). The maximum age for the NW Atlantic population was estimated at 45 yrs (Natanson et al, 1995).

2.2.9. Summary of the growth and reproductive characteristics of *C. brachyurus* and *C. obscurus*.

The growth and reproductive characteristics of *C. brachyurus* and *C. obscurus* were compared with those of other shark species occurring in Australian waters (Table 1 of the Australian Shark Assessment Report; AFFA, 2003). The 21 species and associated data for the parameters are listed in Appendix 4. In comparison with the other species, *C. brachyurus* and *C. obscurus* had low growth coefficients, females became sexually mature at a relatively long length. Additionally, *C. obscurus*, had the longest reported gestation time (Figures 2.10 & 2.11 & Appendix 4). Litter sizes for the two Carcharhinid species were close to the mean for all species. This suggests that *C. brachyurus* and *C. obscurus* may be more vulnerable to over-fishing than other shark species.

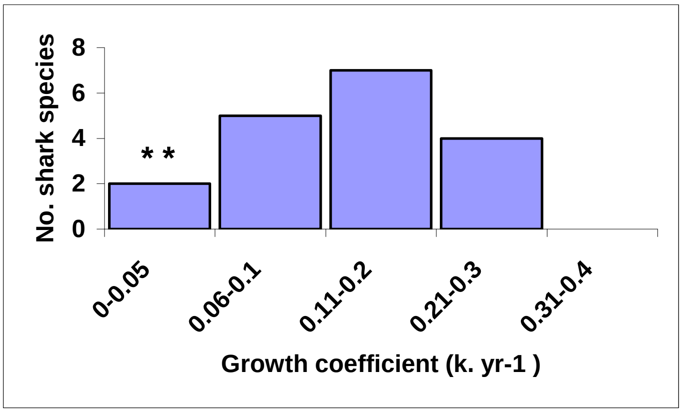


Figure 2.10: Frequency distribution of growth coefficients (*k*.yr^{-1}) for 21 selected Australian shark species, with the position of *C.brachyurus* and *C. obscurus* highlighted thus * (see Appendix 4).

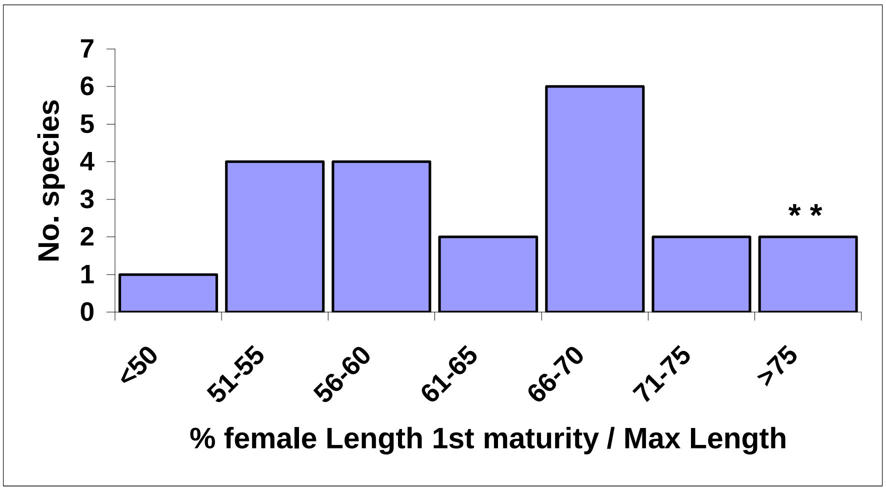


Figure 2.11: Frequency distribution of female 1st maturity length / max. length proportion (%) for 21 selected Australian shark species, with the positions of *C. brachyurus* and *C. obscurus* highlighted thus * (see Appendix 4).

2.2.10: Mortality.

C. brachyurus. No estimates of mortality rates are available for any population of this species.

C. obscurus. For the WA population, Simpfendorfer et al (1999) and Simpfendorfer (1999) estimated the natural mortality rate at between 0.081 – 0.11, based on a maximum estimated age of 60 years, Lmax, k, mean water temperature. Using tagging data, Simpfendorfer (1999) estimated the exploitation rate of neonates at around 30%, with exploitation rates from 9 – 1% for 1 – 5 yr old sharks, respectively. An overall exploitation rate greater than 4.3 %, for all age groups, was believed to be un-sustainable (Simpfendorfer, 1999).

2.2.11: Stock assessment.

C. brachyurus. No detailed stock assessment has been carried out for any of the populations of this species throughout its global distribution, because of insufficient biological and fishery (eg catch at age etc). Fowler (2005) provided a status report of the harvest, effort and CPUE's for bronze whaler sharks based on state-wide data from the SA MSF fishery, and the results are discussed in later chapters. Chapter 3 of this report provides a more detailed review of the spatial and temporal patterns of harvest, effort and CPUE in the SA MSF Fishery.

C. obscurus. Simpfendorfer (1999) used biological and fishery data from the 1990's to provide a demographic analysis. (Stock assessments using traditional age structured models were considered unsuitable because of the longevity of the species relative to the available CPUE data-sets.) McAuley (2005) updated this assessment with more tagging and biological data and revised demographic modelling methods. The new model has been used to assess recent trends in harvest, effort and CPUE's. This assessment indicated that although the exploitation during the mid 1990's was sustainable, the cumulative mortality of older sharks had caused a depletion of the breeding stock to a level, resulting in recruitment failure (McAuley, 2005).

Growth and reproductive parameters for the NW Atlantic *C. obscurus* population have been used to model the rebound potential of this and a number of other Pacific shark species, under assumed levels of depletion and density dependent compensation, and *C. obscurus* had one of the lowest rebound potentials of all shark species studied (Smith et al, 1998).

2.2.12: Knowledge gaps on the fishery biology of whaler sharks in SA.
The information on the key biological characters for the whaler sharks in SA are as follows:

- **Species Identity**. Available data often fail to differentiate the two species. However, morphological differences may be used to separate them.
- **Stock structure.** Populations of both species of whaler sharks in SA and sw WA are considered to be the same stock. Population sub-structuring is not well understood but is considered a low priority.
- **Spatial and temporal distributions of each life history stage.** The spatial and temporal distribution of the various life history stages of *C. brachyurus* is based on tag recapture studies and is poorly understood. Nursery areas are poorly defined, and it is not known whether they are spatially dispersed or discrete. A better understanding of the distribution of the different life history stages would greatly reduce the uncertainties around fishery catch and effort trends and interactions with aquaculture sea pens. Knowledge gaps could be addressed with a carefully designed tagging program. This could determine whether *C. brachyurus* displays philopatric behaviour. Therefore, addressing this information gap is considered to be a high priority for *C. brachyurus*.
- **Biological parameters used in shark assessments and management of whaler sharks.** The age and growth of *C. brachyurus* is poor understood and age methodologies have not been developed or validated for the SA population. There is a high degree of understanding of the age and growth of *C. obscurus* in other regions. Robust age estimates can be used to provide estimates of the mortality and exploitation rates to produce detailed stock assessments to inform management.
- **Age and size at maturity.** Size at maturity is available for other populations of *C. brachyurus* but may vary between sub-populations (Cope, 2006). Thus, the collection of reproduction information for this sub-population of *C. brachyurus* is considered to be a high priority. Little is known on the reproductive status of *C. obscurus* in SA; however, targeted collection of such information is regarded as a low priority, as it could be undertaken at the same time as the higher priority *C. brachyurus*.
- **Position in the food chain.** The Fisheries Management Act, 2007 proposes that SA Fisheries be managed from an ecosystem basis (PIRSA Fisheries, 2007). To understand and model the ecological risk of the effects of fishing one species on the stock and fishery of another species occurring within the same ecosystem, information on the diets and consumption rates of key species within that ecosystem is essential. *C. brachyurus* prey on a variety of pelagic and demersal teleost species. This qualitative information may not be used as inputs in ecosystem models such as Ecopath and Ecosym.

CHAPTER 3. REVIEW OF THE FISHERIES, CATCH AND EFFORT AND MANAGEMENT OF WHALER SHARKS IN SA AND ADJACENT WATERS.

3.1. Introduction

This chapter addresses the fishery component of Objective 1 and firstly describes all known State and Commonwealth managed commercial and recreational fisheries in SA and adjacent waters, which directly target or retain *C. brachyurus* and *C. obscurus* as by-product. The method of collection of data on catch and fishing effort by fishery, and the location where data sets are stored managed is reported here. Where available, the spatial and temporal trends in these data, at various scales, are also analysed. Secondly, information is reviewed for those State and Commonwealth managed fisheries not permitted to retain whaler sharks, but are known to catch and release them as by-catch. Finally, this chapter reviews the information available on the interactions between protected species and fisheries that harvest whaler sharks.

Fisheries for Carcharhinid sharks are arguably the most important shark fisheries in tropical and warm temperate waters worldwide, and are the subject of target, by-product and sport fisheries (Compagno, 1984; Anon, 2002). Demand for shark fins and cartilage (Raloff, 2002) and gamefishing for Carcharhinid species (eg Holtzhausen, 2002) has increased in recent years.

3.2. Information available and gaps in knowledge.

3.2.1. Fisheries permitted to harvest whaler sharks - South Australian managed Fisheries.

<u>Description of the Fisheries.</u>

Three SA managed Commercial Fisheries are permitted to harvest whaler sharks within state waters. These are: the SA Marine Scalefish (MSF), Lakes & Coorong (L & C) and southern and northern zone Rock Lobster (SZRL & NZRL) managed Fisheries. All managed fisheries are limited to holders of a licence pursuant to the *Fisheries (Schemes of Management: Regulations 1991).* These regulations preclude the Director of Fisheries from granting any additional fishing licences in the fishery.

Bronze whaler sharks are targeted in the multi-species commercial MSF. This is a limited entry, owner-operator fishery that is currently managed through input controls, gear/area restrictions and a one-month closure for one species: snapper (*Pagrus auratus*). Numerous types of gear are endorsed on licences and up to 15 target species are harvested at any time.

Consequently, licence holders may switch between target species depending on relative abundances or economic factors in the MSF.

As of 26 July 2005, 371 fishers held a licence to operate only within the MSF. Of these, 351 held 'M' class licences and 20 held restricted or 'B' class licences (Table 3.1). Within the Marine Scalefish Fishery, "M" licence holders traditionally, were the only group whose licences were transferable. Since the licence limitation policy was introduced in the MSF fishery in 1980, the number of B class licences slowly decreased through non-transferability. Also, B licence holders are restricted in the types of gear they are permitted to use (ie nets restricted; Noell et al, 2005).

Table 3.1 Licence holders of South Australian fisheries able to access whaler sharks (Noell, et al, 2005).

Fishery Licence Type	No. Licence Holders
Marine Scalefish Fishery Licences	
Marine Scalefish Fishery	351
Restricted Marine Scalefish Fishery	20
Others with Access to whaler sharks	
Northern Zone Rock Lobster Fishery	68*
Southern Zone Rock Lobster Fishery	181†
Lakes and Coorong Fishery	37
Total	657**

* Of these 68 licence holders, 65 have full access to marine scalefish species, 2 have access for bait only, and 1 has no access (incidental catch only).
† of these 181 licence holders, 154 have full access to marine scalefish species, 12 have access for bait only, and 15 have no access (incidental catch only).
**As of 12 April 2005.

L & C licence holders are able to harvest whaler sharks along the Coorong Ocean Beach and to 3 nautical miles offshore. Most SZ and NZRL licence holders are permitted to retain whaler sharks depending on their entitlements :a) for sale, b) for bait only, or c) only incidentally in lobster pots and which must be returned to the water. Table 3.1 provides the breakdown on the numbers with different entitlements.

Longlines and large mesh gill (shark) nets are used to target whaler sharks in all three of these licenced fisheries. A total of 316 MSF licence holders have a total of 2271 long lines endorsed on their licences, with a maximum of 400 hooks used at any one time. When targeting for whaler sharks, several long lines are deployed at the same time, often with 40 – 50 hooks attached to each long line. Hooks of size 6/0 – 10/0 are baited with by-product species such as striped perch (*Pelates octolineatus*) and tommy ruffs (*Arripis georgiana*) and are attached by a wire trace up to 30 cm length, which in turn is clipped by a stainless steel "shark clip" to the main line. Long lines are anchored at both ends, with yellow floating buoys attached at each end. Depending on the species targeted, the long lines are worked as demersal or floating long lines. In all waters of the state, with the exception of northern Spencer Gulf (ie n of 34^0 S), long line fishers must be in attendance of their set long lines.

As of July, 2005, 37 MSF licence holders had a total of 157 large mesh ("shark") gill nets endorsed on their licences. Large mesh gill-netters are permitted to use up to 600 m. of net, of minimum mesh size of 15 cm. Apart from closed areas (aquatic reserves and netting closures), both groups of fishers are permitted to use their gear throughout state waters.

The large mesh "swinger net" is the main gear used by L & C Licence holders when harvesting whaler sharks. These nets are deployed off the ocean beach of the Younghusband Peninsula, SA, usually when targeting large mulloway, and whaler sharks are taken as a by-product species. Swinger nets, of >15 cm stretched mesh, are attached to several hundred metres of rope and allowed to drift out through the surf with the aid of the offshore rip and then carried ashore with the longshore tidal flow and manual hauling (Ferguson & Ward, 2003).

Rock Lobster (RL) licence holders using long lines or large mesh gill nets take small numbers of whaler sharks in state managed waters.

Due to the recent worldwide rise in market value of shark fins, there was a strong potential for an increase in the targeting of many species of sharks, including whaler sharks. In March, 2003, at-sea shark finning was banned for all SA managed fisheries, thereby, reducing the capacity for large catches of sharks to be made over short periods of time.

<u>Collection, storage and reporting of Catch and Effort information:</u> Since 1976/77, all State managed licence holders have been required by legislation to report monthly catch and effort. Since, 1983/84, MS fishers also reported catch and effort by targeted species and gear type. In 1984/85, L & C licence holders also began to report similar levels of detail. RL licence holders have traditionally used the MSF catch and effort forms to report on their catch and effort when harvesting marine scale fish. In July, 2003, the MSF forms were amended, to provide more detailed information on fishing effort, and to allow voluntary reporting of released by-catch as well as the numbers (and weights) of 2 key MSF species, KG whiting (*Sillaginodes punctata*) and snapper (*Pagrus auratus*). All sharks are reported as carcass weights, with the heads, tails and internal organs removed. A standard conversion factor of 1.5 is used to convert to live weights for all sharks species. In this report, all harvested weights and CPUE's are expressed in terms of live weight.

All CE forms are sent to the SARDI Aquatic Sciences Information Services Unit, on a monthly basis. They are checked for obvious mistakes, forms are collated, and data placed on the GARFIS database. (An example of the MSF form and the locations of commercial fishing blocks through SA are given in Appendices 5 & 6.) Summarised data are provided annually to fisheries scientists and PIRSA fisheries managers for use in annual stock assessments of key species harvested in the MSF (eg Knight et al, 2006). Whaler sharks are one of the species reported (Fowler, 2005).

Analysis of spatial and temporal distributions of whaler shark harvest, effort and CPUE. Analyses for these parameters were carried out in three phases: a) Temporal, Statewide, inter-fishery comparison, b) Temporal and large regional variation within the MSF and c) Detailed regional and temporal information within Spencer Gulf (SG).

a) Temporal statewide, inter-fishery comparison of whaler shark harvest by gear type. Reported harvest by the 3 state-managed fisheries between 1992/93 and 2003/04 has shown: the vast majority is harvested by MSF licence holders, with small proportions, early by RL licence holders and later by L & C licence holders. Reported harvest has fluctuated between 80 and 120 tonnes over this period, with the highest harvest levels in the last two years (2002/03 & 2003/04 (Fig. 3.1).

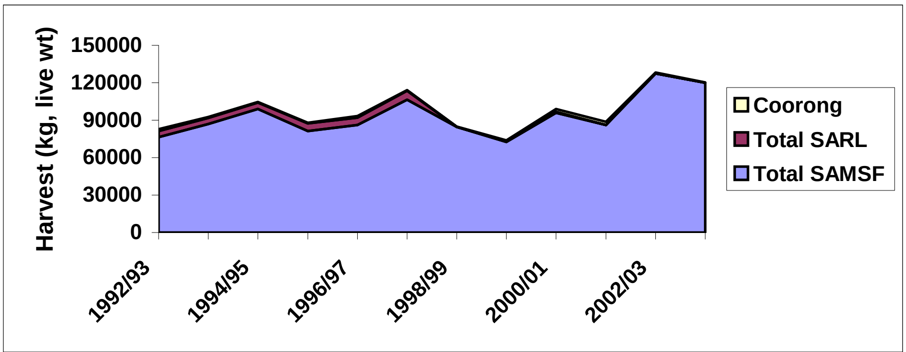


Figure 3. 1: Annual reported harvest of whaler sharks in SA managed fisheries, 1992/93 – 2003/04.

Over the 5 yr period 1999/00 to 2003/04, the proportion of the harvest caught by gill nets has dropped to be replaced by longline operations. In the last two years, the longline harvest has more than doubled (Fig. 3.2).

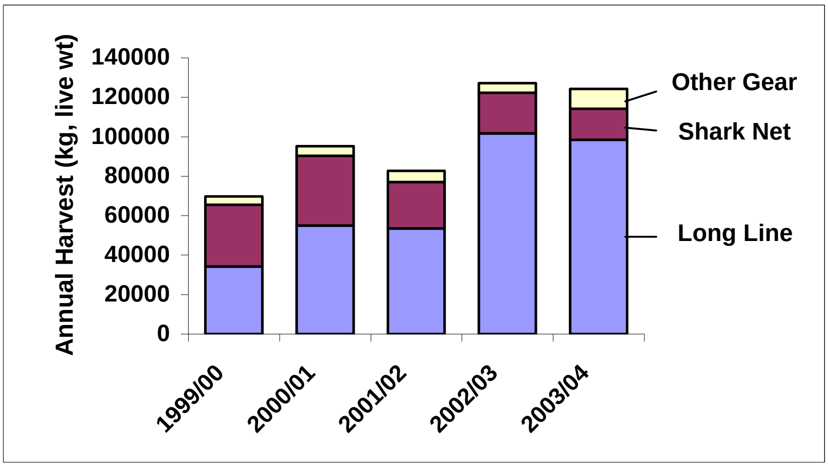


Figure 3. 2 : Reported levels of harvest of bronze whaler sharks by method of capture in the SA managed fisheries, 1999/2000 – 2003/04.

The number of licence holders with endorsements for long lines and shark nets has slightly increased in the case of long lines and decreased for shark nets (Figs.3.3a & Fig, 3.3b). However, for both these gear types, the number of licence holders using their endorsements to harvest whaler sharks, as a proportion of the total numbers harvesting all species has increased, thus indicating the rising importance of whaler sharks in the long lining and shark netting fishing operations.

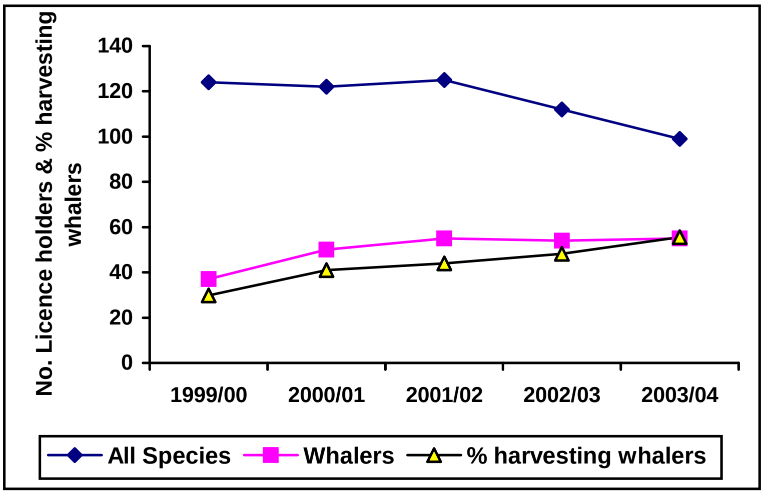


Figure 3.3a: No. Licence holders harvesting all species and whaler sharks (nos. and % of all species) using long lines, 1999/00 – 2003/04.

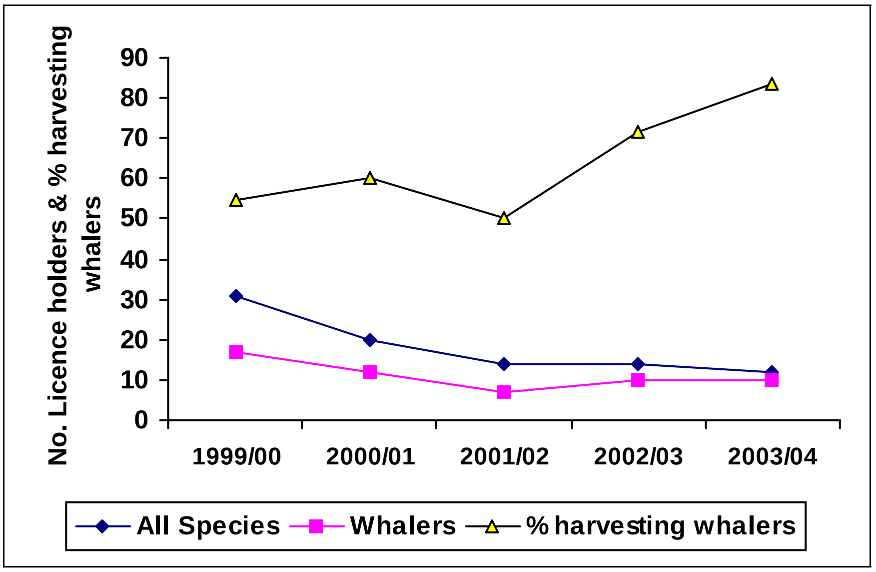


Figure 3.3.b: No. Licence holders harvesting all species and whaler sharks (nos. and % of all species) using large mesh gill nets, 1999/00 – 2003/04.

Regional variation in harvest, effort and CPUE. The harvest in Spencer Gulf increased more than the drop in harvest in all other regions of the state. In west coast waters, the drop in the reported harvest was the greatest of all regions (Fig. 3.4).

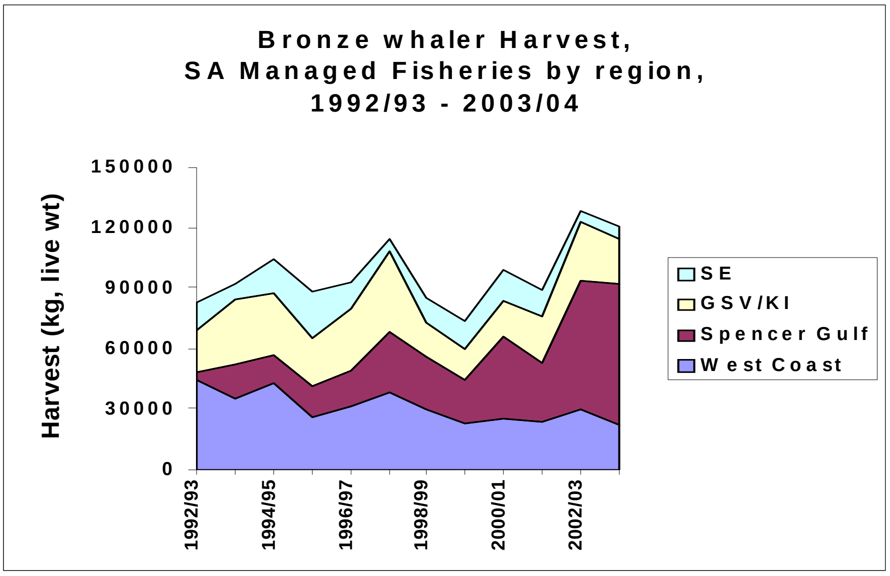


Figure 3. 4 : Cumulative reported harvest of whaler sharks by all regions of SA, 1992/93 – 2003/04, harvested in SA managed fisheries.

Long lining and large mesh gill netting were identified as the main methods of harvesting bronze whaler sharks and consequently, it was important to determine the level of effort on bronze whaler sharks, as a proportion of the total effort by these gear-types. Between 1999/00 and 2003/04, there was a decline in total reported effort (boat-days) by both gear types on all species throughout the state (Fig. 3.5a). This decline was due partly to the licence amalgamation scheme in the SA MSF, which commenced in 1994, and was aimed at reducing licence numbers and effort throughout the commercial fishery. Secondly, the drop in the reported effort by large mesh gill nets may additionally be explained by the shift of state managed gill-netters taking up the opportunity to take shark only under their Commonwealth entitlements. Inspection of the fishing effort data in the main regions where bronze whaler sharks are harvested, (ie: West Coast and northern & southern Spencer Gulf), showed that although effort on bronze whaler sharks increased in all areas, relative to other species, there was an overall decline in effort (boat-days) (Fig. 3.5.b,c & d). In the last two years, in both regions of Spencer Gulf, effort directed towards bronze whaler sharks was between 30 and 40% of all effort by long liners and large mesh gill net fishers. Figures 3.6 a, b & c show how the 2003/04 levels of fishery performance indicators ie regional harvest, fishing effort and long lining CPUE's compare with the previous 4 years average. In terms of harvest (Fig 3.6a), the limit reference points (+/- 20% change) were reached for 3 regions, with southern SG and northern GSV showing substantial rises in harvest and the SE showing a substantial drop. In terms of fishing effort (Fig 3.6b), for all six regions, the limit reference point was reached, with 5 regions expending substantially less effort in 2003/04, relative to the previous 4 yr average. Southern SG was the only region where fishing effort in 2003/04 was higher than the fishery reference point. All 6 regions showed > 20% higher levels of CPUE's (kg/boat-day) in 2003/04 relative to the previous 4 year averages, with the most substantial rises occurring in both regions of GSV.

Fowler (2005) recently provided a fishery (MSF) stock status report for whaler sharks over the period 1999 – 2005, which assessed general performance indicators, on state-wide harvest (kg, live wt), targeted and non-targeted effort (mandays) and targeted CPUE (kg / manday) for long lines and shark nets. Of the eight performance indicators assessed, 3 limit reference points were positively breached (a) target long line effort, (b) ratio of non-targeted : target long line effort and (c) ratio of non-targeted: targeted shark net effort). The limit reference point for one performance indicator (targeted shark net CPUE) was negatively breached. In 2004/05, a drop in total harvest of less than 25 % to just over 100 tonnes of the previous year's harvest, did not breach the limit reference point. Based on a comparison of the number of negatively breached limit reference points for whaler sharks with 13 other species commercially harvested in the MSF, Fowler (2005) concluded that the whaler shark fishery showed less concern than for five other species.

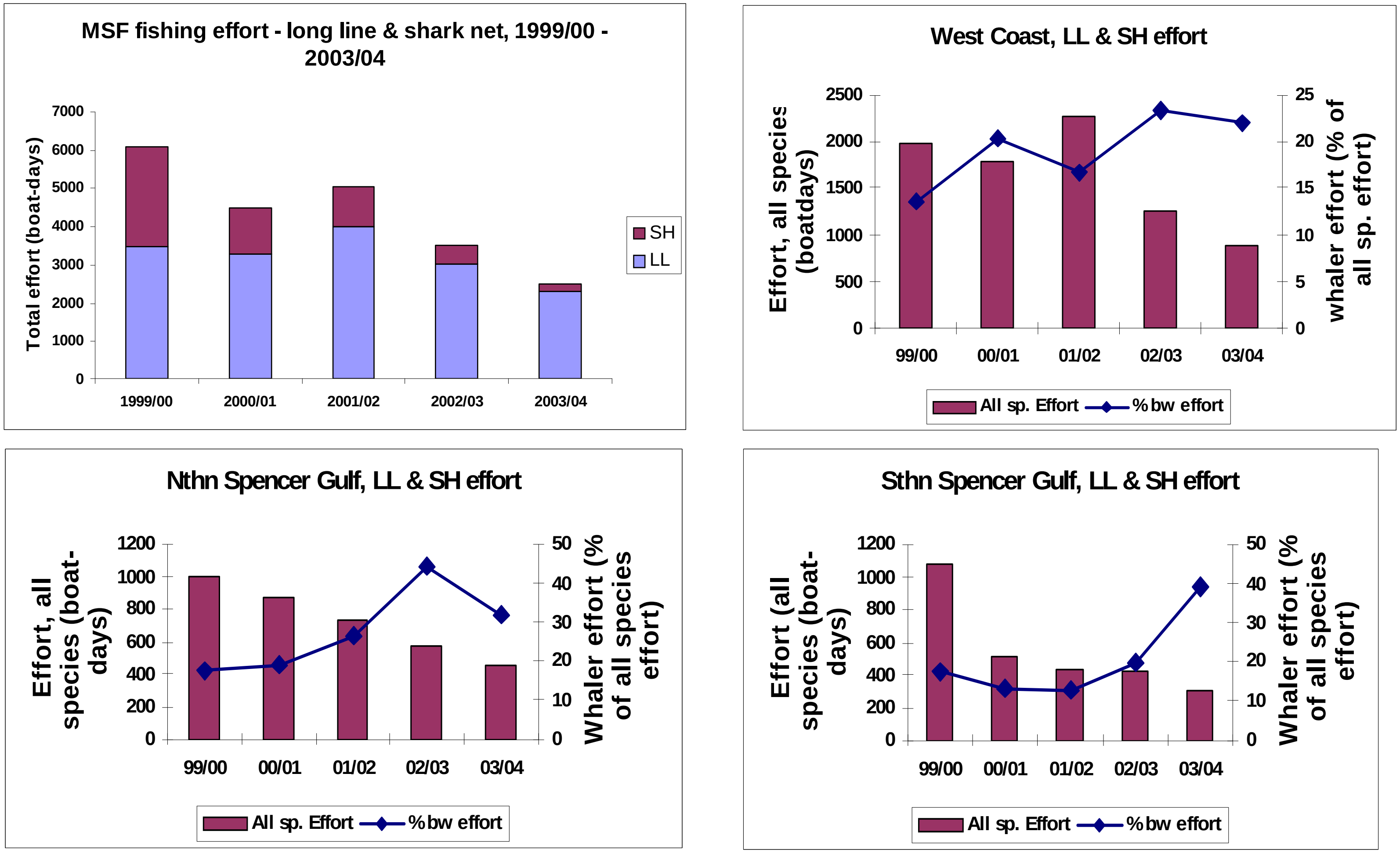
Released by-catch. Inspection of the voluntary component of the MSF catch and effort forms since July 2003 indicated no released by-catch.

Detailed regional and temporal information on harvest, effort and CPUE trends within Spencer Gulf. Spencer Gulf has been identified as the region where the whaler shark harvest has increased the most in recent years (Figure 3.4). Therefore, a more detailed analysis of spatial and temporal trends within this region is provided here. The MSF catch, effort and CPUE were separately analysed for three periods: 1992 – 94, 95 – 99 and 2000 – 2004. Spencer Gulf was divided into 5 regions, according to amalgamated fishing blocks (see Appendix 6 for locations of blocks). The regions were:

- Upper Spencer Gulf (Blocks 11 & 21).
- Mid-northern Spencer Gulf (Blocks 22, 23)
- Central Spencer Gulf (Blocks 19, 20, 29, 32)
- SE Spencer Gulf (Block 33)
- SW Spencer Gulf (Blocks 30, 31)

Trends in Harvest (Figs. 3.7 a - f) The overall temporal changes in harvest between 1992 and 2004 have been:

- Over the entire period, harvest increased throughout the Spencer Gulf (Fig. 3.4). For all three periods, harvest levels were highest during warmer months. In the first 2 periods harvest peaked in Dec-Jan, while in the last period the peak was in Nov – Feb (Fig. 3.7f). Annual commercial harvest increased by 300 %, from 11.2 t to 44.5 t., for the whole of Spencer Gulf.
- The slight shifts in seasonal peak harvests differed within regions (Figs. 3.7 a & b). In the 2000-04 period, harvests in both northern Gulf regions peaked early during the warmer months (November), with lower levels of harvest occurring later during the warmer period. In earlier years, peaks in harvest occurred in Dec – Jan.
- In the central region of the Spencer Gulf (CSG), the timing of the seasonal peak in harvest during the first and third periods did not differ (Dec, Jan) (Fig. 3.7 c).
- For both regions of southern Spencer Gulf, late summer (Jan – April) appeared to be the period of peak levels of harvest in the last two periods Fig.3.7 d & e). In 1992-94, the peaks in harvest differed between the two regions, with a significant April-May peak in SESG and Feb and April peaks in SWSG. These peaks in this early period in both regions reflect a by-product harvest of whaler shark.



Figures 3.5 a,b,c & d: Annual fishing effort (boat-days) by long lining and large mesh gill (shark) netting in the SA managed fisheries, directed at a) all species throughout the state, & b, c &d) all species in northern & southern SG and WC, and the relative proportion of the effort when bronze whaler sharks were harvested.

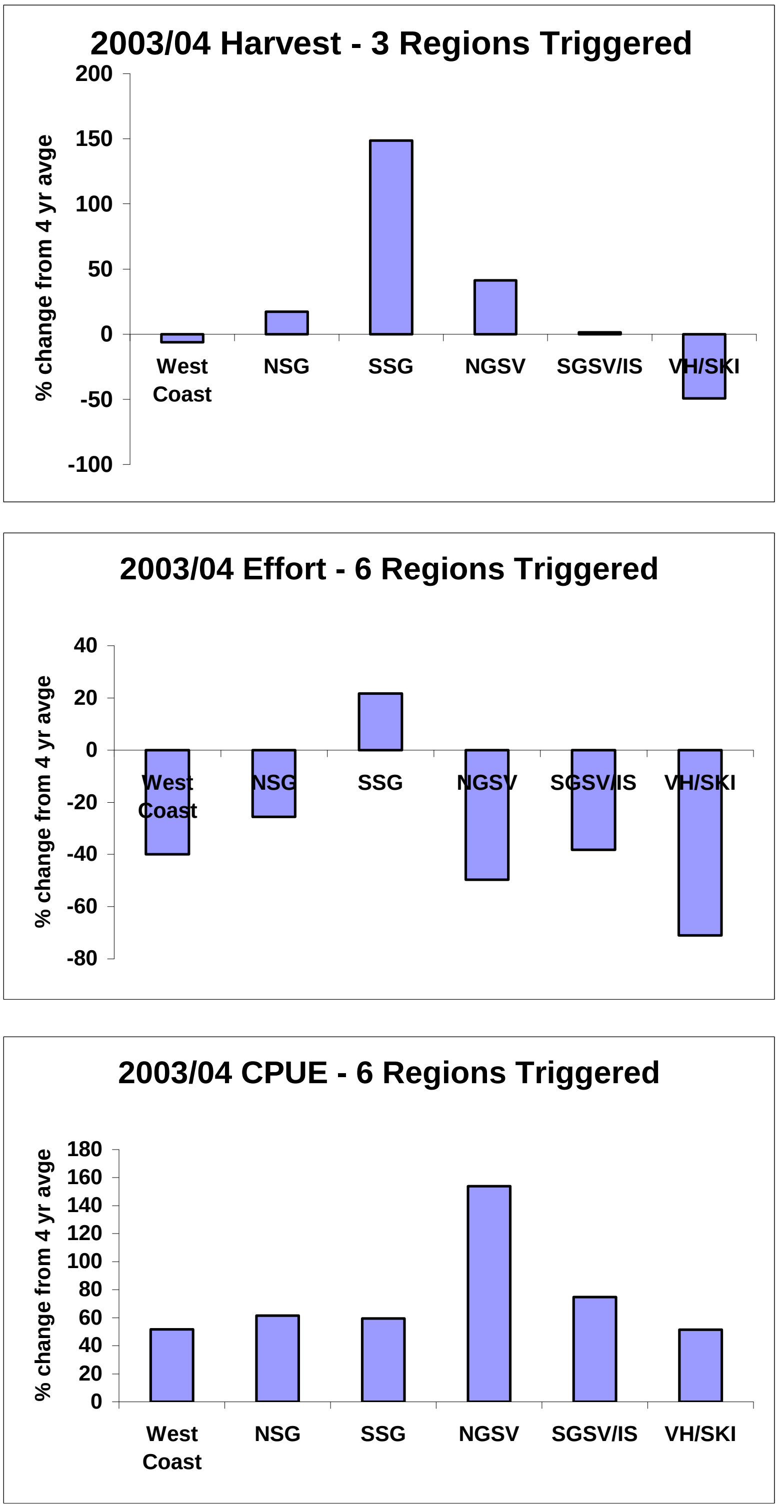
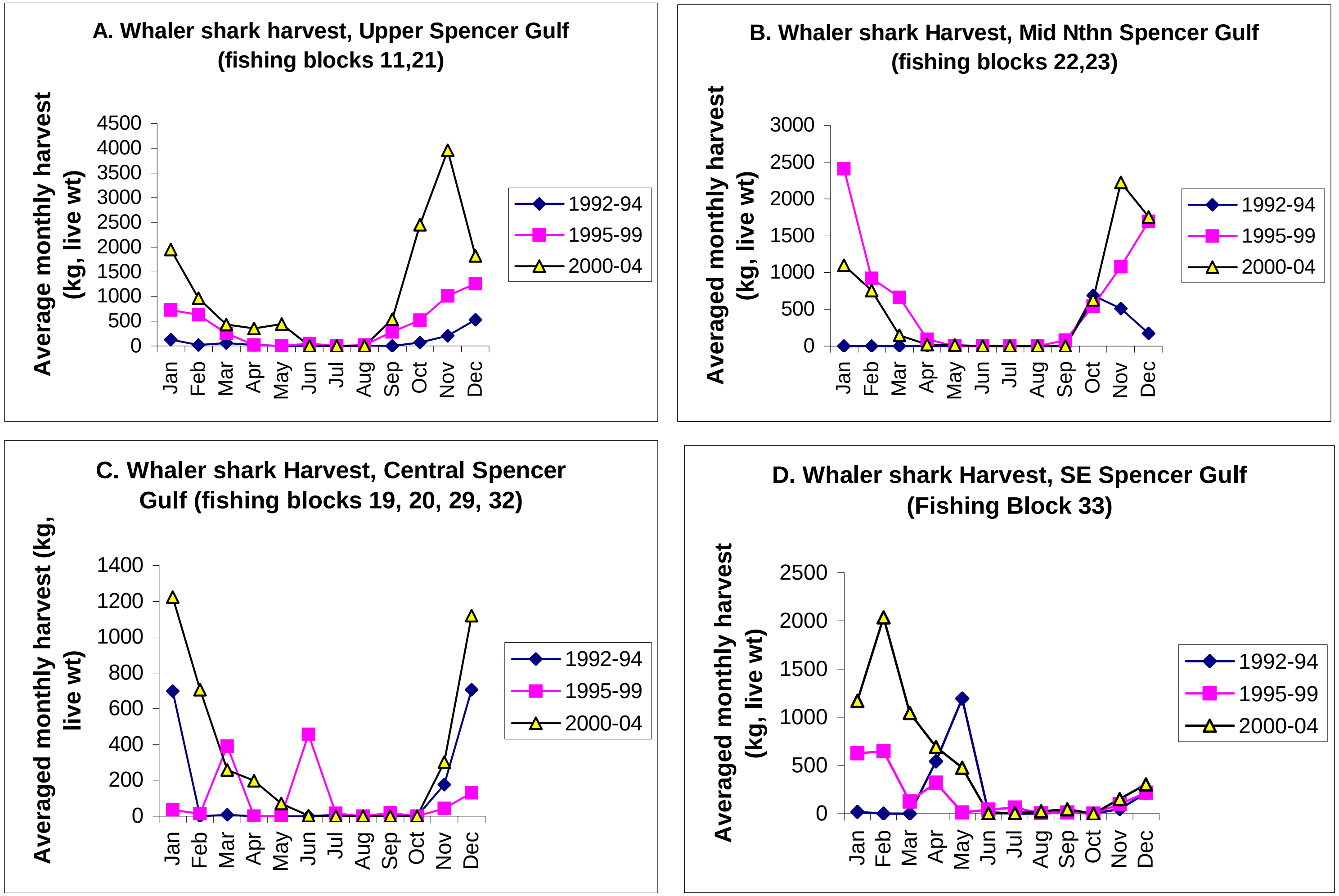


Figure 3.6 : Regional percentage changes in a) harvest, b) effort and c) long lining CPUE in 2003/04, compared with the previous 4 yr average.

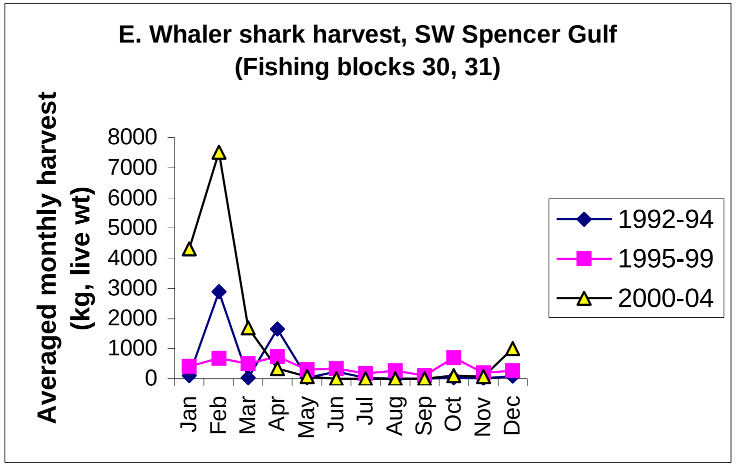
Trends in target effort (boat-days) (Fig. 3.8 a - c). Over the three periods, target effort rose substantially, accompanied with a diversification in regional effort. Mid-northern SG (MNSG) was the only region where whaler sharks were targeted in all three periods. In the

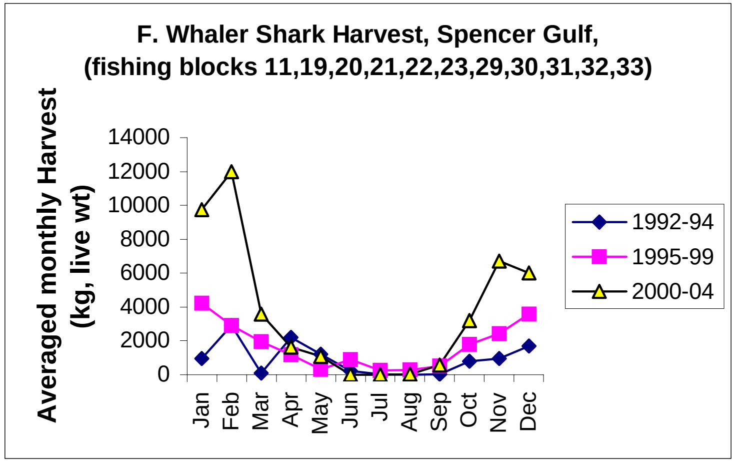
2000/04 period, the combined target effort in USG, CSG, & SWSG comprised 68 % (148 boat-days) of all targeted effort in SG. In the other two regions, one showed a decrease in effort (MNSG) whilst the other (SESG) increased substantially.

Targeted CPUE (kg / boat-day) (Fig. 3.8d). Throughout Spencer Gulf, targeted CPUE rose from 204 to 628 kg / boat-day between 1992-94 and 2000-04. Due to lack of targeted fishing effort in most regions of SG prior to 2000, MN Spencer Gulf was the only region, where a temporal comparison of CPUE be made. CPUE more than doubled between 1992-94 and 2000-04 from 203 – 502 kg / boat-day. For the whole of Spencer Gulf, the area averaged seasonal CPUE peaked from October – February in 2000-04 (Fig. 3.8d)



Figures 3.7 a – d: Monthly average harvest of whaler sharks in Spencer Gulf for upper, mid northern, central and SE Spencer Gulf





Figures 3.7 e, f: Monthly average harvest of whaler sharks in SW Spencer Gulf and combined blocks of Spencer Gulf for the periods 1992-94, 1995-99 and 2000-04.

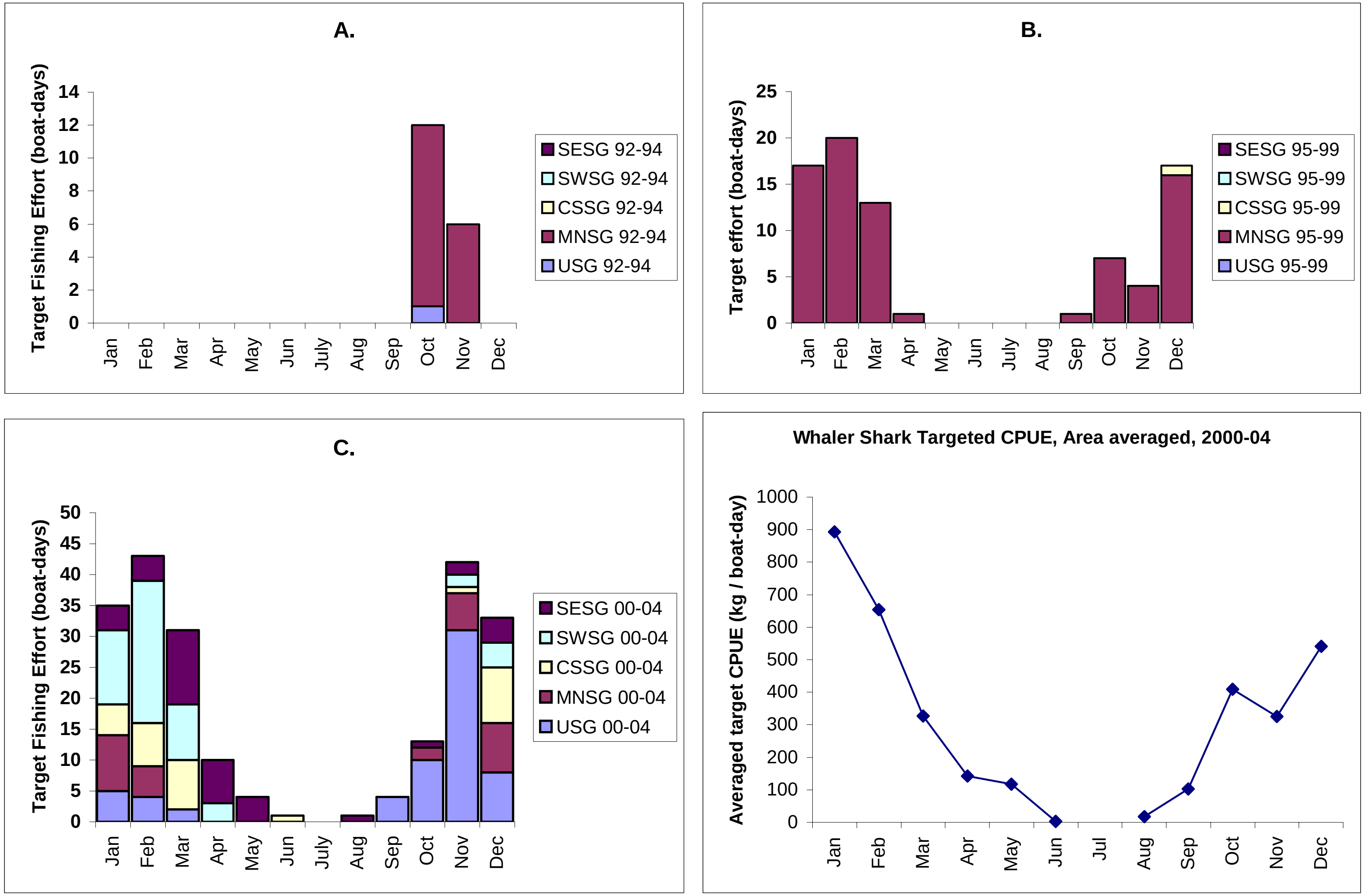


Figure 3.8 a - c: Target Fishing Effort (boat-days) on whaler sharks for the three periods 1992-94, 1995-99 and 2000-04.Figure 4.5.d: Averaged targeted CPUE in Spencer Gulf (long-line and large mesh gill nets combined).

3.2.2. Fisheries permitted to harvest whaler sharks - South Australian Recreational Fishery.

The Fishery.

The capture of whaler sharks has been a popular component of recreational fishing in South Australia for at least 40 years (Hume, 1965; Capel, 1968). They have been part of targeted catch (tag) and release fishing operations and as retained or released by-catch during the target fishing operations for other “sport” species, such as mulloway (*Argyrosomus japonicus*) and salmon (*Arripis* spp.). The target catch-and-release fisheries are both shore-based along high-energy beaches of the Coorong and the west coast of SA, as well as boat fishing in the SA Gulfs and Investigator Strait waters. An unknown proportion of the sharks caught during both shore and boat based operations have been tagged with Australian Gamefish tags (NSW Fisheries Reports (1990 – 2001). Shore based fishers use conventional surf rods and geared reels. Traditionally, ganged hooks (4/0 – 6/0) or tandem rigged 6/0 & 4/0 hooks baited with sardines, strips of mullet, garfish or squid are used. With the introduction of bag limits for large salmon (since 1994) and large mulloway (since 1986) targeted off SA ocean beaches coinciding with the increased interest in catch and release fishing for these species, there is the potential that whaler sharks are becoming a more substantial by-product or by-catch species of these operations. Unfortunately, the temporal data on release and recapture numbers of Gamefish tagged whaler sharks (Figs. 2.7 a & b) cannot be used to determine catch rates, and hence, relative abundances, as there was no information on fishing effort to accompany these data. In boat fishing operations in the deeper waters of the SA gulfs, whaler sharks are caught during target fishing for snapper and in game fishing expeditions.

Catch and effort.

The most comprehensive set of data on recreational catch and effort on whaler sharks in South Australia is that derived from the National Recreational and Indigenous Fishing Survey (NRIFS) undertaken from May 2000 – April, 2001 (Henry & Lyle, 2003). A randomized selection of households throughout Australia were invited to record their monthly catch and effort and other details of their recreational fishing activities throughout the year. By undertaking a national survey of households, it was possible to provide estimates of catch and effort for a particular region / state / territory which incorporated local as well as those fishers who lived in other states. The details of the survey methodology are summarised in Henry & Lyle (2003) and the results of the extraction and analysis of data associated with whaler sharks for SA in Jones & Doonan, (2005). The South Australian component of the National data-base is stored at the SARDI Aquatic Sciences Fisheries Statistics Unit. Jones & Doonan (2005) provide details of the SA regional information from the survey. Whaler sharks (which were recorded as either bronze whaler sharks or whaler sharks) were 31st out of 63 marine finfish species harvested by recreational fishers in this state.

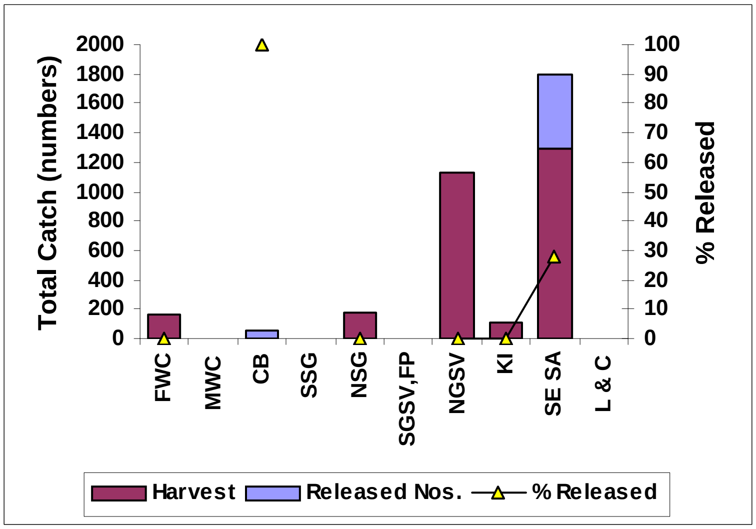


Figure 3.9: Size of harvest and released numbers of whaler sharks in regional areas of SA by recreational fishers in May, 2000 – April, 2001.

Figure 3.9 shows the regional harvested and released numbers of whaler sharks and the proportion released. The highly patchy nature of the fishery is a key feature with the most important areas where whaler sharks were caught in the SE waters (includes the Coorong Ocean Beach) and northern Gulf St. Vincent. Other areas where they were caught were the far west coast, northern Spencer Gulf and KI waters. A high proportion of the harvest was taken from shore-based fishing activities except for Gulf waters, where a higher proportion was harvested by boat fishing operations (Jones & Doonan, 2005).

The size of the harvest is clearly related to the level of fishing effort (Fig.3.10), which shows similarly high levels of targeted and non-targeted effort in the same regions as those where harvest was high. Targeted effort was relatively low compared with the total recreational fishing effort, indicating that other species, such as mulloway and Australian salmon were target species, and whaler sharks were indirectly caught. Coffin Bay and the SE of SA were the only two regions where whaler sharks were released. No information on the size composition of the harvest of whaler sharks were collected during the survey; however, interviews with recreational fishers, indicated that, on average, whaler sharks of 20 kg, live wt are harvested (Henry & Lyle, 2003) and therefore the best estimated biomass of whaler sharks harvested in SA during the survey period was 57.2 t, live wt, an estimate which was more than half the harvest by the MSF commercial fishery (95 t, live wt) for the same period (2000/01).

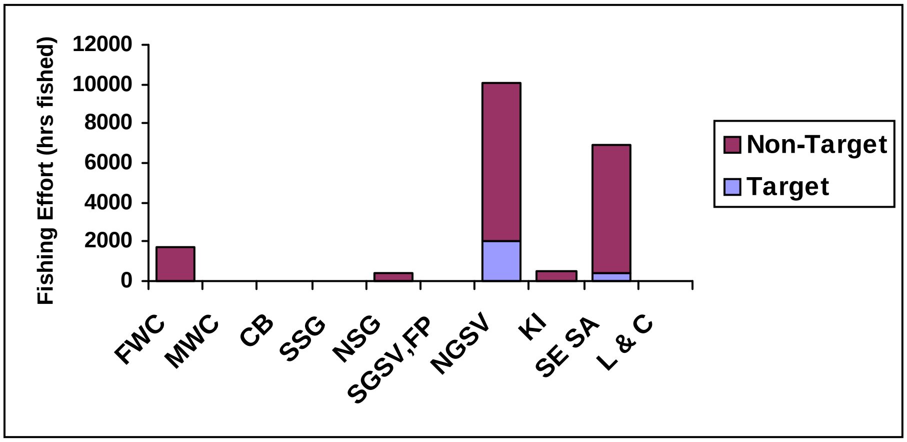


Figure 3.10: Regional target and non-target fishing effort on whaler sharks by recreational fishers during 2000/01.

The other information available on recreational fishing for whaler sharks in South Australia are the results from the Australian Gamefish tagging program, as reported in Chapter 2 of this report. It is unknown how representative these data are of the whole of the recreational fishery, in terms of the size composition of whaler sharks.

Released by-catch. Whaler sharks are caught and released by recreational fishers, either when they are targeted (eg tag and release in game-fishing activities) or when other higher valued sport species are targeted (eg mulloway or Australian salmon). The data from the NRIFS, reported an overall release rate of 16 % of all whaler sharks caught in SA (Jones & Doonan, 2005). Figure 3.9 showed that the highest proportion released occurred in SE SA waters, ranging between Victor Harbor and the SA / Vic border.

3.2.3. Fisheries permitted to harvest whaler sharks – SA managed recreational charter boat fishery.

In August, 2005, a licenced recreational charter boat fishery commenced (Presser & Mavrakis, 2005), with currently 105 licence holders registered to operate in SA marine waters (Chalupa, A., 2007, pers. com.). Whaler sharks are included in the list of permitted species for this fishery and there are no restrictions on their capture (size and bag limits). All licence holders are required to report on their fishing operations (catch and effort) through a trip log, with all completed forms being sent to SARDI Aquatic Sciences for each fishing month, within 15 days of the end of the month. For the first year of catch and effort for 2005-06, the reported harvest of 485 kg (live wt) of bronze whaler sharks throughout the state (Doonan & Knight, 2007). This level of harvest is low compared with the estimated recreational harvest of whaler sharks in 2000/01 (see 3.2.2.).

3.2.4. Fisheries permitted to harvest whaler sharks - Commonwealth Managed Fisheries.

Managed Southern & Eastern Scalefish and Shark fishery.

The fishery.

This comprises an amalgamation of a number of fisheries including a) the demersal gill net fishery for sharks (originally called the southern shark fishery) and b) fishery for sharks and scalefish using lines and traps. The latter method is the only one, where whaler sharks are not harvested (D. Bromhead, BRS, pers. com.). These sub-fisheries are now known by the acronym GHAT: Gillnet Hook and Trap), and encompasses all Commonwealth managed waters of Australia from the SA/WA border (129^0 E) eastwards to waters off Tasmania and then northwards to the QLD/NSW border (28^0 10'S). The southern shark fishery has traditionally targeted school and gummy sharks, and uses demersal set gill nets, with a narrow permitted range of mesh sizes (15 – 18 cm). Off SA waters, these nets are deployed in waters more than 3nm off-shore and at depths ranging from 10 – 100 m. Whaler sharks (reported as bronze whaler sharks) were until recently, taken as by-product species (Walker et al, 2002) in this fishery, however, with changes to management arrangements for school and gummy sharks in 2001 and 2002 (saw-sharks and elephant fish), the potential existed for effort to be re-directed to other shark species, including whaler sharks. As with the SA managed fisheries, no at-sea shark finning is permitted in Commonwealth managed fisheries.

Whaler sharks are taken as by-product off the SA coast by long lining in the SE non-trawl fishery. Long lines were demersally set with up to 2,000 or 1,000 hooks to target gummy and school sharks (depending on permit holders). Recently, the trend is towards pelagic long-lining for whaler sharks.

Commonwealth licence holders in the GHAT Fishery with SA MSF licences that have long line or large mesh gill net endorsements, are also permitted to harvest whaler sharks in state-managed waters. They are required to fill out SA MSF forms (Table 3.1) and GHAT catch and effort forms when harvesting in Commonwealth waters (Appendix 6). The data are provided to AFMA, where they are collated and then provided to MAFRI (see Walker et al (2003) and BRS (D. Bromhead, pers. com) for detailed analysis.

Analysis of Harvest Information.

Catch and effort information on sharks for all Commonwealth-managed fisheries are provided by calendar year and carcass weight (for example, Walker et al, 2003). There is little reported evidence that whaler sharks have ever been targeted (Walker et al, 2003) and non-target CPUE trends for these species are difficult to interpret. For the purposes of this review, only harvest levels by the Commonwealth fisheries have been investigated. All available Commonwealth and SA managed fisheries harvest data on whaler sharks have been converted to live weight (tonnes) by calendar year for the period 1993 – 2004 (Figure 3.11). Data for all fisheries are only available for the period 1997 – 2003.

The harvest from the state managed fisheries (predominantly MSF) dominated the total reported harvest between 1997 and 2003 (average 66 % of the total commercial harvest), however the proportion decreased from 82% in 1997 to 58% in 2003. The GHAT Fishery throughout this period has dominated the harvest by Commonwealth-managed fisheries, with whaler sharks reported predominantly as bronze whaler sharks. Within this fishery, by far the highest proportion of the harvest was taken by gill nets, with other methods including bottom long lines, drop lines, hand and troll lines being the only other gear types reported (Fig. 3.12).

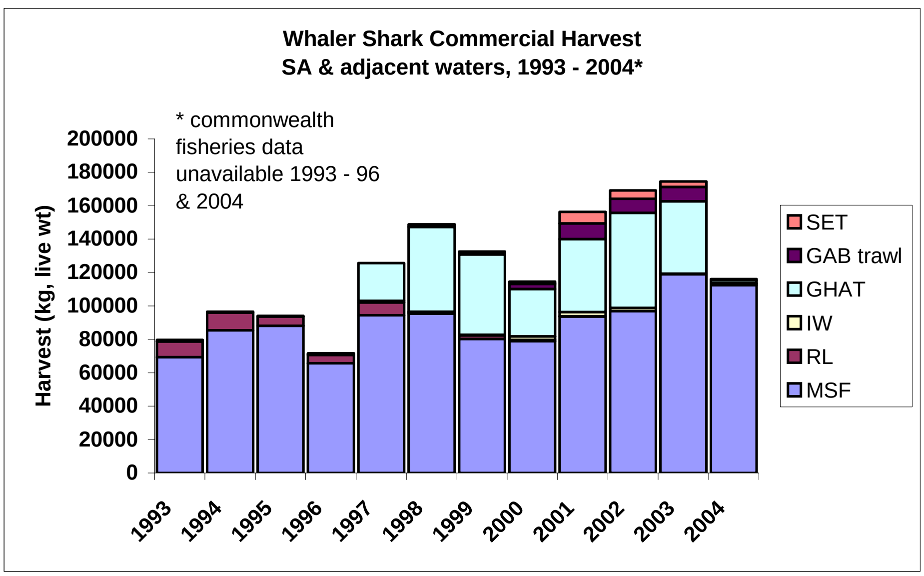


Figure 3.11: Cumulative harvest of whaler sharks for all commercial fisheries adjacent to SA for 1993 – 2004 calendar years (Commonwealth shark data obtained from BRS. D. Bromhead, pers. com.)

Released by-catch: Observer surveys in all southern Australian Commonwealth fisheries in 2000/01, indicated 100 % retention of whaler sharks taken as by-product (AFMA, 2002), and the results are summarised in Table 3.2.

Table 3.2: Level of released by-catch of whaler sharks for Commonwealth managed fisheries off SA, based on scientific observer surveys (AFMA, 2002).

Fishery	**Total catch of bronze whaler (kg, live wt)**	**Reference**
South-East Trawl	656 kg	Table 2.6.1b, AFMA, 2002)
South-East Non-trawl (DL, LL, trap)	20 kg	Table 2.6.3b,c,d, AMFA 2002)
Sthn Shark (Gill Net)	39,484 kg (1999 – 2001 harvest)	Table 2.6.3 g AFMA, 2002)

Similarly, Walker et al (2005) reported on gill net fishing experiments in the southern shark fishery between 1998 and 2001 off the SA coast, and found *C. brachyurus* as the 7th most common elasmobranch species harvested, and there was no released by-catch..

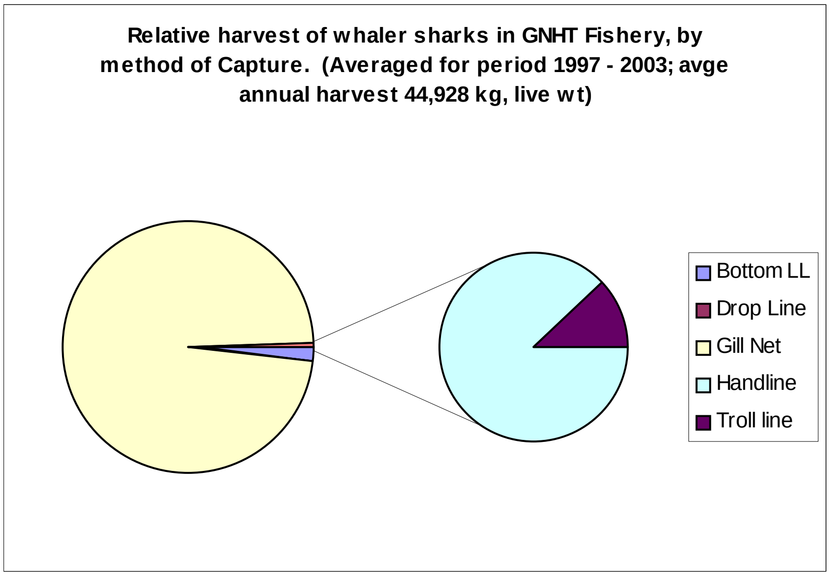


Figure 3.12: Relative size of the harvest of whaler sharks in the Commonwealth managed GNHT fishery.

Commonwealth GAB Trawl Fishery (GABTF). This trawl fishery operates in the waters of the Great Australian Bight from 129^0 E to 138^0 E, at depths from 70m to those at the 200 nm edge of the Excusive economic zone (EEZ). The GABTF a multi-species demersal trawl fishery with two components: the “shelf” fishery which targets deepwater flathead (*Neoplatycephalus conatus*) and bight redfish (*Centroberyx garrardii*) in waters to a depth of 200m, and a "slope" fishery which targets orange roughy (*Hoplostethus atlanticus*) in waters from 200 to 1000 m depth. Whaler sharks are reported as by-product species (Retained by-product) in the "shelf" fishery in the eastern part of the GAB (Ward et al, 2002).

<u>Catch and effort Information.</u> Catch and effort data are collected by AFMA from the GAB trawl log book and summarised annual data on bronze whaler shark harvest have been provided by Bromhead (BRS, pers. com.) for this report. Whaler sharks are not targeted in this fishery, and so attempting to estimate fishing effort applied to whaler sharks in this fishery is problematic. Fig. 3.10 shows the reported size of the harvest of bronze whaler sharks by calendar year between 1997 and 2003. The size of the harvest relative to most other fisheries is small.

<u>Released by-catch</u>. Reports from a pilot observer survey undertaken in 2000/01 in this fishery revealed no retained nor discarded whaler sharks (AFMA, 2002).

3.2.5. Fisheries permitted to harvest whaler sharks - Indigenous Fisheries

The NRIFS of 2000/01 contained a separate component, the Indigenous Fishing Survey of northern Australia (IFSNA), which surveyed a sample of aboriginal communities of northern Australia (WA, NT & Qld). This survey found that sharks / rays made up a significant proportion of their annual harvest (18,294 numbers of sharks / rays), being the 13th most numerous group of species harvested, out of a total of 45 species groups. Further inspection of the data-base, located at NSW Fisheries, might provide an estimate of the number of whaler sharks contributing to this harvest.

There is no comparable information on the harvest of sharks by indigenous communities in southern Australian waters. The SA results would have included the non-commercial fishing activities of indigenous people living in urban areas, where it was believed that high phone ownership rates existed (Henry & Lyle, 2003); however, it did not cover remote communities.

Under the current Fisheries Act (1982), indigenous fishers are defined as recreational fishers. Although South Australian marine coastal fishing activities by indigenous communities for traditional purposes have been recorded for many years, and were known to exist well before white settlement (Noell et al, 2005), the level of hunting and capture of sharks is not known.

3.2.6. Single species fisheries, with whaler sharks not permitted to be harvested.

State-managed Australian sardine purse seine fishery.

Since 1995, a total of 14 licenced MSF fishers have access to clupeoid and engrauliid species in waters throughout the state and out to the edge of the 200 mile EEZ according to the OCS agreement under the Commonwealth and state legislation. Sardines (*Sardinops sagax*) (marketing name provisionally changed to Australian sardine) is by far the most important species harvested within the permitted species group (Shanks, 2005). These licence holders are permitted to use pilchard purse seine nets which have a maximum length of 1000 m, drop of 200m and a mesh size of between 14 and 22 mm. Since the commencement of this managed fishery in 1994, surveys of the eggs and reproductively mature adults have been undertaken annually by SARDI and have been used to estimate spawning biomass of sardines over a large part of SA waters. The estimates are used for the annual setting of TACs for this fishery. During the mid – late 1990's, the estimated spawning biomasses were relatively low, due the major sardine mortality events in 1995 and 1998; however, since then, they have increased significantly (Rogers & Ward, 2005).

As part of their licencing requirements, fishers are required to submit daily catch and effort logs, which include the reporting of any released by-catch, with sharks listed on the forms as one of the species groups required for reporting. To date, the reported by-catch of sharks is low, and of these, the number of whaler sharks are unknown (Shanks, 2004). Commencing in January 2005, a fishery independent program undertaken by SARDI (Aquatic Sciences) has been initiated in this fishery to quantify interactions with endangered and protected species. Included in the species groups are all species of sharks, with each species of shark identified. An ongoing observer program to cover 10% of all fishing sardine purse seining activities was introduced in August 2005 (Shanks, 2005).

SA managed prawn trawl fisheries in SA gulfs and west coast waters.

Since 1968, limited entry licenced bottom otter trawl fisheries have existed in waters > 10 m depth in Gulf St. Vincent, Spencer Gulf and some parts of the SA west coast (PIRSA, 2007). For the fisheries in the two gulfs, western king prawns (WKP) (*Melicertus latisulcatus*), slipper lobster (*Ibacus* spp.) and calamari (*Sepioteuthis australis*) are the only species permitted to be harvested and sold in this fishery, with WKP being the only target species. As with most other prawn bottom trawl fisheries worldwide, by-catch, in terms of numbers and biomass of organisms, can at times, be significant (Kennelly, 1986). Because of differences between the position of whaler sharks and prawn bottom trawling operations in the water column in the SA prawn trawl fishery, there is no documented by-catch of whaler sharks (Svane, 1998; Svane et al, 2007). All elasmobranch species reported were demersal species including Port Jackson sharks (*Heterodontus portjacksoni*) and several species of rays.

Some studies on tropical prawn trawl fisheries suggest that released by-catch from trawling operations may attract whaler sharks (Hill & Wassenberg, 1990). Released by-catch may be consumed by scavenging sharks at three levels in the water column (surface, mid-water and at the bottom). In Spencer Gulf, surface floating by-catch is scavenged mainly by seabirds and dolphins (Svane, 2005), and whaler sharks have not been seen during video-recording of surface scavengers, (Svane et al, 2007). Similar experimental observations were made on sinking by-catch and similarly, no whaler sharks were reported. Most of the discarded by-catch is believed to reach the bottom (Svane, 1998; Svane et al, 2007), and here, bottom elasmobranches scavenge on this component, and no whaler sharks were reported.

Internationally managed Southern Bluefin Tuna (SBT) fishery.

Off the SA coastline the single species southern bluefin tuna (SBT) (*Thunnus maccoyii*) fishery has the potential to capture whaler sharks. SBT is a highly migratory pelagic species captured in the Great Australian Bight (GAB) by the Australian purse seine fishery, and further offshore outside the 200 nm EZ in the Japanese long line fishery. Both these of fisheries are subject to an international management regime, under the Commission for the Conservation for SBT (CCSBT), whereby the catch is managed by TACCs for each member country of the Commission, and within the Australian managed component, through ITQs.

The method of purse seining for surface schools of SBT in the GAB is described in AFMA (2005). The purse seining method is highly size and species specific. At times, poling vessels assist in concentrating the fish at the surface whilst the purse seining operation is undertaken. Once the school has been captured, the diminishing size of the net concentrates the fish, and they are then transferred to an adjacent towing cage. These cages are then towed at speeds up to 3 knots to moored sea cages located off Port Lincoln in SW Spencer Gulf, SA where the fish are farmed. Almost immediately after the towed cages arrive at a designated moored cage, the SBT are counted and weights estimated for later subtraction from the quota allocated to that licence holder.

The 2005 AFMA by-catch plan has identified the absence of verified data on by-catch as one of the issues facing this fishery. In 2002, an observer program commenced and is currently being refined. Based on the information collected between 2002 and 2004, a preliminary risk assessment was undertaken by AFMA to prioritise species (as well as habitat and communities) at risk from purse seine fishing for SBT (AFMA, 2005). The observer program had a 13 % coverage in the 2003/04 fishing season. Sharks were assessed as high risk species, with whaler sharks and blue sharks identified as the main species groups.

Three parts of the overall operation to catch and transfer SBT from the GAB to the fish farms, are identified as potential places for interactions with whaler sharks.

1. During the purse seining operations in the GAB (AFMA, 2005).
2. During the towing of the cages to the farms, especially if the cages are towed through waters over the Continental Shelf, where whaler sharks are more commonly found (Stanley, AFMA, pers. comm.). The sharks are thought to bite into the towed cages, and are difficult to remove. Release panels exist in some of the towed cages (AFMA, 2005).
3. During the transfer of SBT from the towed cages to the moored cages off Port Lincoln.

The Long Line fishery for SBT occurs in waters, off the continental shelf throughout warm temperate waters of the southern hemisphere, and at times, occurs to the south of South Australia. Observer surveys of these operations indicated minimal interactions with bronze whaler sharks occurred (Harris & Ward, 1999).

3.2.7. Interactions between protected species and fisheries harvesting whaler sharks.

Two examples of interactions are provided here.

<u>Capture of white sharks (*Carcharodon carcharias*) on long lines set for whaler sharks.</u> The inadvertent capture of white sharks on long lines in the SAMSF has been reported previously (Malcolm et al, 2001). Since 1998, the inadvertent capture of white sharks by any SA managed fishery is required, by legislation to be reported by the fisher to PIRSA Fisheries (Presser & Allen, 1995). Since 1998, there has been one verified report of a white shark (juvenile male, 1.5 m length) inadvertently caught during a long lining operation by a SA MSF licence holder fishing

for whaler sharks in this state (PIRSA Fisheries, 2006b). This occurred in March 2005 in SE Spencer Gulf. The gear used was a floating long line. Malcolm et al, 2001 reported white sharks inadvertently captured on long lines in Spencer Gulf, used mainly to target snapper (*Pagrus auratus*) during April – November, using demersal long lines, and this appears to continue to have been the case since that publication. The recent report of the white shark caught during whaler shark long lining operations may reflect the increasing long lining effort directed at whaler sharks, especially in southern SG (Fig. 3. 6).

<u>Incidental capture of snapper during the closed snapper season with whaler shark fishing gear.</u>
Since 2000, there has been a total ban on the capture and harvesting of snapper throughout the state for part of the year. From 2000 – 2002, the closure was for two 3-week periods in August and November, respectively, and since 2003, the ban has been in place throughout November (Fowler & McGarvey, 2006). Snapper are caught by commercial fishers on handlines and long lines, with November previously being a high effort month (Fowler & McGarvey, 2006). One of the potential reasons for the recent increased effort on whaler sharks during that month of the year, especially in upper Spencer Gulf, may have been due to the redirection of effort from snapper to whaler sharks (see Fig. 3.7a, 3.8c). The methods of long lining for the two species differs (see # 3.2.6.1), however, there is a risk that snapper may be inadvertently caught when whaler sharks are being targeted in the month of November. Based on the reported catch of snapper during the closed month (Fowler & McGarvey, 2006), the consequence and likelihood of the whaler shark long-lining operations affecting the sustainability of the snapper fishery is considered to be very low.

3.3. Future Research needs for Fishery data and Assessments

3.3.1. Location and collation of fishery-dependent catch and effort data from all fisheries catching whaler sharks.

This report is the first attempt to combine the harvest and effort data from all known SA and Commonwealth managed fisheries that harvest and/or catch and release whaler sharks in SA and adjacent waters. All SA harvest information was made available from the SARDI commercial catch and effort databases generated from the regular reporting of catch and effort by each managed fishery in this state. The annual harvest of whaler sharks caught by Commonwealth managed fisheries were made available from Bureau Resource Sciences database on shark fisheries (D. Bromhead, BRS, Canberra). As whaler sharks are not harvested as target species, no specific data on fishing effort were analysed; however, if warranted for future assessments, fishery- and area-specific data on non-targeted effort by these fisheries may be procured from AFMA.

3.3.2. Reliability of status report on whaler sharks.

The State of the SA Fisheries Report for 2007 (PIRSA, 2007) defines a fishery stock status report as “an assessment of general performance indicators (catch, effort and CPUE) against limit reference points, with the clear dependence of the assessment on fishery-dependent information”. The reliability of these stock status reports for the different fisheries reviewed here can be rated, ranging at levels from low to medium (Table 3.3). The criteria for setting these levels are:

- Low: Voluntary reporting of data only; or no time series of catch and effort data;
- Medium: Time series of compulsory data by gear type, limited validation;

High: Time series of compulsory catch and effort data and validated from scientific observer surveys on fishing vessels.

The uncertainty on the status of whaler sharks is highlighted by the following issues:

- There is currently no time series information on total harvest levels. The SA recreational fishery, which was shown in 2000/01 to harvest a significant proportion of the total harvest (ie 38.3%), is the one sector where there is currently no provision to collect such a time series.
- Catch and effort data for the SA MSF fishery, which reportedly harvests the highest annual landings (ie 45.2% of the total harvest in 2000/01) is un-validated. Also, the proportion of the harvest composition of the two species is uncertain, although it has been assumed to be weighted towards *C. brachyurus* in SA waters.
- The levels of released by-catch in SA managed fisheries is only known for one fishery and only for one year, ie the SA recreational fishery. The current level of released by-catch in the SA commercial fisheries is likely to be low, as there are no catch restrictions, size limits and only limited spatial closures for certain gear types and high financial incentives to retain whaler sharks.
- The greatest uncertainty relating to the Commonwealth managed fisheries, is in interpreting the reasons for the recent increased harvest of whaler sharks in these fisheries. It had been perceived that this was because of the shift in effort from the tighter managed Commonwealth shark species (ie gummy and school sharks) towards the whaler

sharks (see Fig. 3.9); however, there is little evidence that whaler sharks are a target species in these fisheries (Walker et al, 2003).

Table 3.3. Reliability of status reporting in each managed fishery harvesting or catch-and-releasing whaler sharks in waters off SA.

Managed Fishery	**Whaler Shark Component**	**Reliability of status report**		
		Low	**Medium**	**High**
Commercial SA Managed Fisheries	Target & by-product		Time series, limited validation of data	
Recreational SA MSF	Target, by-product, released by-catch	Lack of time series of data, no data validation.		
SA managed Recreational Charter boat fishery	Target, by-product and released by-catch		Time series of data beginning in 2005 (catch), and 2007 (CPUE). No data validation.	
GHAT Commonwealth	By-product			Time series of harvest data, Observer surveys
GAB trawl	By-product			Time series of harvest data, Observer surveys
SA Sardine	Released by-catch			Levels of by-catch estimated from observer surveys on vessels, limited biological information.
SBT	Released by-catch	No validation of data up to 2005.		

3.3.3. Stock assessment needs for whaler sharks in SA and adjacent waters.

Reliable stock assessments require a) syntheses and analyses of fishery dependent data and b) quantitative numerical modelling, with reliable data underpinning the assessment (PIRSA, 2007). Unlike the stock assessments undertaken on *C. obscurus* on the WA stock (Simpfendorfer, 1999; McAuley, 2005), the data for the SA whaler shark fisheries are data poor, and insufficient to undertake to this level of detail. This level of assessment incorporates a need for both biological and fishery dependent data and will be the subject of later chapters (5 & 6).

CHAPTER 4. INTERACTIONS BETWEEN WHALER SHARKS AND MOORED AQUACULTURE SEA PENS IN SOUTH AUSTRALIA.

4.1. Introduction

This chapter documents the finfish aquaculture operations in Spencer Gulf and the recorded interactions between whaler sharks and the moored sea pens. It also provides recommendations for 10 improved data collection and 2) mitigation measures for whaler shark interactions. Whaler sharks may be attracted to moored sea pens for a number of reasons. Firstly, to the food used to feed the cultured fish or the actual cultured species in the sea pens. They may also be attracted to wild fish assemblages aggregating outside the sea pens.

4.2. Finfish aquaculture operations in Spencer Gulf and documented interactions with whaler sharks.

4.2.1. Southern bluefin tuna (SBT).

Since 1995, moored pens have been used, initially within the waters of Boston Bay, SW Spencer Gulf, and then in the last 6 years, in waters to the east of Boston Island. These pens are used to feed and maintain SBT caught in the GAB by the Australian SBT purse seine fishery, and subsequently transported in towed cages to the moored sea pens. (Information on the interactions between whaler sharks and the wild fishery, towing and transferring operations have been provided in chapter 3 of this report.)

Details of the number, locations and dimensions of the moored pens have been described in Murray-Jones (2005). SBT are farmed in pens for up to 8 months per year, from January – August. Development of the SBT Finfish Aquaculture Industry in Spencer Gulf is summarized in Table 4.1 and a map of the location of lease sites for all finfish aquaculture moored sea pens in SW Spencer Gulf is shown in Figure 4.1.

It is thought that direct interactions between whaler sharks and the moored sea pens occur when whaler sharks bite through the meshes of the pens in pursuit of either: a) SBT food, b) dead SBT ("morts") or c) other smaller pelagic species (eg Australian salmon and herring) which had entered the pens through the meshes as juveniles and remained in the pens feeding on SBT food. Divers are employed by the finfish aquaculture industry to undertake daily checks for SBT "morts", and the conditions of SBT and the pens, and divers logs report on log sheets on these details. On these logs, voluntary information on the numbers of holes in the pens and bronze whaler sharks, are also provided (PIRSA Fishwatch, pers. comm.). Bruce (1998) considered that whaler sharks were the main shark species interacting with SBT moored sea pens.

Table 4.1. Temporal changes in the development of finfish aquaculture, using moored sea pens in Spencer Gulf.

Period of Development	Species developed	Type of development
1963 – 1994	Australian managed pole fishery for SBT in GAB.	Landings predominantly occurred at Port Lincoln, SW Spencer Gulf No ranching of SBT in Spencer Gulf.
1995 – 1999.	1. SBT aquaculture.	SBT ranching using moored sea pens in Boston Bay, SW Spencer Gulf (Fishing block 31), dependent on wild caught SBT towed in cages from GAB to Boston Bay. Between 1997 and the end of 1999, the location of the moored sea pens shifted from inside Boston Bay to waters immediately east of Boston Island.
2000 – ongoing.	1. SBT aquaculture. 2. Mulloway aquaculture. 3. Yellowtail Kingfish aquaculture	1. Since 2000, all SBT moored sea pens were located in waters immediately east of Boston Island, SW Spencer Gulf (Fishing block 30). 2. Hatchery reared mulloway grown out in moored seapens at Arno Bay, central western Spencer Gulf (CSG) (Fishing block 19). 3. Hatchery reared YTK grown out in moored seapens at Arno Bay (CSG) and Fitzgerald Bay, upper Spencer Gulf (USG) (Fishing block 21)

4.2.2. Mulloway.

In the last 3 years, moored pens have been installed in waters off Port Lincoln, and Arno Bay for the purpose of growing out hatchery reared mulloway (*Argyrosomus japonicus*) (Table 4.1). Fingerling mulloway are introduced to the pens as 0^+ fish, and are grown out for one or two years, using prepared pellets (M. Deveney, PIRSA Aquaculture, pers. comm.). No interactions between the pens containing mulloway and whaler sharks have been reported (Bedford-Clarke in Murray-Jones, 2005). Suggested reasons for the lack of interactions include relatively few mulloway "morts", incompatibility between the type of mulloway food and the normal diet of whaler sharks, and the swimming behaviour of mulloway in the pens, which are usually found associated with the bottom of the pens. Nevertheless, it seems very unlikely that whaler sharks won't interact with these pens.

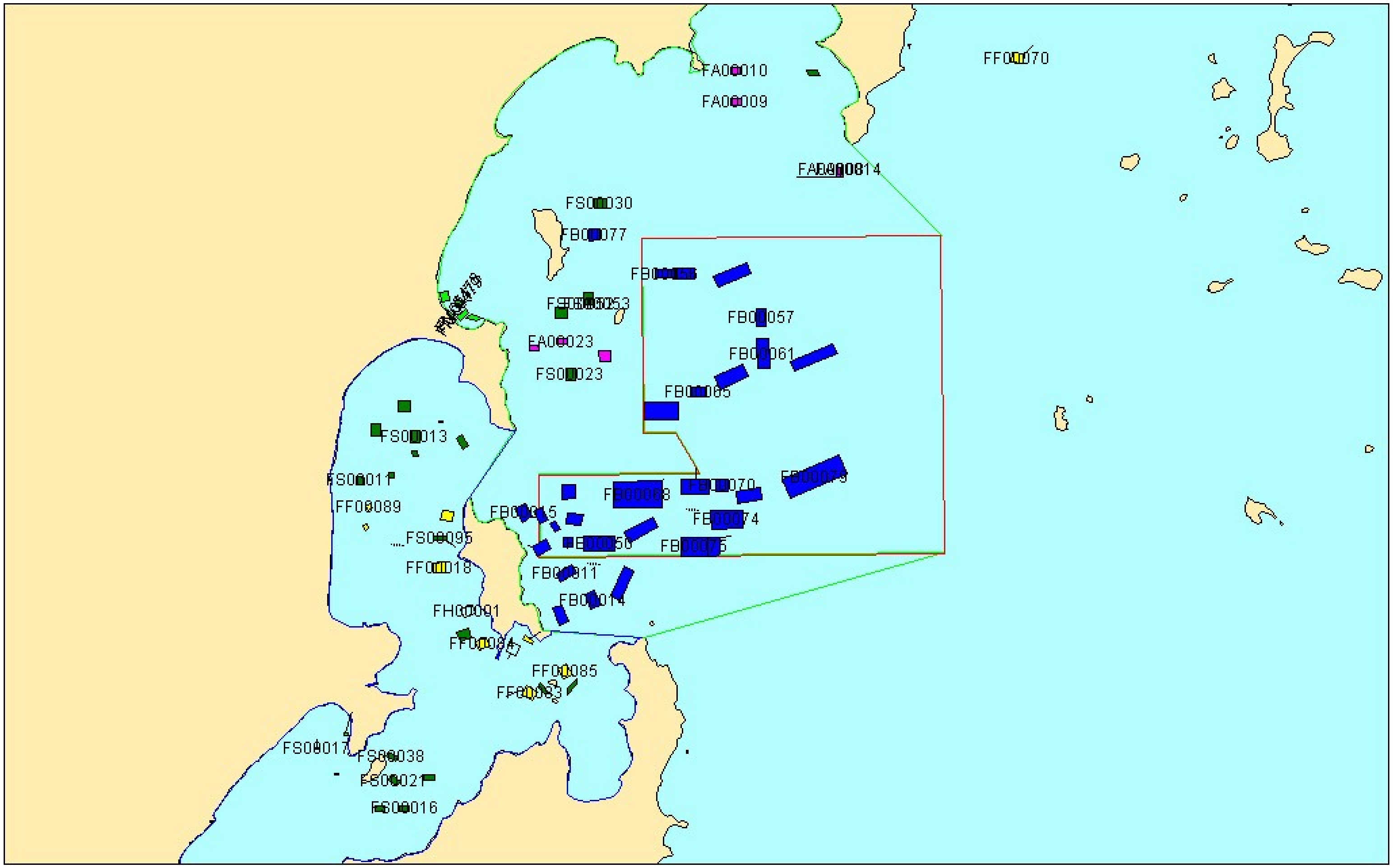


Figure 4.1: Location of lease sites of finfish aquaculture moored sea-pens in SW Spencer Gulf, 2005, used for SBT and other finfish. (Map provided by PIRSA Aquaculture).

4.2.3. Yellowtail Kingfish.

Since 2000, sea pens have been moored in the waters offshore from Arno Bay (central western SG) (7 lease sites) and Fitzgerald Bay, NW SG (5 lease sites) for the purpose of growing out hatchery reared yellowtail kingfish (YTK) (*Seriola lalandi*) (Fowler et al, 2003, PIRSA Aquaculture, 2004, 2005). In both areas, "bronze" whaler sharks are reported to seasonally interact with these pens (Arno Bay, Bedford-Clarke in Murray-Jones, 2005 and Fitzgerald Bay, this report). Bedford-Clarke (Murray-Jones, 2005) reported that commercial shark fishers were contracted by farm mangers at Arno Bay to set their long-lines, in the vicinity of the sea pens at times when whaler shark interactions were high, with the aim of reducing the numbers of whaler sharks at times of increased frequency of attacks on pens.

At the Arno Bay site, YTK are kept in the moored pens throughout the year, but whaler sharks interactions are highly seasonal (December and March – June). This is thought to be associated with anecdotal accounts of initial northward movement of whaler sharks in December to pupping areas to the north of Arno Bay, and later, during March – June a southward movement of returning sharks which had "bred" (anecdotal observations, Bedford-Clarke in Murray-Jones, 2006). These anecdotal accounts have not been validated to test this "movement" hypothesis. Harvest and target fishing effort data during 2000 – 04 from central SG (Fig. 3.7c & Fig. 3.8c) suggests strong seasonality in whaler shark catch and effort between December – March, however, the reporting of fishing locations is too coarse to be able to link whaler shark harvesting with the YTK aquaculture operations at Arno Bay.

During these periods, observations from the farm managers suggest fresh mortalities of YTK within the pens are sufficient to attract whaler sharks, and the main interaction occurs when sharks bite through the bottom of the pens and feed on the fresh "morts" (Bedford-Clarke in Murray-Jones, 2005). Divers are employed to daily check for "morts" and the condition of the pens, and when whaler sharks are found in the pens, they are generally killed instantly and then removed

For the Fitzgerald Bay site, YTK are maintained in the moored pens throughout the year, interactions between the pens and whaler sharks have been identified as being highly seasonal. Since 2000, one YTK farm business in this area has kept detailed log information on the number of holes in the pens, the number of whaler sharks seen and/or sacrificed in the pens and surface water temperatures in waters adjacent to the pens. These data have been kindly provided for this report (P. Hart, pers. comm.). Commercial catch and effort by fishers targeting whaler sharks in the fishing block adjacent to the Fitzgerald Bay sea pens have been summarized and are superimposed on the graphs of monthly interactions between whaler sharks and the pens (see Figure 4.2). Although YTK were maintained throughout the year in these pens, the seasonality in the number of holes in the sea pens closely coincides with the peaks in CPUE's by MSF commercial long line shark fishers operating in the vicinity of the sea pens. Thus, holes in the sea pens found between October and February, and CPUE's for whaler sharks occurred at similar times suggests some linkage. Although great white sharks are found in this region of the gulf throughout the year (K. Jones, pers. obs), the number of interactions between that species and the YTK seapens is thought to be minor compared with those by whaler sharks. Average monthly water temperatures peaked in February, which was not at the same time as the peaks in CPUE's or the interactions with the sea pens.

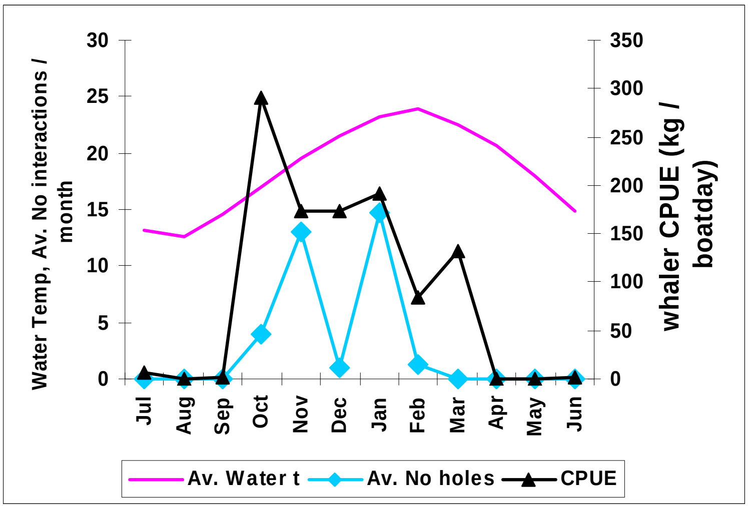


Figure 4.2 : Interactions between yellowtail kingfish sea pens and whaler sharks (no. holes in sea pens) in YTK culture operations in Fitzgerald Bay, NW Spencer Gulf, averaged for period, Oct, 2000 – November, 2004.
(Superimposed are graphs of average monthly surface water temperatures and whaler shark CPUE's from commercial long lines set adjacent to sea pens (Acknowledgement: P. Hart, C. Fewster).

4.3. Discussion

A number of Charcarhinid shark species are known to be attracted to fish aggregations around flotsam and fishing vessels discarding by-catch (Au, 1991, Hill and Wassenburg, 1991, respectively). Whaler sharks may be attracted to moored sea pens in South Australian marine waters, and may attempt to enter the pens and feed on injured or dead fish, escaped fish or other wild fish species that are attracted to these pens. Whaler sharks may be killed, enter or adjacent to the pens.

Fishery independent research elsewhere has shown that wild fish may be attracted from as far as 200 m; eg, Atlantic salmon farms in Scottish sea lochs (Carss, 1990), and sparid fish farms off the east coast of Spain (Dempster et al, 2002). The former study focused on a demersal wild species, saithe (*Pollachius virens*) and the second study found up to 27 species (small and large pelagic and demersal teleost species) were attracted. A more extensive spatial study (Machias et al, 2005) demonstrated the possible enhancing effect of sea pens in the Aegean Sea on wild fish populations, and covered control sites up to 20 km distant from the pens. Fish tagging studies have also demonstrated the attractiveness of sea pens to wild fish. Saithe were tagged adjacent to Norwegian salmon farms and were found to remain in the same area for up to 7 months (Bjordal & Skar, 1992). No similar research on the attractive nature of sea pens to whaler sharks has been carried out.

This chapter documents what data are available on whaler shark interactions with moored sea pens. Information is not validated and consists of voluntary information either from the logs of fish farm divers or managers. Some of this voluntary information has reported, at times, whaler sharks breaking through to the inside of the pens, and this has been anecdotally verified (Bruce, 1998, Bedford-Clarke in Murray-Jones, 2005). However, the total numbers of whaler sharks interacting this way is unknown.

Under the Aquaculture Regulations 2005 there is no requirement for aquaculture licensees to report any species entangled in moored sea pens, other than protected animals (ie those protected under the National Parks & Wildlife Act 1972 or species listed under the EPBC Act (1999) such as great white shark (*Carcharodon carcharias*)). Thus, the immediate impact of moored sea pens on the whaler shark populations (through their mortality within the sea pens), in comparison with the size of their harvests in all commercial and recreational fisheries remains uncertain. All shark species should be placed on the list of species required for compulsory reporting; however, this is likely to increase the need for independent verification. Any whaler sharks sacrificed in the pens could be provided to SARDI (Aquatic

Sciences) based at Port Lincoln, to assist in gathering much needed biological information on these species.

The previous chapter on the fisheries for whaler sharks reported a substantial rise in harvest levels and targeted effort on whaler sharks since 2000. These rises coincided with the development of finfish aquaculture in Spencer Gulf and furthermore, the seasonality in interactions coincide with the seasonal occurrence of whaler sharks in the Gulf would suggest some correlation. However, it is difficult to demonstrate such a causal relationship. This is because a) data on catch and effort by MSF fishers lack resolution to investigate any correlation and b) a number of additional fishing strategies by the MSF since 2000, could just as easily explain the reasons for the rise in targeted effort, harvest and CPUE for whaler sharks in Spencer Gulf. For example, targeted whaler shark CPUE's increased substantially over the same period in other areas of the state (eg NGSV) at the same time (Chapter 3).

An experimental approach may be taken to improve our understanding on the significance of the attraction of whaler sharks to moored sea pens in influencing the increase in mortality of whaler sharks in SA. There are two parts to this proposed research:

- Undertake controlled fishing experiments in collaboration with MSF long line fishers, measuring their catch rates of whaler sharks at varying distances from empty sea pens and those pens containing cultured finfish;
- As whaler sharks are known to swim near the surface (floating long lines are now used to target whaler sharks in SA, C. Fewster, pers. com.), use satellite tagged whaler sharks to monitor their localised movements, and thereby validate the results from the long lining fishing experiments.

In the meantime, methods to minimise the potential for whaler sharks to be attracted to moored sea pens should continue to be practiced by farm managers. These practices include:

- Ensure weakened cultured sock or "morts" are regularly removed from moored sea pens;
- Ensure the condition of the nets of sea pens are regularly checked to ensure holes are repaired quickly;
- Monitor and minimise feeding rates for the cultured stock in pens to minimise loss to the environment and to the sea pens;

- Develop escape panels in nets to allow whaler sharks and protected species which have entered the pens, to escape unharmed;
- Minimise the potential for escapes of cultured stock to the wild.

CHAPTER 5: RISK ANALYSIS OF RESEARCH AND MANAGEMENT NEEDS FOR WHALER SHARKS IN SA AND ADJACENT WATERS.

5.1. Introduction.

This chapter addresses objectives 2 – 4 of this project through a semi-quantitative risk assessment using the previously reviewed information on the biology and relative impacts by the fisheries sectors and finfish aquaculture.

Recently, risk assessments have been used on Australian fisheries in which sharks are captured either as target, by-product or released by-catch species. These assessments have been used to explore the relative effects of either different gear types in spatially overlapping fisheries (Braccini et al, 2006), or the relative sustainability of numerous species of elasmobranchs by the one type of gear in a single fishery (eg Stobutski et al, 2002). Ultimately, where extensive information on fisheries biology is available, quantitative risk assessments are able to be produced for species such as school (*Galeorhinus galeus*) and gummy (*Mustelus antarcticus*) sharks (eg Punt et al, 2005). This review has highlighted that it is only possible to extend the risk assessment on whaler sharks in SA to a semi-quantitative level. Using this process, priorities for further research and management options on these species in SA and adjacent waters are provided.

5.2. Review of methods of qualitative and semi-quantitative risk assessments undertaken on Australian Fisheries capturing sharks.

Fletcher (2005) developed a qualitative risk assessment methodology for prioritising Western Australian fisheries management issues. Through stakeholder workshops, the various issues for each fishery were identified across three ecological areas (retained, non-retained and the broader ecosystem), and were summarised in separate component trees. For each issue, the potential consequences (impacts) and the likelihood (probability) of a level of the consequence actually occurring were scored, and their multiplied combination of scores used as an estimate of the comparative risk for that issue. Depending on that calculated risk, so the appropriate level of management for that issue was recommended. However, as pointed out elsewhere (Astles et al, 2006), in calculating the risk, the consequence occurs both as the impact and as a means to determine the level of risk and is therefore not independent.

Other fisheries researchers have developed a slightly different method of risk assessment that relies on the development of a matrix combining two independent factors (fishery impact profile and resilience of the species) that describe the factors that determine the risk of an undesirable event (Astles et al, 2006). Stobutski et al (2002), Walker (2005) and Braccini et al (2006) developed this approach when undertaking semi-quantitative risk assessments of shark species, either within a single fishery, or spatially overlapping fisheries.

Most recently, Braccini et al (2006) used a case study of piked spurdog (*Squalus megalops*) to develop a 3 tiered risk assessment of the effects of a number of overlapping fisheries on this non-targeted species in southeastern Australia. At the first level, a qualitative analysis was done for each fishing method that may impact *S. megalops* based on expert knowledge. A number of direct and indirect impacts on each fishery method were described, and then a score (1 - 6) was assigned to each impact on a spatial and temporal scale, intensity and consequence of the fishing activity. Fishing activities with low consequence scores were then eliminated from further assessments.

For a level 2 assessment, the species was assessed based on its productivity and catch susceptibility for each fishing method, deemed to require level 2 assessment. The biological productivity was inferred from the reproductive rate or natural mortality rate. Species with low productivity rates are at a higher risk from the effects of fishing than species with high productivity. Catch susceptibility was defined as a measure of the extent of the fishing impact of each fishing method and was calculated by the following formula:

Catch susceptibility = availability * encounterability * selectivity * post-capture mortality

where:

Availability (Av) = proportion of the spatial distribution of the population that is fished by the fishing method;

Ecounterability (Ec) = proportion of the available population by one unit of fishing effort;

Selectivity (Sel) = proportion of the encountered population that is captured by the fishing gear; and

Post-capture mortality (PCM) = proportion of the captured animals that die (Walker, 2005).

As each of the fishing parameters ranges from 0 – 1, the fishing susceptibility will also have the same range. Each parameter was then assigned one of three risk categories (< 0.33 : low, 0.33 - 0.66 : moderate or 0.67 - 1.0 : high) and then based on expert judgement and a precautionary approach (ie high, if unknown), the parameters were then determined for each fishing method. Additional information, such as the diet of the species, and where the species occurs in the water column in relation to the gear, has led to increased confidence in determining the catch susceptibility (Stobutski et al, 2002).

If a species was identified as having low biological productivity with a moderate to high catch susceptibility, the necessity for a risk assessment at level 3 would be signalled. However, a level 3 risk assessment requires fishery and biological information more detailed than that available for whaler sharks in SA, and so will not be considered further.

5.3. Risk assessment for whaler sharks in SA and adjacent waters.

The risk assessment for whaler sharks in SA largely followed the method by Walker (2005) and Braccini et al, (2006) as far as the 2nd level. However, at both levels of assessment, an additional issue was considered, ie, the ecosystem effects of removal of whaler sharks. Although detailed information on the diets of whaler sharks in SA is lacking, sufficient information was considered available to include this as one of the issues. The risk assessment was undertaken by the PI.

Level 1 assessment.

All potential direct and indirect impacts by the various types of fishing methods and seapen operations were listed in Table 5.1. All fisheries and seapen operations reviewed in chapters 3 and 4 were included in the level 1 assessment.

Table 5.1. Description of potential impacts of different fishing and aquaculture activities on whaler sharks in SA.

Impact	Fishing Activity
Direct	Capture (damage or mortality due to gear deployment, including discards)
	Cryptic mortality (unaccounted damage or mortality due to interactions with fishing gear, moored or towed finfish seapens).
	Gear Loss (damage or morality without capture due to interaction with gear lost from vessels or empty moored seapens.
Indirect	Species translocation (introduction of species to the habitat of the assessed whaler sharks
	Provisioning (use of bait, berley or operating seapens to attract whaler sharks)
	Pollution (introduction of chemical and physical pollutants from fishing vessels, and benthic habitat changes around moored seapens).
	Ecosystem (effect of removal of whaler sharks on the ecosystem structure)

Each issue was then assessed using 4 categories: spatial and temporal scales and intensity and consequences, and each of these categories assigned a score of between 1 (lowest) and 6 (highest) (See Braccini et al, 2006 for description of score values).

Finally, the level of certainty for the consequence was scored at one of two levels. The rationale for scoring the levels was:

Level of Confidence	Score	Rationale for the Confidence Score
Low	1	• Data exists, but is poor or conflicting, or is unvalidated • No data exists
High	2	Data exists and is considered to be sound

The level 1 assessment for each issue is seen in Appendix 5. Where there was uncertainty in the score level of the consequences for a number of the impacts, for precautionary reasons, a high score was recorded, and where a consequence level was scored at a level > 2, the issue was assigned to the 2nd level of risk assessment. In this way, of the 12 issues assessed, a total of 5 proceeded to the next level.

Level 2 risk assessment.

Based on the reviewed information on their biological productivity, both species of whaler sharks are characterised by relatively low rates of productivity, compared with those of other Carcharinhid shark species. The characters include:

- long lived species (at least 55 yrs for *C. obscurus*),
- relatively high size /age at first breeding (20 – 32 yrs; stock and species dependent),
- slow growth rates (k = 0.02: *C. obscurus*; 0.04: *C. brachyurus*);
- long gestation times for pups (*C. obscurus > 20 months*); and
- medium number of pups per litter (av. 15).

The assessment of the catch susceptibility for the 5 issues is provided in Appendix 6. Catch susceptibility varied depending on the relate level of impact by the 5 issues.

For most of the issues, the catch susceptibility was estimated as low (< or = 0.33), due to their low to moderate impacts relative to the overall distribution of the stocks and encounterability. The spatially extensive MSF longline fishery, with high impacts from selectivity and encounterability showed a moderate catch susceptibility. The cumulative effects across all issues may cause an underestimation of the total catch susceptibility, and so, based on the low biological productivity, both species of whaler sharks are assessed at a high level of risk and require quantitative risk assessment using more detailed fishery biological data specific to the southern Australian stock (Level 3; see Braccini et al, 2006) to explore options for improved their management.

5.4: Prioritisation of future research on whaler sharks.

Research priorities were considered for both levels of risk assessment. At the first level, priorities included those impacts which were assessed as having a relatively high consequence (> 2) but with some uncertainty in the interpretation of the information. This resulted in five research priorities (Table 5.2):

Table 5.2 : Research Priorities based on level 1 risk assessment.

Potential fishing impact	Research priority
SA MSF Longline fishery	Incorporate reporting of floating longline effort by fishers in MSF log books, when targeting bronze whaler sharks
Recreational Fishery	Development of an ongoing monitoring program on catch and effort in the general recreational fishery to include bronze whaler shark catches.
Commonwealth SBT purse seine and towed cages	Reports from scientific observers on vessels reporting the number of whaler sharks interacting.
Finfish aquaculture – moored sea pens	Validated reported numbers of whaler shark interactions with moored sea pens.

All these priorities relate to objective 3 of this project, ie, to develop methods to improve the collection of catch and effort data on whaler sharks in SA. As a number of different agencies both within the state and the Commonwealth manage the various fisheries and finfish aquaculture operations, it is clear that each of these agencies should take responsibility in collecting the prioritised data sets, and that the regular reporting should be done as a coordinated approach.

The second level of risk assessment, has highlighted the need for a better understanding on the encounterability of whaler sharks to the five issues assessed. For example, an understanding of the variation in spatial and temporal distributions of whaler sharks will assist in determining whether moored sea pens act as a significant attractant. Furthermore, as found with some other Carcharinid shark species, an investigation on the philopatric behaviour (ie homing) for *C. brachyurus* would assist in determining whether localised depletion of whaler shark populations in areas where fishing effort is concentrated is likely to occur.

Finally, an understanding of the spatial and temporal locations of key stages in their life history is essential to determine the feasibility of spatially managing whaler sharks in SA. Studies elsewhere indicate some spatial variation in key biological parameters, including growth rates, age at fist breeding etc, thus requiring the need to collect similar information for the SA population. Such data are also required if it is deemed necessary to carry out a more quantified risk assessment. In the next section I review the management arrangements for whaler sharks in SA and elsewhere, and propose management options for the SA population, based on level 2 risk assessment.

5.5: Review of management of whaler sharks and management options for the SA population.

Generally, the management of shark fisheries elsewhere aim to minimise the anthropogenic impacts on key stages of their life histories (ICUN, 2003). The most important life history stages have been recognised as: breeding adults and neonates. For example, an earlier assessment of *C. brachyurus* throughout its world distribution determined that the south-east Asian population had reached the endangered status, due to the continued capture of breeding females in non-target coastal fisheries (Duffy & Gordon, 2004). Management measures for minimising impacts on these life history stages include spatial closures of breeding grounds and/or nursery areas, and if not practical, methods of reducing effort or harvest by key gear types capturing these stages.

In Australia, sharks species assessed at a threatened (vulnerable or endangered) level are fully protected, with methods developed to minimise all gear interactions (eg white shark and grey nurse sharks). In other Australian and New Zealand jurisdictions, management arrangements specific for whaler sharks are seen below (Table 5.3).

Table 5.3. Methods of managing whaler sharks and associated biological justifications in Australian and NZ jurisdictions (excluding SA managed fisheries).

Management regulation & Jurisdiction.	Biological justification
Recreational bag Limits – NSW & WA	Need for harvest control
Max. Size Limit for *C. obscurus* – throughout WA	Protection of adult breeding population, improving reproductive rate of population
Whaler sharks not to be targeted in shark management areas - NZ	Need for effort control
Gear regulations (max net lengths and hook numbers) for WA shark and Commonwealth shark fisheries.	Need for effort control
Reduction in shark gear lengths and hook numbers – WA shark fisheries since 1992	Need for effort reduction
Spatial closures for WA shark fisheries – Shark Bay to NW Cape, WA	Protection of whaler shark breeding grounds, focussing on *C. obscurus* and sandbar whaler sharks

In South Australian and adjacent waters, there are currently no management arrangements specific to whaler sharks; however, management measures directed to all or other specific shark species (eg gummy, school and white sharks) may assist in protecting whaler shark populations, only if the key life history stages coincide with those for the other shark and

MSF species specifically aimed for management. Alternatively, greater protection of these other shark species may redirect fishing effort redirected towards whaler sharks in this state, nd contributing to the rise in reported harvest of whaler sharks in both the Commonwealth shark and MSF fisheries.

The current management arrangements for SA managed sharks are seen below (Table 5.7):

Table 5.4: Methods of management of shark fisheries in SA waters, which may benefit the sustainability of whaler sharks.

Management regulation & jurisdiction	Biological Justification
Ban on Shark Finning at sea – SA and Commonwealth (14 August, 2003)	Limit wastage of sharks; improve the compliance of harvesting protected shark species (eg grey nurse, white shark) and managed shark species (gummy & school sharks – trip limits)
Licence amalgamation scheme since 1994 - SA MSF fishery	Need for effort reduction in the whole of the commercial MSF
Gear limitation (max. net and hook numbers / endorsements) - SA MSF fishery Gear attendance of nets and long lines (except NSG for long lines)	Need for effort control on main gear types used to target whaler sharks and other species (snapper). Minimise wastage, maximise the survival of protected species (eg white sharks caught on whaler shark long lines)
Large mesh gill netting closures in parts of gulfs and west coast waters	Originally set in Gulfs to limit the snapper catch by shark net fishers In far west coast waters, to protect gummy shark pupping areas, and limit catch of mulloway by nets. (Unknown benefits for whaler sharks)

Prioritising future management options in the whaler fishery in SA is dependent on the level of information available and hence the level of sophistication of the assessment (Table 5.5).

- At the lowest level of management, if stock boundaries are known and only a fishery status reports are available, management options are limited to regulating effort by jurisdiction;
- Additional management options, such as size limits, and the protection of key breeding or nursery areas can only be added if more detailed information on biological characteristics of the stock are known (ie size/age at 1^{st} sexual maturity, age and growth, and spatial and temporal distributions of key life history stages, and whether philopatric behaviour occurs);
- Management by output controls (eg TAC's, catch quotas) may only be applied if there is a good understanding of the population structure and fishable biomass available through a detailed stock assessment report, including estimates of recruitment and exploitation rates, and a quantitative risk assessment at level 3, as discussed previously, is available;

- At the highest level of management, ie ecosystem management, additional information on other key species throughout the ecosystem and their consumer relationships with whaler sharks is required (eg Christensen & Pauly, 1998).

Table 5.5. Information requirements for management options for whaler sharks in SA. (Shaded boxes denote required information needs for the respective management option).

Information requirements for Management Option	**Management Option**					
	Input control by jurisdiction	Size limits	Protection of key nursery or breeding areas	Gear regulations (incl. by-catch minimization in fisheries and fish culture sea pens)	Output controls by jurisdiction	Ecosystem management
Stock boundary / Species identity						
Fishery status report						
Age, growth, reproductive biology						
Spatial, temporal distribution of key life history phases						
Gear selectivity						
Recruitment levels						
Exploitation rates						
Quantitative stock assessment report						
Diet of whaler sharks and other key species, &population structure of key species in ecosystem						

The results of the risk analysis process clearly indicate that the current information level on the status of whaler sharks precludes any of the management options, other than the management of input controls for all jurisdictions harvesting whaler sharks. For improved management of these species, fundamental biological information on the species, especially *C. brachyurus*, is required for setting appropriate size limits and / or assessing the need to protect breeding or nursery areas. This information, together with improved information on catch and effort is required for detailed stock assessments. Finally, improved information on the diets, consumption rates of major prey items by the whaler shark populations and as well as information on the population biology of their major prey items are required before the whaler shark's ecosystem can be managed in a meaningful manner.

CHAPTER 6. GENERAL SUMMARY AND DISCUSSION.

6.1. Introduction.

Over the past 10 years, there has clearly been an increase in the potential for fisheries and aquaculture operations to increase the mortality of whaler sharks in SA. Temporal changes in these operations are summarised in Table 6.1. This chapter summarises the relative impacts of these fisheries and other operations on the whaler shark sub-populations (described in chapters 3 and 4) and their associated levels of uncertainties (Chapter 5).

Table 6.1: Temporal shifts in potential impacts on whaler sharks in SA waters for all commercial and recreational fisheries and finfish aquaculture operations.

<table>
<tr><th>Fishery / Operation</th><th>1995 - 99</th><th>2000</th><th>2001</th><th>2002</th><th>2003</th><th>2004</th><th>2005</th></tr>
<tr><td>SA Wild Fisheries</td><td></td><td></td><td></td><td colspan="4">Increase in relative number of MSF fishers targeting whalers, using floating long lines.</td></tr>
<tr><td>SA Wild Fisheries</td><td></td><td colspan="3">3 week snapper closure in Aug & November potentially shifting effort to whaler sharks</td><td colspan="3">Full month (November) closure potentially shifting effort to whaler sharks.</td></tr>
<tr><td>GHAT Fishery & SA Wild Fisheries</td><td></td><td></td><td colspan="5">Potential shift in effort to whaler sharks since introduction of output controls on Commonwealth managed sharks species (School & Gummy sharks in 2001; Sawsharks and elephant fish in 2002)</td></tr>
<tr><td>SBT PS fishery</td><td colspan="7">Potential by-catch of whaler sharks in SBT purse seine operations and interactions with towed sea cages between GAB and SW Spencer Gulf.</td></tr>
<tr><td>SBT ranching in Spencer Gulf</td><td>Potential mortality of whaler sharks in moored sea pens in Block 31.</td><td colspan="6">Potential mortality of whaler sharks in moored SBT sea pens in SW SG (Block 30) from 2000 onwards with shifting of moored sea pens to outside Block 31.</td></tr>
<tr><td>Other SG finfish ranching</td><td></td><td colspan="6">Potential mortality of whaler sharks in moored YTK sea pens in Central western SG and upper SG (Blocks 19 & 21).</td></tr>
<tr><td>SA Wild Fisheries using moored sea pens at attractants</td><td></td><td colspan="6">Potential attraction of whaler sharks to moored sea pens and targeted fishing effort by MSF fishers on whaler sharks adjacent to sea pens in Spencer Gulf.</td></tr>
<tr><td>SA sardine PS fishery</td><td colspan="7">Potential mortality of whaler sharks as released by-catch in purse seine fishery for sardines (sthn Eyre Peninsula waters).</td></tr>
<tr><td>SA Recreational Fishery</td><td colspan="7">Potential shift in effort to un-regulated whaler sharks, through the introduction of bag limits on high valued sport species taken off ocean beaches (1994 for large salmon, 1986 for mulloway) & implementation of limited entry Charter Boat Fishery in 2005.</td></tr>
</table>

A total of six State or Commonwealth managed commercial fisheries and the SA recreational fishery and managed recreational charter boat fishery harvests whaler sharks (both species) off the South Australian coast.

Temporal data on catch and effort are only available for the SA and Commonwealth commercial fisheries. In 2000/01, these fisheries harvested more than 70% of the total reported harvest, the remainder being the recreational harvest. Therefore, no status report based total harvest or effort trends can be provided.

For the two major fisheries where temporal trends in harvest and effort are available (SA MSF and GHAT fisheries), the information up to 2003/04, indicated rising levels in reported whaler shark harvest between 1997 and 2004 for the SA MSF (+ 4% per year) for the GHAT fishery (+ 29% per year). In the SA MSF, there were regional differences with the highest rise in harvest in 2003/04 occurring in southern Spencer Gulf and a drop in harvest in the Victor Harbour / southern KI region in the same year. Both these changes were outside the limit reference points set for the 14 primary and secondary species of the MSF (see Fowler, 2005). Most of these rises in harvest can be attributed to the increase in the targeted effort directed at whaler sharks relative to the total effort for the two combined main gear types (long lining and shark nets), despite the observation that targeted effort still declined. Average CPUE's increased substantially for all regions, with the highest rise occurring in northern GSV. On face value, these rises suggest an increase in the biomass of whaler sharks available to the fishery, however, considerable uncertainty prevails with this assumption, as unquantified changes in effective effort (from demersal to surface long lining), and the uncertain levels of whaler shark attraction to moored sea pens in Spencer Gulf, which could cause increasing encounterability, have not been taken into account.

In the GHAT fishery, no effort is reportedly directed at whaler sharks, and so the reason for the rise in whaler shark harvest in this fishery can only be due to the rise in by-product harvest when fishers targeted gummy or school sharks. This may relate to the tightening of harvest limits for gummy and school sharks in this fishery, and fishers supplementing their shark catches with whaler sharks off the South Australian coast.

The status of the third major fishery, the SA recreational fishery for whaler sharks is very uncertain, as there is only one year of data. A second survey of the SA Recreational Fishery commenced in 2007, using the same survey methodology as was used in 2000/01, and a second estimate of the whaler shark harvest will become available in early 2009.

The results of this assessment agree with the general assessment of whaler sharks throughout Australia, and reported in the Australian Shark fishery assessment (AFFA, 2003), which reported solely that bronze whaler shark catches were rising. The rise in harvest is partly due to the rise in target effort by one of the major fisheries catching these species. However, the effects of this level of rising effort on the population biology of the whaler sharks remain uncertain.

The additional reason for the uncertainty of the status of the fished stock is the current lack of validated information on mortalities of whaler sharks in most of the fisheries / aquaculture operations which are not permitted to harvest these species.

6.2. Recommended methods of collection and maintenance of catch and effort data.

With the relatively large number of fisheries harvesting whaler sharks off the SA coast, numerous databases on catch and effort on whaler sharks currently exist, both within state and Commonwealth jurisdictions.

The catch and effort databases for all commercial state managed fisheries (MSF, L & C and RL Fisheries) are kept at SARDI Aquatic Sciences Fisheries Statistics and Information Unit, as is the SA Regional database from the 2000/01 National Recreational and Indigenous Fishing Survey.

Catch and effort databases for all Commonwealth Managed Fisheries are kept at AFMA. There is an annual exchange of summarised whaler shark catch and effort (by fishing block) between AFMA and PIRSA Fisheries. A summarised catch by gear type database for each Commonwealth shark fishery is also available from BRS (AFFA) and updated annual information can again be exchanged between SA and the Commonwealth.

As the southern Australian population of *C. obscurus* is shared between WA and SA, regular detailed exchanges of information on all aspects of whaler shark biology and fishery status should occur.

The report has highlighted the information gaps surrounding the levels of mortalities associated with released by-catch of whaler sharks from single species purse seine fisheries off the SA coast, and the need for databases on mortalities observed during scientific surveys of these fisheries, to be developed. As with the harvest fisheries, AFMA and SARDI should exchange scientific observer data on the number of whaler shark mortalities in the SBT and Australian Sardine purse seine fisheries, respectively.

Finally, no formal reporting system exists on the number of whaler sharks dying as a result of interactions with moored sea-pens in Spencer Gulf. Reports of interactions between protected species (eg white sharks and marine mammals) are currently the only ones required to be provided to PIRSA Fisheries. For whaler sharks, only voluntary information on the number of whaler sharks in the sea pens through divers logs is available. Reporting could be improved by requiring all sea pen managers to include whaler sharks in their compulsory reporting program (SA Aquaculture Act, 2003; PIRSA Aquaculture, 2006). Regular validation of the reporting program should be undertaken by independent observers, and information provided to PIRSA Fisheries. Any whaler sharks sacrificed in the moored sea pens should be provided to SARDI Aquatic Sciences for research purposes.

6.3. Recommended biological research.

The recommendations for additional research on whaler sharks were based on the second level of the risk assessment (chapter 5). However, the risk levels could only be analysed for a relatively small number of biological characters available for the species in the SA and Commonwealth fisheries. Research on their known growth and reproductive biology carried out on populations of the species elsewhere suggest they have an intrinsically low population growth and reproductive potential, which requires a very conservative approach to their management. Indeed, the east-Asian population of *C. brachyurus* has recently been assessed as vulnerable, because multi-species fisheries in this region are likely to depress the population through the capture of pregnant females and juveniles (Duffy & Gordon, 2004). At the completion of the second level of risk analysis, it was concluded that the cumulative effects of all the potential impacts placed the SA whaler sharks at a high level of risk, therefore suggesting additional management.

However, the number of available management options is limited due to the uncertainties about the catch susceptibility of the whaler sharks to the various potential impacts, the key biological parameters (eg size/age at first breeding) and location of key nursery and breeding areas . Research priorities should therefore, focus on providing that fundamental biological understanding for the two species in SA waters. This includes age, growth and reproductive biology and whether the species exhibits philopatric behaviour.

Recently, additional management of *C. obscurus* in WA waters has occurred, whereby, a maximum size limit has been implemented to protect breeding adults in all fisheries that harvest this size group. Although the proportion of the *C. obscurus* population entering SA from WA is believed to be small, implementation of a similar management strategy in SA waters should be considered. Research to resolve this strategy in SA can be done in two ways. Firstly, through a better understanding of the level of proportional harvest of the two species in SA waters (through the extension of the National Shark DNA data-base into SA Fisheries). Secondly, fishers could be trained in distinguishing between the two species, and assist in the collection of reproductive biological information on *C. brachyurus* so that the recommended maximum size limit for *C. obscurus* in WA is also appropriate for *C. brachyurus* in SA waters.

6.4. Options for managing whaler sharks in SA waters.

Currently, there is no species specific management directed at whaler sharks in SA waters. When uncertainties surrounding the status of whaler sharks are resolved, and if concerns on the fishery status are then expressed, a number of options to improve the management are provided. These include:

- Spatial / temporal closures for clearly identified events (eg, high encounterability, biologically vulnerable phases);
- Minimise impact of towed and moored sea pens on the mortality of whaler sharks through the prohibition of fishing at sea cages sites;
- Set a maximum legal length on harvested whaler sharks to sustain neonate production. This strategy is supportable for public health reasons, as mercury levels in the flesh of large bronze whaler sharks significantly exceed the NHS standard of 1.0 ppm (Hancock et al, 1977).
- Adjust the method for controlling fishing effort targeting whaler sharks; or
- Control harvest of whaler sharks.

The research strategies for each of these options are summarised in Chapter 5, and their choice is clearly dependent on the level of information required.

With the increased concern on the status of *C. obscurus* in the WA fishery, and as it is known that part of this population is shared with the SA fishery, these above management options should be considered in consultation with WA Fisheries and Commonwealth management authorities.

A possible interim approach to the management of whaler sharks in SAmay be to:

- Introduce industry codes of conduct for the release of whaler sharks in all fisheries and aquaculture operations:

- Implementation of release panels / doors to all towed and moored sea pens in the SBT, YTK and Mulloway Aquaculture Industries;
- Improved reporting of catch, target effort, released by-catch for all sectors.
- Implement a maximum size limit, based on sound information on the reproductive biology of the whaler shark populations in SA. This strategy would be supported for public health reasons.

BENEFITS

This review has improved fishers', researchers' and managers' understanding on the status of whaler sharks in SA waters, but has also highlighted the need for additional information. It has provided a forum for useful discussion of issues relating to the sustainable management of these species. The project provides advice on priorities for future research to improve the advice on the stock(s) status. The project has also highlighted the numerous anthropogenic effects on the populations of whaler sharks, and the need for an improvement in collaborative research, not only between researchers and industry in this state, but also through the introduction of national projects (eg national DNA database on sharks).

FUTURE DEVELOPMENTS

This review is intended to serve as a basis for future research and management of whaler shark populations in SA and adjacent waters. The review has identified important gaps in the information required to interpret fishery stock status reports on these species, and it has highlighted that it is currently not possible to undertake a more detailed stock assessment using a numerical modelling approach.

Based on this review, future research proposals have and will be developed. The highest priority is a greater understanding of the effort directed at whaler sharks by the SA MSF. This fishery had the highest reported harvest level of all fisheries reviewed. Secondly, there is a need to clarify the relative impact of towed and moored aquaculture sea-pens on the whaler shark populations, and if found to be significant, mitigation measures need to be adopted. This was similarly concluded at the shark interactions workshop in 2003 (Murray-Jones, 2005); however, it remains an issue because there is still no formal process in place to report on the number of interactions between whaler sharks and finfish pens.

With the substantial relative size of the recreational harvest of whaler sharks shown in 2000/01, there is a need for ongoing quantification of the exploitation rate by this sector (including the charter boat fishery) on the stock(s).

The other pressing need for future developments is the need to determine the level of impact of the SA fishery on dusky whaler shark population, apparently centred off the WA coast. This is mainly because the biological status of *C. obscurus* has recently been upgraded to one of increasing concern, with evidence of recruitment failure, and the need to stop the harvest of large adult dusky whaler sharks (McAuley, 2005). An extension of the National shark DNA profile program into the SA fishery is required to assist in determining the relative impact of the SA fisheries on this overfished population.

CONCLUSIONS AND OUTCOMES

The report has provided the following outcomes.

- A statement on the status of the fishery, and level of uncertainty;
- Recommended method of collection and maintenance of catch and effort data.;
- Recommendation for biological research to augment catch and effort information and improve the number of options available for managing whaler shark species in SA waters.

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APPENDIX 1: Intellectual Property

None.

APPENDIX 2:   Staff

Dr. G.K. Jones

APPENDIX 3: Method of at-sea identification of bronze whaler (*C. brachyurus*) and dusky whaler (*C. obscurus*) sharks.

All whaler sharks are recorded in South Australian managed fisheries and others in adjacent waters as either bronze whaler or whaler sharks (CABB). Three Carcharhinid (whaler) sharks are reported for southern Australian waters (Gomon et al, 1994); one (*C. longimanus*; the ocean whitetip whaler) has been recorded once from offshore waters off SA, whilst the other two (*C. brachyurus* and *C. obscurus*) have been commonly reported. Tis appendix summarises the current information to determine how these two more common species can be distinguished in the catches by the various fisheries.

External characters have been used extensively to develop taxonomic keys for sharks of the Genus Carcharhinus (Garrisk, 1982; Compagno, 1984; Smith & Heemstra, 1986; Gomon et al, 1994 & Last & Stevens, 1994) and field guides have also been prepared (Eschenmeyer & Herald, 1983; Cliff & Watson, 1994; Daley et al, 2002 & McAuley, 2002). The distinguishing features of sharks of this genus are listed in Table A3.1. Some of the authors note intraspecific variation in some of the characters, which often make keying out the species difficult (eg see Smith & Heemstra, 1986). However, all agree that the presence or absence of inter-dorsal ridges, fin markings and tooth shape are vital characters. Naylor & Marcus (1994) used tooth shape to develop a phylogenetic tree for all sharks o this genus.

Table A3.1. Distinguishing morphological features of all sharks of the Genus Carcharhinus (as described in Smith & Heemstra, 1986).

Distinguishing morphological features of all sharks of the Genus Carcharhinus
2 spineless dorsal fins
Cylindrical body shape
5 pairs of gill slits on either side of head
A moveable nictiating eyelid
No spiracles
1st dorsal fin closer to pectoral fin than ventral fin
1st dorsal fin much larger than 2nd dorsal fin
2nd dorsal fin origin in front of the middle of the anal fin
No keels on caudal peduncle
Teeth blade like, uni-cuspid, upper teeth serrated, lower teeth serrated or smooth

The morphological characters listed in the taxonomic descriptions have been used to distinguish between *C. brachyurus* and *C. obscurus* (Table A.3.2.), and follows on from the initial study by Cappo (1992a), who used upper jaw tooth shape to confirm the presence of both species in South Australian waters.

Table A.3.2: Morphological characters used for distinguishing *C. brachyurus* and *C. obscurus* (adapted from taxonomic keys prepared from Compagno, 1994; Smith & Heemstra, 1986 & Gomon et al, 1994).

Morphological character	**Bronze whaler *(C. brachyurus)***	**Dusky whaler *(C. obscurus)***
Shape of teeth on upper jaw	Upper teeth narrow, lateral margins deeply concave or notched	Upper teth broad, lateral margins slightly concave or notched
Tooth Formula	15-1-15 (upper jaw) 15-1-15 (lower jaw)	14 or 15-2-14 or 15 (upper jaw) 14-1-14 (lower jaw)
Fin markings	Plain, or with slightly dark tips	Dusky tips or plain
Presence of inter-dorsal ridge	Usually not present	Inter-dorsal ridge present
Colour of body of the shark	Upper body: bronze, copper Belly: white	Upper body: dusky brown Belly: pale grey
No. of pre-caudal vertebrae	96 - 103	175 - 191

Most whaler sharks caught as part of target or by-product fisheries are processed at sea, with the trucks (heads and internal organs) being the only part of the body landed. (NB: Since 2004, shark finning at sea has been prohibited). Clearly, this makes species identification for both fishers and researchers highly problematic, with the only remaining characters (inter-dorsal ridge, and colour of trunk of the whaler shark being available for rapid identification.

Using these characters, both species were identified whilst inspecting whaler shark carcasses at the Adelaide Fish Market during November and December, 2004.

However, to confirm species identities, biochemical / genetic profiles have now been developed for many Carcharhinid species from Australian / NZ waters (Lavery, 1992, Smith & Benson, 2001). Yearsley et al (1999) used the protein fingerprints of shark fillets and fins taken from commercial landings in NZ and Australia, resp. to identify a number of shark species, including *C. brachyurus*). Rapid forensic methods to identify species specific DNA are now available too (Ho, 1998; Chan et al, 2003) and this technique also has useful implications for collecting stock identity information for protected shark species

APPENDIX 4: Summary of growth and reproductive parameters for selected Australian shark species. (Information adapted from Table 1: Conservation status, distribution, habitat and life history traits for species in the Australian shark catch and species of concern. In: Shark Advisory Group (2004) Shark Assessment Report – Overview. Report prepared for AFFA by the Shark Advisory Group, p. 47 – 53.) (*C. obscurus* and *C. brachyurus* **highlighted**)

Common Name	**Species Name**	**Growth rate (K/yr)**	**Female Length 1st maturity (cm)**	**Max. Length (cm, TL)**	**Fem. Length /Max. L (%)**	**Avge. Litter size**	**Gestation Time (months)**
Thresher shark	*Alopias vulpinus*	0.11	375	550	68.2	3	
Basking shark	*Cetorhinus maximus*	0.06	450	895	50.3	5	>12
White shark	*Carcharodon carcharias*	0.06	450	640	70.3	5	>12
Shortfin Mako	*Isurus oxyrinchus*	0.23	280	394	71.1	10	
Porbeagle	*Lamna nasus*	0.17	152	300	50.7	3	
School shark	*Galeorhinus galeus*	0.16	130	175	74.3	29	12
Gummy shark	*Mustelus antarcticus*	0.18	85	175	48.6	19	12
Graceful shark	*Carcarhinus amblyrhynchoides*	0.29	113	170	66.5	3	10
Spinner shark	*C. brevipinna*	0.21	195	280	69.6	9	
Nervous shark	*C. cautus*		82.5	150	55	2.5	9
Silky Shark	*C. falciformis*	0.1	205	330	62.1	8.5	
Common blacktip	*C. limbatus*	0.24	165	250	66	7.5	12
Oceanic whitetip	*C. longimanus*	0.04	190	300	63.3	8	11
Dusky shark	***C. obscurus***	**0.02**	**280**	**365**	**76.7**	**8.5**	**23**
Bronze whaler	***C. brachyurus***	**0.04**	**245**	**295**	**83.1**	**14.5**	
Sandbar shark	*C. plumbeus*	0.06	165	240	68.8	7.5	12
Spottail shark	*C. sorrah*	0.75	92.5	160	57.8	4.5	10
Blacktip shark	*C. tilstoni*	0.17	115	200	57.5	3.5	10
Tiger shark	*Galeocerdo cuvier*	0.14	330	600	55	45	12
Blue shark	*Prionace glauca*	0.14	220	383	57.4	60	12
Scalloped hammerhead	*Sphyrna lewini*	0.06	200	350	57.1	10	

APPENDIX 5: Level 1 risk assessment of all issues on the impacts of fishing and finfish aquaculture operations (see Chapter 5.3 for descriptions of potential impacts.

Fishing Activity	Presence	Spatial Scale	Temporal Scale	Intensity	Consequence	Certainty	Rationale
a) SA MSF – longline, target and non-target							
Capture	1	6	3	3	3	2	Seasonal targeted fishing annually, in most of SA state waters, with nominal effort increasing in some areas of Spencer Gulf. CPUE data for longline fishery are coarse, as fishing effort (man-days) may not fully reflect effective effort. Eg shift to floating long-lines
Cryptic Mortality	1	6	3	2	2	2	Caused by escapement of large whaler sharks injured from encounters with long-lines may happen, however, difficulties in measuring this impact.
Gear Loss	1	6	3	1	1	2	Loss of long-lining gear set overnight may occur, however, increasing costs of stainless steel (ss) traces and ss hooks, will create incentive not to lose the gear.
Species translocation	0					1	Species translocation does not occur with this fishing activity.
On-board processing and catch discarding	1	6	3	3	1	1	All whaler sharks landed on deck are retained as carcasses. This species is eviscerated on board the vessel and only head and guts discarded. Under legislation the carcass is not permitted to be finned, with carcass discarded and fins retained. Compliance on this legislation is high.
Provisioning	1	6	3	1	1	1	Main bait species for long lines are t. ruffs and s. perch, purchased by long lining fishers from properly managed commercial net fishery in adjacent areas.
Pollution	1	6	3	1	1	1	Chemical and physical pollutants derived from long lining operations might have minor risks,

							with avoidance ability > scale of hazard. Impact on stock considered negligible.
Ecosystem	1	6	3	1	1	2	Information from dietary studies on other whaler shark populations, suggest pelagic component of the ecosystem could be affected if whaler shark abundances reduced significantly, however, insufficient information for South Australian stock to demonstrate any effects.

Fishing Activity	**Presence**	**Spatial Scale**	**Temporal Scale**	**Intensity**	**Consequence**	**Certainty**	**Rationale**
b) SA MSF – large mesh gill net, target and non-target							
Capture	1	6	3	2	2	1	Seasonal targeted fishing annually, in most of SA state waters. Although long-term effort by large mesh gill nets for all species has decreasing due to reduction in number of MSF licences with this gear endorsement, relative proportion remaining fishers harvesting whaler sharks has increased.
Cryptic Mortality	1	6	3	1	1	2	Escapement of large whaler sharks injured from encounters with gear may happen, however, difficulties in measuring this impact. . Mesh selectivity experiments for whaler sharks in WA suggests it may be minimal.
Gear Loss	1	6	3	1	1	2	Loss of large mesh gill net gear during whaler shark netting may occur, however, increasing costs of nets, will create incentive not to lose the gear.
Species translocation	0					1	Species translocation does not occur with this fishing activity.
On-board processing and catch discarding	1	6	3	3	1	1	Refer to part a.
Provisioning	0					1	Provisioning does not occur with this activity
Pollution	1	6	3	1	1	1	Refer to part a
Ecosystem	1	6	3	1	1	2	Refer to part a.

Fishing Activity	Presence	Spatial Scale	Temporal Scale	Intensity	Consequence	Certainty	Rationale
c) SA Lakes & Coorong – large mesh gill net – swinger net, non-target							
Capture	1	3	2	2	1	1	Whaler sharks are a seasonal non-target harvest of swinger nets on Coorong Beach and appears to occur more in years of high freshwater flow from mouth of River Murray. Reported levels of harvest relatively low compared with other fishing gear in SA.
Cryptic Mortality	1	3	2	2	1	2	Larger mesh sizes used in swinger nets compared with shark nets, may result in higher chance of damage to larger female sharks, however, level of effort is low, suggesting low consequences.
Gear Loss	0					1	Loss of swinger nets along Coorong Beach is not known to occur.
Species translocation	0					1	Species translocation does not occur with this fishing activity.
On-board processing and catch discarding	0					1	Shark carcasses processed on beach, not discarded at sea.
Provisioning	0					1	Provisioning does not occur with this activity
Pollution	1	6	3	1	1	1	Refer to part a
Ecosystem	1	6	3	1	1	2	Whaler sharks may be attracted to increased supply of food (carp and bony bream) swept from Murray mouth in years of higher flow. Little known effect on oceanic ecosystem.

Fishing Activity	Presence	Spatial Scale	Temporal Scale	Intensity	Consequence	Certainty	Rationale
d) SA general recreational fishery – shore and boat line fisheries, non-target and target							
Capture	1	6	6	3	3	2	Whaler sharks are seasonal target and non-target harvest by shore fishers at ocean beaches and boat and jetty fishers in gulfs. Estimated annual harvest for a single year relatively high compared with most other gears. Uncertain annual trends in harvest and effort.
Cryptic Mortality	1	6	6	2	1	2	Escapement of all sizes of whaler sharks due to "bite-offs" and some catch and release fishing. Unknown mortality rates of released sharks.
Gear Loss	1	6	6	2	1	2	Loss of fishing lines and hooks occurs. Level of loss and effects on whaler sharks and other species populations unknown.
Species translocation	0					1	Species translocation does not occur with this fishing activity.
On-board processing and catch discarding	1	5	6	2	1	1	Shore based shark carcasses processed on shore, not discarded at sea. Boat based catches in the gulfs processed at sea. Relative size of boat harvest low
Provisioning	1	6	6	2	1	1	Main baits used include t. ruff and s. perch, often directly caught by fisher. Berley including fish oil used. Increasing use of lures will diminish this effect.
Pollution	1	5	6	1	1	1	Refer to part a
Ecosystem	1	6	6	1	1	2	Refer to part a

Fishing Activity	Presence	Spatial Scale	Temporal Scale	Intensity	Consequence	Certainty	Rationale
e) SA recreational Charter Boat fishery – Licenced boat fishery, non-target and target							
Capture	1	6	6	2	2	1	Limited entry licenced charter boat fishery, with harvest level of whaler sharks relatively low, compared with other shark fisheries.
Cryptic Mortality	1	6	6	2	1	2	Escapement of all sizes of whaler sharks due to “bite-offs” and some catch and release fishing. Unknown mortality rates of released sharks.
Gear Loss	1	6	6	2	1	2	Loss of fishing lines and hooks occurs. Level of loss and effects on whaler sharks and other species populations unknown.
Species translocation	0					1	Species translocation does not occur with this fishing activity.
On-board processing and catch discarding	1	6	6	2	1	1	Boat based retained catches processed at sea. Relative size of boat harvest low
Provisioning	1	6	6	2	1	1	Main baits used include t. ruff and s. perch, often directly caught by fisher o the same day of fishing. Berley including fish oil used. Increasing use of lures will diminish this effect.
Pollution	1	5	6	1	1	1	Refer to part a
Ecosystem	1	6	6	1	1	2	Refer to part a

Fishing Activity	Presence	Spatial Scale	Temporal Scale	Intensity	Consequence	Certainty	Rationale
f) Commonwealth GHAT – Non-trawl licenced fishery, mainly non-target							
Capture	1	6	6	3	3	1	Mainly non-targeted capture by large mesh gill net licence holders. Increased reported harvest in recent years. Third highest harvest of all assessed fisheries. Harvest by other gear – longlines and traps minimal.
Cryptic Mortality	1	6	6	2	1	2	Escapement of large whaler sharks injured from encounters with gear may happen, however, difficulties in measuring this impact. Mesh selectivity experiments for whaler sharks in WA suggests it may be minimal.
Gear Loss	1	6	6	2	1	2	Refer to part b.
Species translocation	0					1	Refer to part a.
On-board processing and catch discarding	1	6	6	2	1	1	Refer to part a.
Provisioning	1	6	6	2	1	1	This does not occur with gill net fishery. Minimal consequence for longline fishery.
Pollution	1	5	6	1	1	1	Refer to part a
Ecosystem	1	6	6	1	1	2	Refer to part a

Fishing Activity	Presence	Spatial Scale	Temporal Scale	Intensity	Consequence	Certainty	Rationale
g) Commonwealth SE Trawl – non-target							
Capture	1	4	6	2	2	1	Non-targeted capture by trawl fishery in SE SA. Minimal harvest level, as availability of whaler sharks to gear is low.
Cryptic Mortality	1	4	6	2	1	1	Escapement of whaler sharks from bottom trawls may occur, but considered to have low impact on whaler shark stock.
Gear Loss	1	4	6	2	1	1	Trawl net loss is rare event because of their high price, creating high incentive not to lose them and to retrieve them.
Species translocation	1	4			2	1	Invertebrate and vertebrate species caught in trawl nets can be translocated up to several miles between shots but is unlikely to have a measurable effect on whaler shark stock through habitat modification.
On-board processing and catch discarding	1	4	6	2	1	1	Moderate to large quantities of organisms discarded in trawling operations. This practice may attract opportunistic species, such as whaler sharks, however, effects not investigated
Provisioning	1	6	6	2	1	1	Provisioning does not occur with this method.
Pollution	1	5	6	1	1	1	Refer to part a
Ecosystem	1	6	6	1	1	2	Refer to part a

Fishing Activity	Presence	Spatial Scale	Temporal Scale	Intensity	Consequence	Certainty	Rationale
h) Commonwealth GAB Trawl – non-target							
Capture	1	6	6	2	2	1	Non-targeted capture by trawl fishery in GAB of SA. Minimal harvest level, as availability of whaler sharks to gear is low.
Cryptic Mortality	1	6	6	2	1	1	Refer to part g
Gear Loss	1	6	6	2	1	1	Refer to part g
Species translocation	1	6			2	1	Refer to part g
On-board processing and catch discarding	1	4	6	2	1	1	Refer to part g
Provisioning	1	6	6	2	1	1	Refer to part g
Pollution	1	5	6	1	1	1	Refer to part a
Ecosystem	1	6	6	1	1	2	Refer to part a

Fishing Activity	Presence	Spatial Scale	Temporal Scale	Intensity	Consequence	Certainty	Rationale
i) SA Managed sardine purse seine fishery							
Capture	0					1	Whaler sharks not permitted to be harvested in this fishery
Cryptic Mortality	1	5	6	2	1	1	Whaler sharks captured in purse seine operations. – check observers reports.
Gear Loss	0					1	Purse seine gear not lost, due to high costs
Species translocation	1	5	6	2	2	2	Some dead sardines may be lost during hauling operations of purse seine gear, which may attract whaler sharks. Has not been measured.
On-board processing and catch discarding	1	5	6	2	1	1	All whaler sharks dying in the purse seine net are discarded. This may result in attraction of scavengers, including protected great white sharks. Reported numbers of dead whaler sharks discarded is low.
Provisioning	0					1	Refer to part g
Pollution	1	5	6	1	1	1	Refer to part a
Ecosystem	1	5	6	1	1	2	Refer to part a

Fishing Activity	Presence	Spatial Scale	Temporal Scale	Intensity	Consequence	Certainty	Rationale
j) SA Managed prawn trawl fisheries in west coast, Spencer Gulf and GSV							
Capture	0					1	Whaler sharks not permitted to be harvested in this fishery
Cryptic Mortality	0					1	Whaler sharks not captured in bottom trawling for prawns.
Gear Loss	0					1	Purse seine gear not lost, due to high costs
Species translocation	1	4	6	2	2	2	Refer to part g.
On-board processing and catch discarding	0					1	No whaler sharks caught as by-catch in this fishery
Provisioning	1	4	6	3	2	2	Other prawn trawl fisheries suggest carcharinhid sharks are attracted to surface and sinking bycatch product. Has not been investigated in SA.
Pollution	1	4	6	1	1	1	Refer to part a
Ecosystem	0					1	No whaler sharks removed in this fishery.

Fishing Activity	Presence	Spatial Scale	Temporal Scale	Intensity	Consequence	Certainty	Rationale
k) Commonwealth SBT fishery – purse seine and towed cages							
Capture	0					1	Whaler sharks not permitted to be harvested in this fishery.
Cryptic Mortality	1	5	5	2	3	2	There may be interactions between whaler sharks and purse seine nets (inadvertent capture) and towed cages (biting through towed nets) with subsequent mortalities; however, no data available on mortality rates during these operations. Consequence level set at precautionary high level till data becomes available.
Gear Loss	0					1	Purse seines and towed cages not lost, due to high costs
Species translocation	1	5	6	2	2	2	Some dead SBT may be lost during hauling operations of purse seine gear and die in towed cages, which may attract whaler sharks. Has not been measured.
On-board processing and catch discarding	1	5	6	2	1	1	Refer to part i.
Provisioning	0					1	Refer to part g
Pollution	1	5	6	1	1	1	Refer to part a
Ecosystem	1	5	6	1	1	2	Refer to part a

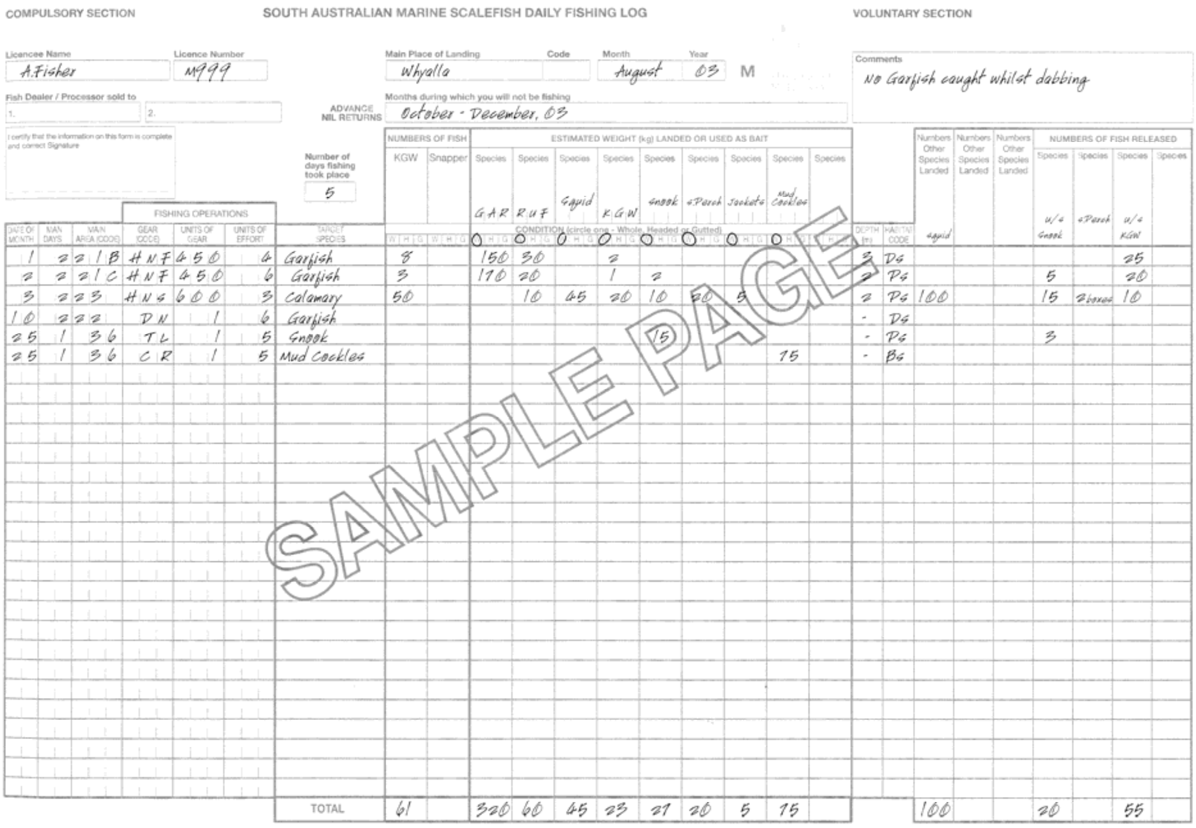
Fishing Activity	Presence	Spatial Scale	Temporal Scale	Intensity	Consequence	Certainty	Rationale
l) SA finfish aquaculture – moored sea pens in Spencer Gulf							
Capture	0					1	Whaler sharks not permitted to be harvested in this fishery.
Cryptic Mortality	1	3	6	2	3	2	There are interactions between whaler sharks and moored seapens used to ranch SBT and YTK, through the purposed mortality of sharks biting through nets of seapens, but no data available on mortality rates. Consequence level set at precautionary high level till data becomes available.
Gear Loss	0					1	Mooed sea pens not lost, due to high costs
Species translocation	1	3	6	2	2	2	Escapes of ranched SBT, YTK and mulloway occur locally, which may attract whaler sharks., resulting in increased targeted fishing effort adjacent to moored seapens by both commercial shark and recreational SBT and snapper fishers.
On-board processing and catch discarding	1	3	6	2	1	2	Refer to part i.
Provisioning	0					1	
Pollution	1	3	6	1	1	1	Higher nutrients derived from feed for ranched fish, change benthic habitat beneath moored sea pens.
Ecosystem	1	3	6	1	1	2	Changes to benthic habitat beneath sea pens may change local ecosystem. Unknown effects on whaler shark stocks.

APPENDIX 6: 2nd level risk assessment of the fishing issues with consequence levels > 2. See Chapter 5.3 for method for estimating catch susceptibility.

Fishing Issue	**Parameter**					**Rationale**
	Availability	**Encounterability**	**Selectivity**	**Post-capture mortality**	**Catch susceptibility**	
MSF Long-line fishery	Moderate	High	High	High	Moderate (0.5)	**Av:** Long-lining mainly in gulfs and west coast waters, about 50% of spatial distribution of *C. brachyurus* and < 33 % for *C. obscurus*. **EC**: Floating long lines ensure high encounterability for *C. brachyurus*. **Sel**: High, as hook size probably does not affect catch. **PCM**: high. All sizes of whaler sharks retained.
SA recreational fishery	Moderate	High	High	Moderate	Low (0.33)	**Av**: Recreational fishing for whaler sharks widespread in SA coastal waters at least 50% of spatial distribution. **Ec**: High encounterability as whaler sharks commonly caught as by-catch species when rec fishers targeting higher sporting value species, including salmon and mulloway. **Sel**: High, as hook size probably does not affect catch. **PMC**: medium. Some catch and release. Species with 0.33 – 0.66 probability of survival after capture, released shark with a fragile structure and ram-jet ventilation.
Com. Gillnet fishery	Moderate	Moderate	Low	Moderate	Low (0.1)	**Av**: Shark gill net fishery extends throughout Commonwealth waters adjacent to SA. **Ec**: Medium. Usually bottom set nets, although whaler sharks more in upper waters. **Sel**: Low. Mesh sizes mainly 6.5 " for targeting other shark species, small size range of whaler sharks retained. **PMC**: Moderate
Com. SBT towed cages	Low	Moderate	High	Moderate	Low (0.15)	**Av**: Low. Towed cages occur in relatively small part of spatial distribution for both species **Ec**: Moderate. Whaler sharks may be attracted to towed cages, when cages towed over shelf waters. **Sel**: High, as attraction may occur for all sizes of sharks

						PMC: Moderate. Not all whaler sharks attracted to towed cages are sacrificed.
Moored sea pens	Low	High	High	high	Low (0.33)	**Av**: Low. Moored seapens occur in relatively small area of overall spatial distribution of both species. **Ec**: High. Whaler sharks attracted to moored sea pens. **Sel**: high, as attraction may occur for all sizes of sharks. **PMC**: High, as all sizes of sharks retained.

APPENDIX 7. MSF Catch and effort form used for reporting on whaler sharks in the SA Managed Fisheries.



COMPULSORY SECTION

SOUTH AUSTRALIAN MARINE SCALEFISH DAILY FISHING LOG

VOLUNTARY SECTION

Licencee Name: A.Fisher
Licence Number: M999
Main Place of Landing: Whyalla
Code:
Month: August
Year: 03
M

Comments: No Garfish caught whilst dabbing

Fish Dealer / Processor sold to: 1. 2.

ADVANCE NIL RETURNS: Months during which you will not be fishing: October - December, 03

I certify that the information on this form is complete and correct Signature

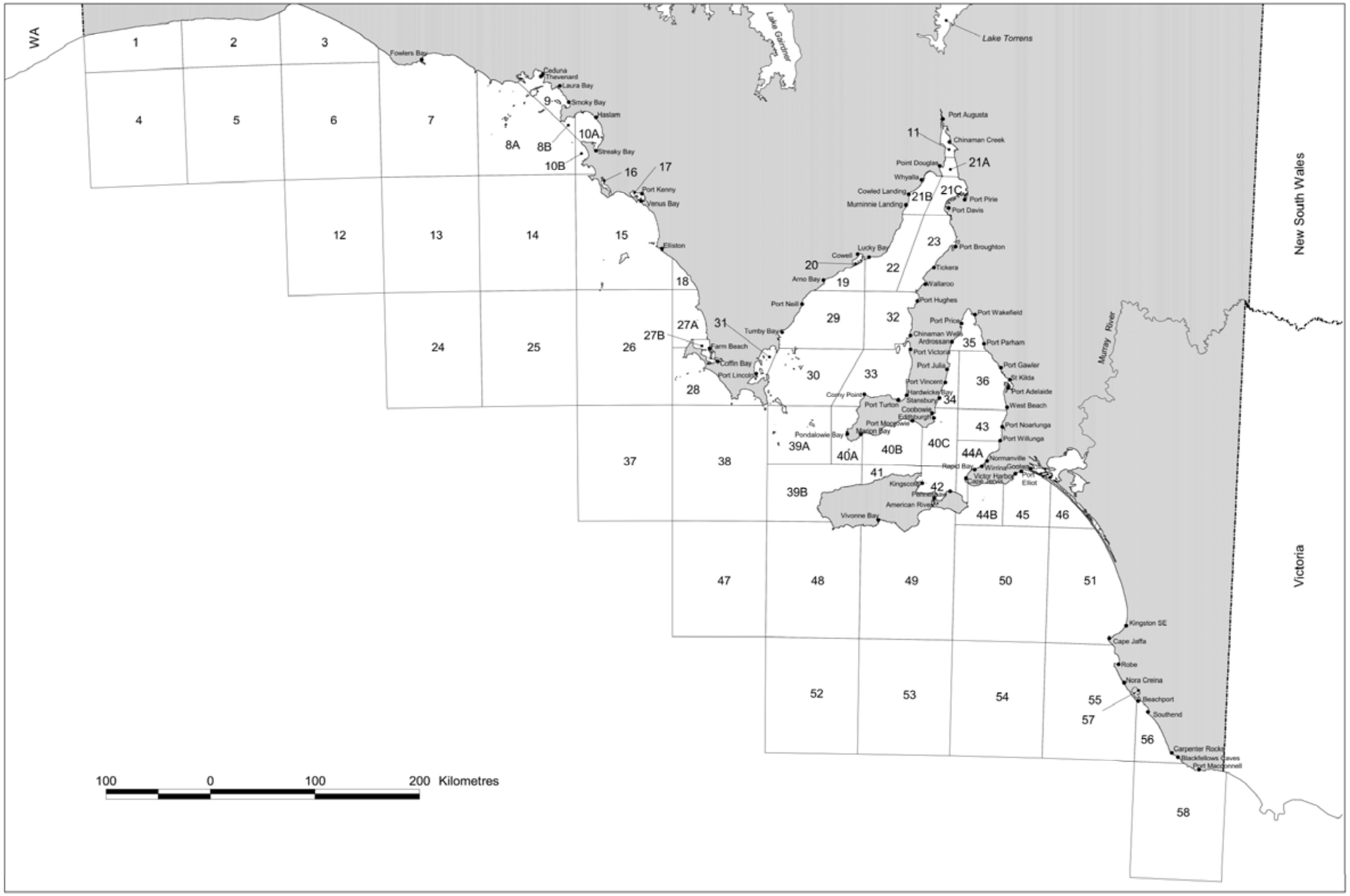
Number of days fishing took place: 5

SAMPLE PAGE

Date of Month	Man Days	Main Area (Code)	Gear (Code)	Units of Gear	Units of Effort	Target Species	Numbers of Fish: KGW	Numbers of Fish: Snapper	Est. Weight (kg): GAR	Est. Weight (kg): RUF	Est. Weight (kg): Squid	Est. Weight (kg): KGW	Est. Weight (kg): Snook	Est. Weight (kg): s.Perch	Est. Weight (kg): Jackets	Est. Weight (kg): Mud Cockles	Est. Weight (kg): Species	Depth (m)	Habitat Code	Numbers Other Species Landed: Squid	Numbers Other Species Landed	Numbers Other Species Landed	Released: u/s Snook	Released: s.Perch	Released: u/s KGW	Released: Species
1	2	21B	HNF	450	4	Garfish	8		150	30		2						3	DS						25	
2	2	21C	HNF	450	6	Garfish	3		170	20		1	2					2	PS				5		20	
3	2	23	HNS	600	3	Calamary	50			10	45	20	10	20	5			2	PS	100			15	2 boxes	10	
10	2	22	DN	1	6	Garfish												-	DS							
25	1	36	TL	1	5	Snook							15					-	PS				3			
25	1	36	CR	1	5	Mud Cockles										15		-	BS							
						TOTAL	61		320	60	45	23	27	20	5	15				100			20		55	

CONDITION (circle one - Whole, Headed or Gutted)

APPENDIX 8. Location of Fishing Blocks in SA waters, used by SA Managed Fisheries to report on whaler shark catch and effort.



APPENDIX 9. Gill Net catch and effort form used to report on sharks caught in Commonwealth Managed Southern Shark Fishery (part of GHAT Fishery).

Australian Fisheries
Management Authority.
Box 7051
Canberra Mail Centre ACT 2610

Catch and Effort – NT01 Daily Fishing Log

Log No:	Page No:

Boat Name:	Dist. Symbol:	Prior Landing Number:

NON-FISHING PERIOD
I did not work between / / and / /

NON-FISHING CODES (Circle)

Other fishery. Which?	In Port Searching	Bad Weather Steaming

TRIP DATES
Date Departed / /
Date returned / /

FISHERY DETAILS

Fishery (circle)	SESS Other (specify)________________________

Shot Date		/ /	/ /	/ /
Start fishing time (24hr)				
Start position degs/mins	Latitude			
	Longitude			
End position degs/mins	Latitude			
	Longitude			
Start Haul time (24hr)				
End haul time (24hr)				
Min depth Max depth	**Circle** Metres or Fathoms	Metres / Fathoms	Metres / Fathoms	Metres / Fathoms
NET SIZE	Mesh Size (mm)			
	Total net length (m)			
	Net height (m)			
Total length of net lost (m)				

CATCH DETAILS

Species (targeted: tick box)		(tick box)	Weight (kg)	No	Form Code	Discard Weight (kg)	Discard Code	Weight (kg)	No	Form Code	Discard Weight (kg)	Discard Code	Weight (kg)	No	Form Code	Discard Weight (kg)	Discard Code
School Shark	SHS																
Gummy Shark	SHG																
Southern Saw Shark	SHN																
Common Saw Shark	SAW																
Elephant Fish	SHE																
Wiskery Shark	SWH																
Bronze Whaler	BWH																
Spikey Dogfish	SDF																
Boarfish	BOA																

Please provide an estimate of the time taken to complete this form: ______ mins

Did you have an interaction with a Listed Marine or Threatened Species? (circle)
Yes No
Further details of all Listed Marine and Threatened Species interactions must be recorded on the Listed Marine and Threatened Species Form at the back of the logbook.

Concession holder or authorised person - *I certify that the information provided on this form is a true and accurate record.*
Printed Name:
Signature: Date / /

Comments: