Australian Government
Bureau of Rural Sciences

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Fisheries Research and Development Corporation

Information to support management options for upper-slope gulper sharks (including Harrisson's Dogfish and Southern Dogfish)

Wilson DT, Patterson HM, Summerson R, and Hobsbawn PI

Centrophorus harrissoni

Centrophorus moluccensis

Centrophorus zeehaani

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OBJECTIVES:

1. Review the success of international management arrangements to address the sustainability of fisheries catches involving similar upper-slope low productivity shark species.
2. Consider the historical identification of Harrisson's dogfish including catch statistics and scientific surveys.
3. Investigate and improve estimates on the nature and extent of interactions with Harrisson's dogfish and similar upper-slope gulper sharks in all sectors of Australia's SESSF.
4. Provide an analysis, with supporting rationale, for alternative management options for reducing the ecological risk to Harrisson's dogfish and similar upper-slope gulper sharks in Australia's Southern and Eastern Scalefish and Shark Fishery (SESSF).

OUTCOMES ACHIEVED TO DATE

- This report results from a request by the Australian Fisheries Management Authority (AFMA) to the Bureau of Rural Sciences (BRS), to meet additional provisions made to the SESSF declaration of an approved wildlife trade operation (WTO) made by the Minister for the Environment, Water, Heritage and the Arts in December 2008. Specifically, the variation to the WTO requires AFMA to investigate and report back to the DEWHA on the extent and nature of Harrison's dogfish interactions in all sectors of the SESSF, and provide alternative management options.
- The DEWHA will use the report during its assessment of upper-slope gulper sharks as threatened species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The assessment is due to be completed by 30 September 2010.
- AFMA and CSIRO were consulted extensively during the preparation of the report and industry was given the opportunity to comment through AFMA's Harrisson's dogfish workshop held in Melbourne on 24 March 2009.
- This report also considered the recommendations of the AFMA Chondrichthyan Technical Working Group (CTWG) regarding methods to reduce bycatch of gulper sharks identified as high risk in the SESSF through AFMA's ecological risk assessment process. This expert panel consisted of scientific experts and representatives from AFMA, BRS, DEWHA, industry and NGOs.
- Alternative management options provided in the report are discussed in terms of their likely success in reducing the ecological risk to upper-slope gulper sharks from fishing gears (e.g. longline and trawl), taking into account current international management arrangements, the quality of historical identifications of gulper sharks in catch statistics and scientific surveys, and where possible, impacts on industry.

1.0 Non-technical Summary

This report reviews the research and information available for the three main species of gulper shark occurring on the upper-slope habitat of Australia's Southern and Eastern Scalefish and Shark Fishery (SESSF): *Centrophorus harrissoni* (Harrisson's dogfish), *C. moluccensis* (Endeavour dogfish) and *C. zeehaani* (formerly *C. uyato,* Southern dogfish) with notes on two other species sporadically caught on the upper-slope habitat (*C. westraliensis*, Western gulper shark and *C. squamosus*, Leaf-scale gulper shark). Of this group, *C. harrissoni*, a species considered endemic to south-eastern Australia and adjacent seamounts, is the most vulnerable and this species, along with *C. zeehaani* and *C. moluccensis,* is currently under consideration for listing as threatened under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). These three species predominantly occupy upper-slope habitats (200–650 m) and interact with multiple gear types in the SESSF. Demersal trawl and longline (including auto-longline) methods have accounted for the majority of interactions. A list of 31 prioritised management, data and research options is provided at Appendix 9, covering requirements for improved data collection, immediate and long-term management measures and research. The management, data and research options aim to meet the primary objective of the study, that is, to reduce the ecological risk to upper-slope gulper sharks in Australia's SESSF and as such, should be considered in light of the broader management context for the fishery, including the likely social, economic and wider ecological effects.

For the purposes of this report, the name 'gulper shark' will be used throughout to describe all species of the genus *Centrophorus*, despite the standard common name of 'dogfish' being used for three of the species. Based on the information identified in this report, the following summarises the status of each gulper shark species identified as being taken on the upper-slope habitat of the SESSF:

Harrisson's dogfish (*C. harrissoni*) and Southern dogfish (*C. zeehaani*). We confirm that *C. harrissoni* and *C. zeehaani* have undergone very severe reductions in numbers throughout their restricted ranges. Both species have geographic distributions that are precarious given that they are considered endemic to waters off south-eastern Australia and adjacent seamounts (*C. harrissoni*), and southern Australian waters (*C. zeehaani*), largely or wholly within the SESSF management area. The confirmed declines in catches of these two species of greater than 90 percent over the 20 year period from 1976–77 to 1996–97 (Graham et al. 2001) and continued low catches (Walker et al. 2008), combined with their K-selected life history strategy (slow growth, late age at maturity, low fecundity and low natural mortality), indicate that their viability is at risk given the very low numbers of mature individuals being caught by fishery-dependent and fishery-independent studies. This leads us to conclude that there is a very high risk of biological extinction for these two species within their geographic ranges.

Endeavour dogfish (*C. moluccensis*) and Leafscale gulper shark (*C. squamosus*). *C. moluccensis* and *C. squamosus* have undergone very severe reductions in numbers throughout the upper-slope of the SESSF (greater than 90 percent). However, as both of these species are known to occur extensively in areas outside the fishery, we conclude that the activities of the SESSF will not cause either to become biologically unviable within their entire range. However, as the number of individuals have undergone severe declines on the SESSF upper-slope, measures should be undertaken to ensure that further depletion within the SESSF does not occur, and where possible, begin to rebuild local populations. If measures are taken to rebuild stocks of *C. harrissoni* and *C. zeehaani*, a flow-on benefit for *C. moluccensis* and *C. squamosus* will likely occur.

Western gulper shark (*C. westraliensis*). Little is currently known about this species of gulper shark other than its highly restricted distribution from Shark Bay to Cape Leeuwin, Western Australia, its restricted depth distribution (616 to 750 m) and its K-selected life history strategy (White et al. 2008; Last and Stevens 2009). The combination of these factors make *C. westraliensis* highly vulnerable to overfishing. Given the experiences with other *Centrophorus* species in the SESSF, the fact that a sustainable harvest level for this deepwater species is currently unknown, and that the literature reviewed in this report suggests that many deepwater species are unable to endure catches exceeding five percent of their virgin biomass (e.g. Morato et al. 2004, Forrest and Walters in press), we advise that targeted fishing for this species should not be allowed (via a zero TAC) and measures are implemented to avoid incidental catch throughout its range (via area closures).

One of the main issues pertaining to gulper sharks is the lack of accurate and robust fishery-dependent data. We found, similar to previous studies, that Commonwealth fishery logbook data were incomplete and unreliable for these species. This is largely due to historical difficulties in identifying these species correctly, combined with limited recording of discards until late in 2002. Gulper shark logbook data consists entirely of group species codes, where individuals are lumped into a single genus or family category rather than identified to the species level (i.e. the 'Endeavour dogfish' code is sometimes used as a genus code in logbooks rather than referring only to *C. moluccensis*, the true Endeavour dogfish). Species groupings also exist within the scientific observer data for the SESSF. These data are further undermined by the reporting of gulper shark species from areas where they are thought not to occur. However, recent clarification of species identifications by White et al. (2008) means that with appropriate training, the accurate recording of gulper shark catches could be substantially improved. Thus, we conclude that using historic and current fishery-dependent data as a means of determining the ecological risk to gulper sharks in the SESSF is not possible without drawing upon fishery-independent research data.

Our review of the available fishery-independent research data confirms previous reports of a substantial decline (greater than 90 percent) in populations of upper-slope gulper sharks over the past several decades (e.g. Graham et al. 2001; Daley et al. 2002; Walker et al. 2008). The clearest example was a series of research surveys by the New South Wales (NSW) Department of Primary Industries that reported declines of 98.4–99.7 percent in the relative abundance of *C. harrissoni*, *C. moluccensis* and *C. uyato* (now C. *zeehaani*) on the upper-slope of the NSW between 1976–77 and 1996–97 (Graham et al. 2001). During the survey period, Graham et al. (2001) carried out a total of 246 trawl tows (ca. 273 hrs) in 1976–77 and 159 trawl tows (ca. 159 hrs) in 1996–97, providing the most complete time series available for assessment. Based on a review of the raw data gathered during the NSW fisheries research surveys and others throughout the SESSF, we were able to confirm and agree with the position taken by Andrew et al. (1997) and Graham et al. (2001) that sustained fishing in the SESSF is the most likely and predominant cause of the observed changes in the relative abundance and size structure of gulper shark species on the upper-slope habitat.

In this report we considered various options to reduce fisheries interactions with gulper sharks and improve their survivorship where interactions do occur. The report also considered the recommendations of the Australian Fisheries Management Authority (AFMA) Chondrichthyan Technical Working Group (CTWG) regarding methods to reduce bycatch of gulper sharks in the SESSF. We conclude that given the advanced state of decline for gulper shark stocks on the upper-slope habitat of the SESSF, and their low resilience to overfishing, only immediate and substantial measures are likely to restore stocks to levels that could be determined as sustainable within this area. Given the slow recovery rate for these sharks, recovery will not be measurable for at least several decades, thereby requiring the implementation of a long-term management strategy, in tandem with short-term measures.

In terms of the three main gulper shark species alone, and not withstanding broader fisheries management objectives, a network of area closures which prohibit fishing of all gear types is considered the best option to reduce the actual number of interactions with gulper sharks and to rebuild stocks of these species to viable levels within the fishery. This is despite the recent structural adjustment of the fishery whereby fishing effort was removed. Removing effort would certainly have reduced the pressure on gulper shark populations. However, given the very conservative life history strategies of upper-slope gulper sharks that indicate a very low resilience to fishing pressure and the literature reviewed that suggests that gulper sharks, as with many deepwater species, are unable to endure catches exceeding five percent of their biomass (e.g. Morato et al. 2004, Forrest and Walters in press), we conclude that closures to all fishing methods capable of taking gulper sharks is necessary. In the short-term, this strategy may involve precautionary closures that would substantially increase the total area of upper-slope habitat protected from all fishing activities, while research is carried out to determine the optimal areas for long-term protection. The research will assist in determining a clear scientific basis for the size and location of area closures required to protect not only gulper sharks, but also the upper-slope ecosystem as a whole, noting that current closures in the fishery do not adequately protect gulper shark populations as most have been designated for one or two gears only. In real terms, this means that the majority of the upper-slope habitat in the SESSF is currently open to at least one fishing gear capable of taking gulper sharks. For example, we determined that only 3154 km^2 of the total 43 846 km^2 of upper-slope habitat in the SESSF is protected (7.19 percent) from all forms of fishing capable of taking gulper sharks.

Additional spatial/area closures are likely to have negative impacts on the income of SESSF operators. However, this may only be a short term impact as closures are likely to incidentally assist the rebuilding of target species in the medium and long-term. The greatest implication for industry is that they will lose important fishing grounds, resulting in them having to fish potentially less productive or more remote areas to catch their quota of target species. Closures may also result in increased fishing effort on traditional fishing areas left open, and may therefore require a reduction of fishing capacity.

The CTWG recommended that an improvement in handling practices, such as changes to de-hooking techniques once a gulper shark is caught, may improve post-release survival. Tagging research currently underway by the CSIRO has clearly shown that gulper sharks taken on longline gear and handled appropriately before being released have a high rate of survival (R. Daley pers. comm.). We are of the opinion that an immediate prohibition on automated de-hooking machines would be required to substantially reduce the ecological risk to gulper sharks in the SESSF. This measure could be implemented by AFMA almost immediately, subject to industry consultation. However, this measure would only apply to gulper sharks that are captured as bycatch and are then released, thus requiring a zero-retention policy to ensure all live gulper sharks are returned to the water. A no-take rule, in conjunction with robust estimation and recording of gulper shark discards, needs to be implemented in areas that remain open to fishing. In addition, measures such as improved quality of logbook data, requiring the training of industry and observers in the accurate identification and recording of gulper shark interactions, and more information about the biology and ecology of gulper sharks is necessary. In the long-term, spatial/area closures and other management measures would need to be implemented as part of a formal management strategy for each species.

The management, data and research options contained in this report are consistent with international management recommendations for deepwater species that acknowledge the high vulnerability and low productivity of deepwater species and advise that harvest of such species should be prohibited unless such harvest can clearly be demonstrated as being sustainable (NEAFC 2000; ICES 2002, 2005a). As a sustainable harvest level for upper-slope gulper sharks in the SESSF is currently unknown, and significant declines in the abundances of these species have been reported (Graham et al. 2001) and validated in this report and others (Daley et al. 2002; Walker et al. 2008), the harvest, either targeted or incidental (byproduct), needs to be substantially reduced from current levels or halted altogether. Without such substantial measures it is likely that populations of *C. harrissoni* and possibly *C. zeehaani* will become biologically unviable within the SESSF. Noting the points raised in this report, we consider that the continued take of gulper sharks at current levels from the upper-slope of the SESSF is not consistent with a precautionary and/or responsible approach to fisheries management.

KEYWORDS: Gulper sharks, overfishing, upper-slope, deepwater sharks, SESSF, low productivity, population depletion, fisheries, spatial/area closures.

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3.0 Background
Global concern over the continued increase in chondrichthyan catches and the likely consequences of potentially unsustainable harvest rates on populations of some shark species, prompted member countries of the Food and Agriculture Organisation (FAO) of the United Nations to develop an International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks; FAO 1999). The term 'shark' covers all chondrichthyan groups (sharks, batoids and holocephalans). The IPOA-Sharks is a voluntary international instrument that emphasises that the harvest of chondrichthyans should be biologically sustainable, economically rational, encouraging full utilisation of all body parts of the sharks killed, and managed to ensure biodiversity conservation and maintenance of ecosystem structure and function (FAO 1999). Australia developed a National Plan of Action for sharks in 2004 (Shark Advisory Group and Lack 2004).

Concern for the sustainability of chondrichthyan stocks stems from their vulnerability to fishing pressure (Baum et al. 2003; Myers and Worm 2003, 2005; Baum and Myers 2004). This is driven by their K-selected life-history characteristics such as slow growth, late age at maturity, low fecundity and low natural mortality (Stevens et al. 2000; Kyne and Simpfendorfer 2007). These characteristics naturally make sharks highly susceptible to overfishing and subsequent population depletion (Pankhurst 1999), and imply that the precautionary approach is particularly important for this group of fishes. However, despite the best intentions for better management by governments to reduce or eliminate shark catch and bycatch, targeted fishing for these species continues to increase (Myers and Worm 2003, 2005). This trend is mainly due to the ever growing demand for shark meat and other products such as fins (Rose and McLoughlin 2001). Elasmobranchs, particularly sharks, have become more commercially important and their product value has increased accordingly (Catarci 2004; FAO 2008). According to the FAO global fishery production statistics (FAO Fishstat Plus, FAO 2008), world catches of chondrichthyans increased from 271 813 MT in 1950 to 896 950 MT in 2003 (FAO Fishstat Plus). Since 2003, global production has declined slightly with 758 498 MT recorded in 2006 (Fig. 1; FAO 2008). Whether this decline represents a decrease in total effort or collapsing shark stocks is yet to be determined.

The greatest diversity of chondrichthyan species is found on the continental slope habitat (Rose and McLoughlin 2001; Last and Stevens 2009). However, the slope habitat represents only about 13 percent of the ocean bottom worldwide (Angel 1997). Deepwater chondrichthyans are defined as bathyal species occurring at depths greater than 200 m. Relatively few studies of deepwater chondrichthyans exist in the scientific literature and the majority deal with squaloids, reflecting their greater commercial importance (Hernández-Pérez et al. 1997; Hareide and Garnes 1998; Clarke et al. 2002b; Hareide et al. 2005). Historically, deepwater chondrichthyans have been a bycatch and byproduct component of many commercial fisheries that predominantly target teleosts and crustaceans (Piñeiro et al. 2001; Figueiredo et al. 2005). Although the proportion of deepwater shark bycatch has been in decline for several decades (Graham et al. 2001; ICES 2004b) (in contrast to the global production for chondrichthyans as a whole), in most cases, this is not due to alternative targeting, but rather, serial stock depletion of deepwater species (Graham et al. 2001; Kyne and Simpfendorfer 2007). Targeted fishing for deepwater chondrichthyans remains an important component of some fisheries and is largely driven by international demand for their byproducts such as liver oil (King and Clark 1987; Davenport and Deprez 1989; Deprez et al. 1990; Hernández-Pérez et al. 1997).

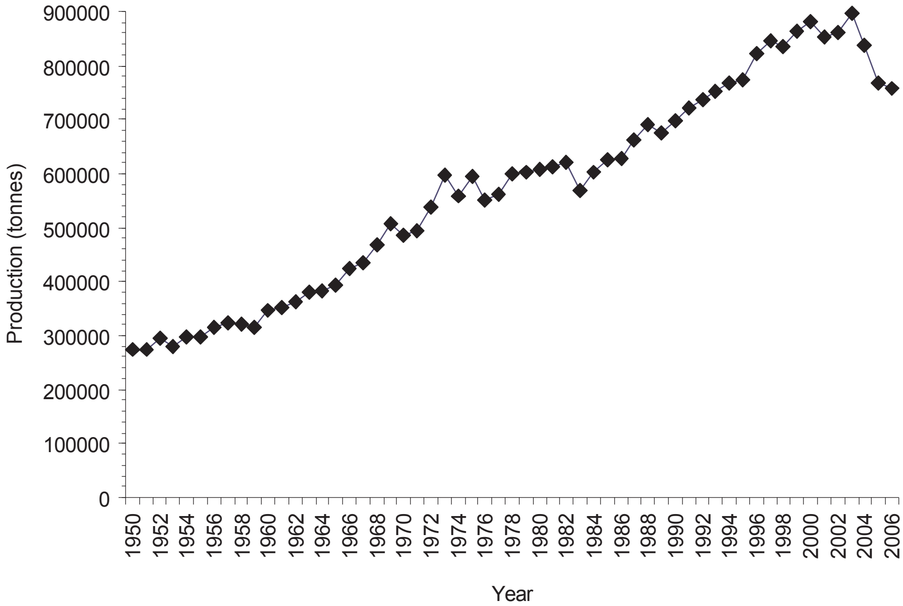

Figure 1. Global production of chondrichthyans, 1950-2006 (data source: FAO 2008).

In Australia, exploitation of deepwater chondrichthyans did not generally begin until after 1970 (Smith and Smith 2001). Before then, the Commonwealth South-East Fishery (now the Southern and Eastern Scalefish and Shark Fishery or SESSF) was limited to shelf waters of less than 200 m depth off the south-east coast of Australia (Tilzey and Rowling 2001). In the 1970s, the fishery was expanded to include non-trawl methods (gillnet, trap and line) and to deeper waters over the continental shelf-break to upper-slope grounds down to about 600 m (Tilzey and Rowling 2001). Spatial expansion of the fishery southwards to waters around Tasmania and westwards into western Bass Strait also occurred during this period (Smith and Smith 2001; Tilzey and Rowling 2001). Although Australia is not a major shark fishing nation, it is recognised that vessels regularly take shark as target and non-target (byproduct, bycatch) catch (Rose and McLoughlin 2001; Rose and Shark Advisory Group 2001). During the early to mid 1980s, sharks were a common byproduct and bycatch of deepwater commercial trawlers and constituted about 25 to 50 percent of the catch off southern Australia (Davenport and Deprez 1989). Upper-slope gulper sharks (*Centrophorus* spp.) were targeted in the SESSF and Western Australian shark fisheries in the 1990s with peak landings of around 380 t reported in 1992 (Daley et al. 2002; Walker et al. 2003). Upper-slope species are now seldom targeted, and have become a minor component of trawl and longline catches (Daley et al. 2002; Walker and Gason 2007).

Species within the Centrophoridae are believed to have the lowest reproductive potential of all shark and ray species (Irvine 2004; Kyne and Simpfendorpher 2007, Forrest 2008), thereby placing them at high risk of overfishing. As with other deepwater sharks, the low fecundity (1 to 2 pups maximum every 1 to 2 years) (Daley et al. 2002), high longevity (in excess of 46 years) (Fenton 2001; Irvine 2004) and late age at first maturity (15-36 years) (Daley et al. 2002; Irvine 2004) of *Centrophorus* species not only result in rapid population depletion in fished areas, but also prevent them from quick recovery after such depletion occurs (Clarke et al. 2001b). Deepwater sharks (including gulper sharks) have been described by the International Union for Conservation of Nature (IUCN) Shark Specialist Group as being more vulnerable to overfishing than perhaps any other marine species group, and declines of over 99 percent of some species of gulper sharks have been reported in Australian waters (Andrew et al. 1997; Graham et al. 2001).

Fishery-independent trawl research surveys carried out on the upper-slope trawling grounds by the Fisheries Research Vessel "Kapala" in 1976–77 and 1996–97 in the Sydney area (central NSW), Ulladulla and the Eden-Gabo Island Area (southern NSW / northern VIC), found that *Centrophorus harrissoni* (Harrisson's dogfish) had declined substantially over the 20 year period. Specifically, in 1976–77 a total of 173 tows yielded over 5000 kg of *C. harrissoni*, equivalent to over 1100 sharks (see length-frequency data, in Graham et al. 1997). In contrast, only 15 kg (a total of 8 sharks) of *C. harrissoni* were caught in 165 tows in the 1996–97 surveys (Graham et al. 1997). In 1976–77, *C. harrissoni* occurred in nearly 50 percent of the tows (84 of 173), in comparison with only three percent of tows (5 of 165) in 1996–97 (Graham et al. 1997).

The relatively narrow continental upper-slope habitat of this and similar species, and the reported very severe declines in catches, suggests that it may only be present in substantial numbers on non-trawlable areas such as deepwater canyons (Daley et al. 2002). However, dropline fishers are reported to have been targeting finfish aggregations at the entrance to these potentially important refuge habitats and taking gulper sharks as bycatch (S. Weekes pers. comm.), thereby placing further pressure on remnant gulper shark populations.

In recognition of the potential severely depleted state of upper-slope sharks within the family Centrophoridae, *Centrophorus harrissoni* (Harrisson's dogfish), *C. moluccensis* (Endeavour dogfish) and *C. uyato* – now *C. zeehaani* (Southern dogfish) were considered for listing in 2005 as threatened species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) by the Threatened Species Scientific Committee (TSSC). However, this assessment could not be completed due to taxonomic uncertainty within the genus. These taxonomic issues were resolved by White et al. (2008) and the three species were subsequently placed by the TSSC on the Proposed Priority Assessment List (PPAL) for the Minister for the Environment, Water, Heritage and the Arts to consider. Upon consideration of the PPAL, the Minister agreed to retain the three species on the Finalised Priority Assessment List (FPAL). The FPAL was published on 5 September 2008 and public comment on the species nominations has been requested and will be assessed during the assessment period commencing on 1 October 2008. The assessment of these species is due to be completed by 30 September 2010.

This report will aid fisheries managers and fisheries assessment officers by providing options for mitigating the adverse impacts from the SESSF on upper-slope gulper shark stocks.

4.0 Need

The ecological risk assessment (ERA) process recently undertaken by AFMA and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) has identified that sharks generally are high risk species that require focused management attention. In the SESSF, this is particularly the case for upper-slope gulper sharks (including Harrisson's dogfish (*Centrophorus harrissoni*) and southern dogfish (*C. zeehaani*)) that have been reported as being severely depleted and nominated as threatened species under the EPBC Act. AFMA is now developing management responses to address these identified ecological risks, and there are a number of complementary processes underway. These include the bycatch working groups in the SESSF which are currently preparing a bycatch work plan to be developed and implemented during 2008 and 2009. AFMA has also establishing an expert panel (Chondrichthyan Technical Working Group; CTWG) to develop appropriate bycatch mitigation responses for gulper sharks and other species. The Commonwealth Trawl Sector (CTS) and the auto-longline sector of the SESSF are examining the deepwater shark species of the mid-slope and additional work is being undertaken to provide immediate management recommendations in relation to Harrisson's dogfish (*C. harrissoni*). However, despite these initiatives, there is a need to review available information on all upper-slope gulper sharks to improve understanding of levels of interaction and to provide advice on future management options.

5.0 Objectives

1. Review the success of international management arrangements to address the sustainability of fisheries catches involving similar upper-slope low productivity shark species.
2. Consider the historical identification of Harrisson's dogfish including catch statistics and scientific surveys.
3. Investigate and improve estimates on the nature and extent of interactions with Harrisson's dogfish and similar upper-slope gulper sharks in all sectors of Australia's SESSF.
4. Provide an analysis, with supporting rationale, for alternative management options for reducing the ecological risk to Harrisson's dogfish and similar upper-slope gulper sharks in Australia's SESSF.

6.0 Methods

6.1 Southern and Eastern Scalefish and Shark Fishery Overview

The Southern and Eastern Scalefish and Shark Fishery (SESSF) is a complex multi-sector, multi-species fishery that covers nearly half of the waters within the Australian Fishing Zone (AFZ) off mainland Australia and Tasmania (extending from the coast off Fraser Island in Queensland, then south and west to Cape Leeuwin in Western Australia; Fig. 2; AFMA 2008b, c). The historical development of the SESSF has been marked by successive declines of exploited stocks followed by the discovery of new resources (Tilzey 1994; Baelde 2001). Over 20 ports are used by the fleet from New South Wales (NSW) to Western Australia (WA). The major ports are Ulladulla, Eden, Lakes Entrance, Hobart and Portland (AFMA 2007a). The four principle sectors that are managed under the *Southern and Eastern Scalefish and Shark Fishery Management Plan 2003* (The SESSF Plan) are shown in Table 1 and maps of each sector are provided at Appendix 3.

The Commonwealth Trawl Sector (CTS), formally the South-East Trawl (SET) Fishery, predominantly uses otter trawl and Danish seine methods, with some midwater trawling also used (Table 1). The SESSF Plan also permits the use of pair trawling, but limited effort has been recorded to date (AFMA logbook data). The East Coast Deepwater Trawl (ECDWT) Sector uses both demersal and midwater trawl. The Great Australian Bight Trawl (GABT) Sector predominantly uses otter trawling with some midwater trawling occurring (Lynch and Garvey 2003; AFMA 2008c). The Gillnet, Hook and Trap (GHAT) Sector primarily uses scalefish and shark hooks, gillnets and fish traps depending on the specific Statutory Fishing Right (SFR) or fishing permit (AFMA 2008b). However, within the GHAT, only scalefish hook (including auto-longlines) are now used on the upper-slope areas, as shark gillnets and shark hooks were banned in depths below 183 m in 2007. A detailed description of the SESSF can be found in the management arrangements booklets (AFMA 2008b, c) available from the AFMA website (www.afma.gov.au).

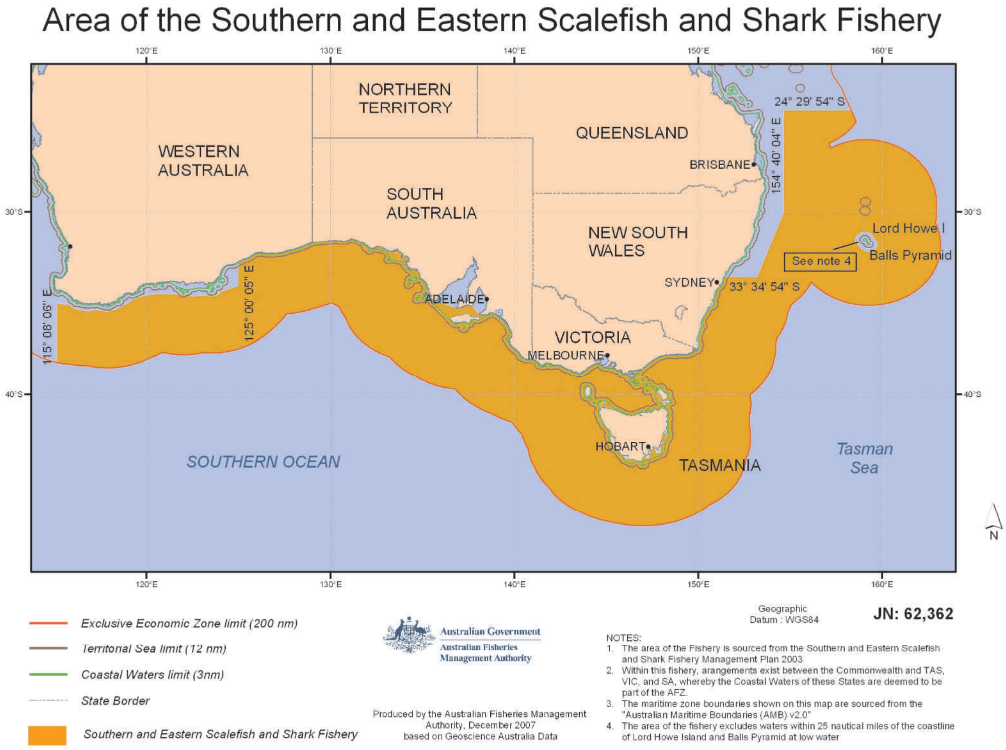

Figure 2. Area of the Southern and Eastern Scalefish and Shark Fishery (source: AFMA data section).

Table 1. Overview of current SESSF gears for the four principle sectors.

SESSF Sector	Sub-sector	Gear Type/s
Commonwealth Trawl Sector (CTS)	-	Demersal otter trawl Danish seine Midwater trawl
East Coast Deepwater Trawl (ECDWT) Sector	-	Demersal trawl Midwater trawl
Gillnet, Hook and Trap (GHAT) Sector	Scalefish Hook	Demersal longline (incl. auto-longline) Dropline Trotline
	Shark Hook	Demersal longline
	Gillnet	Demersal gillnets
Great Australian Bight Trawl (GABT) Sector	-	Demersal otter trawl Midwater trawl

6.2 The Ecosystem

6.2.1 Upper-Slope

The focus of this report will be on the ‘upper-slope’ components of the SESSF. By definition, the upper-slope includes all habitats (benthic and pelagic) below the edge of the continental shelf, generally considered to be at a depth of 200 m to a maximum depth of 650 m (Williams et al. 2005). Using this definition, the total area of the SESSF upper-slope benthic habitat is approximately 42 403 km^2. However, there are also areas such as seamounts that rise up from waters greater than 650 m depth, but do not necessarily reach 200 m and are not connected to the continental shelf slope. The total area of this habitat within the SESSF is estimated at 1443 km^2. For simplicity, the term ‘upper-slope’ will be used throughout this report to describe the combined areas of habitat (both the slope and seamounts) occurring in the 200-650 m depth range. The total area of habitat between 200 and 650 m in the SESSF is therefore estimated at 43 846 km^2 (Fig. 3).

6.2.2 Species

The Centrophoridae consist of two genera, *Centrophorus* (seven species) and *Deania* (two species), and both occur in Australian waters (Last and Stevens 2009). Gulper shark species of the genus *Centrophorus* spp. predominantly occur on upper continental and insular slopes in depths ranging from 200 to 2400 m (Compagno 1984; Andrew et al. 1997; Graham et al. 2001; Daley et al. 2002; Compagno et al. 2005; Last and Stevens 2009). However, specimens of *C. uyato* (now *C. zeehaani*) have been reported from shallower depths (150-200 m) by Walker and Gason 2007, observed from the GHAT longline fishery.

Despite the importance of gulper sharks to commercial fisheries in a number of countries, there has been a distinct lack of clarity around species identifications, resulting in historic catches being lumped into broad, non-descript categories, such as gulper shark, black shark, dogfish or deepwater shark (Compagno 1984; Muñoz-Chápuli and Ramos 1989; Graham et al. 2001; Daley et al. 2002; Compagno et al. 2005; Walker and Gason 2007). Compounding the identification problems for gulper sharks is that most species were poorly described originally (White et al. 2008). A recent study by White et al. (2008) found that the southern dogfish, formerly known as *C. uyato*, is in fact a different species (*C. zeehaani*) and is likely to be endemic to Australia. Similarly, White et al. (2008) also described a new species (*C. westraliensis*) that had previously been identified as a different colour morph of *C. harrissoni*. White et al. (2008) determined that *C. westraliensis* is endemic to Western Australian waters from Shark Bay to south of Cape Leeuwin, while *C. harrissoni* occurs in Australia only on the east coast.

A review of the gulper shark species caught in the area of the SESSF (primarily from the Integrated Scientific Monitoring Program (ISMP) and research survey data) resulted in a total of five *Centrophorus* species being identified in catches taken from the upper-slope habitat (Table 2). Both *C. squamosus and C. westraliensis* were identified in relatively small numbers and are treated at a cursory level throughout this report; *C. squamosus* is also considered to be primarily a mid-slope species (Koslow et al. 1994; Daley 2007; Last and Stevens 2009). The remaining three species (*C. harrissoni, C. moluccensis* and *C. zeehaani*) are the main focus of the present study.

Deepwater sharks in general, and gulper sharks in particular, possess a unique set of life history characteristics that result in them being highly vulnerable to fishing pressure. They possess a K-selected life history strategy (slow growth rate, high age at first maturity, few offspring and long life span) making them highly vulnerable to exploitation (Stevens et al. 2000; Kyne and Simpfendorpher 2007; Garcia et al. 2008). Detailed descriptions of the ecology and biology of each of the five gulper shark species examined in this study are provided at Appendix 4. Although the trophic importance of gulper sharks has not specifically been determined and the indirect ecological effects of their removal cannot be predicted with any certainty, as with other shark species (Stevens et al. 2000) they are likely to be important components of the upper-slope habitat ecosystem.

Table 2. *Centrophorus* species recorded as occurring on the upper-slope habitat of the SESSF.

	Scientific name	**Common Name**	**CAAB Code**
CLASS	Elasmobranchii	Sharks and rays	-
ORDER	Squaliformes	Bramble, sleeper and dogfish sharks	-
FAMILY	Centrophoridae, plus four other families.	Five families, including Gulper sharks	37020000
GENUS	*Centrophorus* spp.	Gulper sharks	37020902
SPECIES	*C. harrissoni*	Harrisson's dogfish	37020010
	C. moluccensis	Endeavour dogfish	37020001
	C. squamosus	Leafscale gulper shark	37020009
	C. westraliensis	Western gulper shark	37020050
	*C. zeehaani**	Southern dogfish	37020011

*formerly identified as *C. uyato*.

6.3 Management history of the SESSF relevant to gulper sharks

Throughout the history of the SESSF, numerous management arrangements have been implemented that were likely to have had an impact on gulper sharks either directly or indirectly. Direct management arrangements have occurred in recent years and include measures such as area closures and trip limits, specifically designed to protect upper-slope gulper sharks (such as the Endeavour dogfish closure). Less focused or indirect measures include general area closures in the SESSF or closures designed for other species (such as the Great Australian Bight Marine Park), and fleet structural adjustment (removal of fishing effort) that also produce a flow-on benefit in terms of protection for gulper sharks. Other examples include depth closures of the mid-slope habitat where the range of some upper-slope gulper shark species is known to extend (e.g. 700 m depth closure to trawling in the CTS). We reviewed all available current and historical management arrangements for the SESSF and extracted those of both direct and indirect relevance to gulper shark species (Table 3). These measures will be taken into consideration when management, data and research options are developed.

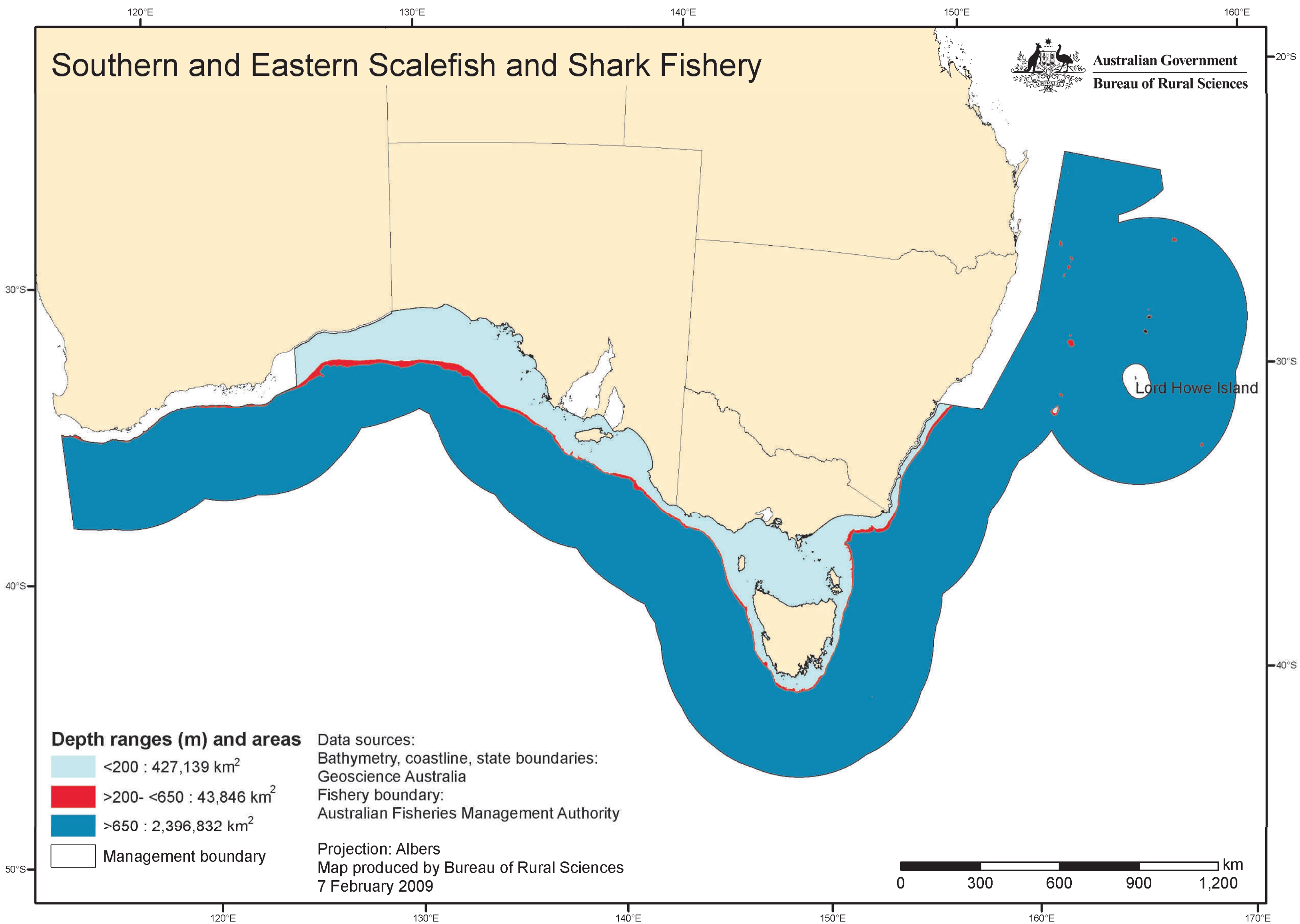

Figure 3. The upper-slope habitat (shown in red) of the Southern and Eastern Scalefish and Shark Fishery (SESSF) (200-650 m).

Table 3. Current SESSF management measures that contribute directly or indirectly to the conservation and sustainable use of upper-slope gulper shark species. Specific area coordinates, maps and restrictions are described in the 'Southern and Eastern Scalefish and Shark Fishery (Closures) direction No. 2 2008' (AFMA 2008a), the SESSF management arrangements booklet (AFMA 2008b), and the Department of the Environment, Water, Heritage and the Arts website: www.environment.gov.au.

SESSF Sector	Management Policy	Details/ Purpose	First implemented
Commonwealth Trawl Scalefish Hook	SESSF Closures Direction 2008 – Schedule 18	**Area closure name: Gulper shark closure – Endeavour dogfish** To protect populations of Endeavour dogfish, AFMA implemented the following closure in waters off Sydney in the area of the submarine cable protection zones. All fishing methods are prohibited from fishing in the area, in waters between 200 – 500 m deep, except those exempt in clause 6 of the closure direction: ***Clause 6*** *"provides for an exemption for persons who otherwise fish in accordance with another plan of management in force under the Act, or State or Territory law applying in the area of the fishery; and provides an exemption for persons who wish to complete scientific research in the closed areas of waters upon the receipt of a scientific permit from the AFMA."* **Total Area of closure 507 km^2; all upper-slope habitat.**	27 Jun 2007
Commonwealth Trawl Scalefish Hook Gillnet and Shark Hook	SESSF Closures Direction 2008 – Schedule 19	**Gulper shark closure – Harrisson's dogfish (eastern Bass Strait) – area closure** To protect Harrisson's dogfish the area of the proposed Flinders Marine Protected Area (multiple use zone) was closed to all hook and trawl methods, in waters enclosed by the area except for those exempt in clause 6. **Total Area of closure 1231 km^2; 971 km^2 of upper-slope habitat.**	27 Jun 2007
All, excluding GAB	SFR condition	**Trip limits** SFR/fishing permits for the SESSF allow the taking and carrying of no more than a combined total of 150 kg trunked weight per trip of the following Endeavour dogfishes (*Centrophorus* spp.): • Harrisson's dogfish (*C. harrissoni*), and • Endeavour dogfish (*C. moluccensis*); and • Southern dogfish (*C. uyato*) per trip. Within this combined total of 150 kg trunked weight, not more than 30 kg trunked weight of Harrisson's dogfish (*C. harrissoni*) may be taken or carried per trip.	2002 SET 2003 GHAT
All, excluding ECDWT	Interim management arrangements, under the *EPBC Act* 1999.	South-east Commonwealth marine reserve network. Various closure types (see Fig. 5) Multiple use zones that allow commercial hook methods, but exclude others: Murray Multiple Use Zone (west): **Total Area of closure 25 803 km^2; 180 km^2 of upper-slope.** Murray Multiple Use Zone (east): **Total Area of closure 25 803 km^2 ; 121 km^2 of upper-slope.** Zeehan Multiple Use Zone: **Total Area of closure 19 897 km^2; 85 km^2 of upper-slope.** Tasman Fracture Multiple Use Zone: **Total Area of closure 42 501 km^2; 328 km^2 of upper-slope.** Huon Multiple Use Zone: **Total Area of closure 9991 km^2; 400 km^2 of upper-slope.** Freycinet Multiple Use Zone: **Total Area of closure 57 942 km^2; 84 km^2 of upper-slope.** Flinders Multiple Use Zone: **Total Area of closure 27 043 km^2; 193 km^2 of upper-slope.** East Gippsland Multiple Use Zone: **Total Area of closure 4137 km^2; 3 km^2 of upper-slope.** Sanctuary and Recreational use zones that exclude commercial fishing: Tasman Fracture Sanctuary Zone: **Total Area of closure 42 501 km^2; 35 km^2 of upper-slope.** Freycinet Recreational Use Zone: **Total Area of closure 57 942 km^2; 34 km^2 of upper-slope.**	3 Sept 2007

SESSF Sector	Management Policy	Details/ Purpose	First implemented
ECDWT and Scalefish Hook	Elizabeth and Middleton Reefs Marine National Nature Reserve Management Plan 2006 - 2013, under the *EPBC Act* 1999.	The Elizabeth and Middleton Reefs Marine National Nature Reserve (the 'Reserve') was declared on 23 December 1987 by proclamation under the *National Parks and Wildlife Conservation Act 1975*. It is now protected and managed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Closed to all commercial fishing methods. **Total Area of closure 1880 km^2; 181 km^2 of upper-slope habitat.**	27 Dec 1987
All	SFR condition	**Processing restrictions** Dogfishes of the Family Squalidae may be landed headed and gutted with belly flaps removed. The dorsal and caudal (tail) fins must not be removed from their carcass. The tail tip may be cut off at the sub terminal notch. Pectoral fins, belly flaps, pelvic fins and claspers may be removed or left attached to their carcass.	2000 - scalefish hook sector of GHAT 2002 - shark sector of GHAT
All	SFR condition	**Liver restrictions** Carrying, retaining and landing livers obtained from sharks is prohibited unless the individual carcasses from which the livers were obtained are also landed at the same time.	2000 - scalefish hook sector of GHAT 2002 - shark sector of GHAT
Commonwealth Trawl	SESSF Closures Direction 2008 – Schedule 5	**St Helens Hill closure – area closure** The closure was initially implemented for orange roughy following consultation between SETMAC and AFMA management. The area closure (<u>to all trawl methods</u>), in conjunction with a precautionary TAC, is expected to re-establish healthy spawning aggregations or orange roughy, but affords other species a level of protection as well, including gulper sharks. **Total Area of closure 560 km^2; 89 km^2 of upper-slope habitat.**	1 Jan 2003
Commonwealth Trawl	SESSF Closures Direction 2008 – Schedule 21	**Tasmanian Seamounts Marine Reserve – area closure** Describes the permanent area closure of the Tasmanian Seamounts Marine Reserve, which is <u>closed to fishing to all trawl methods</u> except for those exempt in clause 6. The Tasmanian seamounts are located approximately 170 km south of Hobart. This area is closed to trawling due to the high number of endemic benthic species in the area. **Total Area of closure 389 km^2; 0 km^2 of upper-slope habitat.**	27 Jun 2007
Commonwealth Trawl	SESSF Closures Direction 2008 – Schedule 20	**700 m Trawl closure - Depth closure** Describes the permanent area closure of the Commonwealth South East Trawl Sector 700 m Depth Closure, which is <u>closed to all trawl methods</u> of fishing in waters deeper than 700 m, except for those exempt in clause 6. **Total Area of closure 911 629 km^2; 0 km^2 of upper-slope habitat.**	27 Jun 2007
Great Australian Bight Trawl	Management plan for the marine park, under the *EPBC Act* 1999.	**GAB Marine Park - Benthic Protection Zone (GABTS and GHATS) - area closure** Established to preserve a representative sample of the unique seafloor plants, animals and sediments of the area (i.e. benthos). Demersal trawl fishing is not permitted in the BPZ at any time. This area is closed to all Commonwealth GABTS Boat SFRs. **Total Area of closure 16 086 km^2; 548 km^2 of upper-slope habitat.**	1 Apr 1998
Great Australian Bight Trawl	SESSF Closures Direction 2008 – Schedule 24	**GAB Deepwater Closure – Central west zone** <u>Closed to fishing using demersal otter trawl gear</u>. **Total Area of closure 11 825 km^2; 105 km^2 of upper-slope habitat.**	30 Jun 2008

SESSF Sector	Management Policy	Details/ Purpose	First implemented
Great Australian Bight Trawl	SESSF Closures Direction 2008 – Schedule 25	**GAB Deepwater Closure – Salisbury Canyon** Closed to fishing using demersal otter trawl gear. **Total Area of closure 10 141 km^2; 27 km^2 of upper-slope habitat.**	30 Jun 2008
Great Australian Bight Trawl	SESSF Closures Direction 2008 – Schedule 26	**GAB Deepwater Closure – Far West** Closed to fishing using demersal otter trawl gear. **Total Area of closure 64 260 km^2; 120 km^2 of upper-slope habitat.**	30 Jun 2008
Great Australian Bight Trawl	SESSF Closures Direction 2008 – Schedule 17	**Great Australian Bight Trawl Sector Gulper Shark Closure – Southern Dogfish – area closure** To protect southern dogfish (*Centrophorus zeehaani*), AFMA implemented the following permanent closures in waters off South Australia: 1. The area between 133° 45' E and 134° 45' E in depths between 300-600 m is closed from demersal trawl; and 2. The area between 133° 45' E and 134° 45'E in depths between 183-600 m is closed to all scalefish hook fishing. Describes the permanent area closure which is closed to fishing using demersal otter trawl gear except for those exempt in clause 6. **Total Area of closure 727 km^2; all upper-slope habitat.**	27 Jun 2007
Great Australian Bight Trawl	Industry administered - voluntary	**Annual limit of 2 tonnes** Voluntary limit of 2 t for the whole fleet. **Note:** The SESSF Management arrangements booklet indicates that in recognition of the longer length of trips in the Commonwealth GABTS, a bycatch allowance of 500 kg per month is allowed. However, AFMA have indicated that this is an error (S. Weekes pers. comm.) and the voluntary limit is 2 t.	2006
Scalefish Hook	SESSF Closures Direction 2008 – Schedule 2	**Cascade Plateau - area closure** Closed as a precautionary measure until more is known about blue eye trevalla population dynamics and how major fishing effort on mature blue eye trevalla would affect that sector and the blue eye trevalla stock as a whole. Closed to hook methods (i.e. auto-longline). **Total Area of closure 1743 km^2; 7.5 km^2 of upper-slope habitat.**	22 Dec 2004
Scalefish Hook	SESSF Closures Direction 2008 – Schedule 16	**Commonwealth Scalefish Hook Sector Gulper Shark Closure – Southern Dogfish – area closure** Describes the permanent area closure of the "Commonwealth Scalefish Hook Sector Gulper Shark Closure – Southern dogfish", which is closed to fishing using hook methods except for those exempt in clause 6. **Total Area of closure 1212 km^2; all upper-slope habitat.**	27 Jun 2007
Scalefish Hook	SESSF Closures Direction 2008 – Schedule 15	**183 m Auto-longline closure – depth closure** Describes the permanent area closure of the waters shallower than 183 m to all Auto-longlines, which is closed to fishing except for those exempt in clause 6. **Total Area of closure: N/A, 0 km^2 of upper-slope habitat.**	2002
Gillnet and Shark Hook	SESSF Closures Direction 2008 – Schedule 13	**Gillnet 183 m Depth Closure** Describes the permanent area closure of waters deeper than 183 m to gillnet methods. Depth Closure, which is closed to fishing except for those exempt in clause 6. **Total Area of closure 1 018 767 km^2; 26 019 km^2 of upper-slope habitat.**	27 Jun 2007

SESSF Sector	Management Policy	Details/ Purpose	First implemented
Gillnet and Shark Hook	SESSF Closures Direction 2008 – Schedule 14	**West Coast Tasmania Shark Hook and Shark Gillnet Sector Depth Closure** Describes the permanent area closure of the West Coast Tasmania Shark Hook and Shark Gillnet Permanent Closure, which is closed to fishing using gillnet and shark hook except for those exempt in clause 6. Waters deeper than 130 m are closed to fishing. **Total Area of closure 264 052 km^2; 8463 km^2 of upper-slope habitat.**	27 Jun 2007
East Coast Deepwater Trawl	SESSF Closures Direction 2008 – Schedule 9	**East Coast Deepwater Trawl Sector Exclusion Zone – area closure** Describes the permanent area closure of the East Coast Deepwater Trawl Exclusion Zone, which is closed to fishing using trawl methods except for those exempt in clause 6. **Total Area of closure 187 869 km^2; 1864 km^2 of upper-slope habitat.**	22 Dec 2004

Each of the spatial/area closures or gear restrictions for the SESSF that were identified as potentially impacting on gulper shark stocks (Table 3) were then mapped (Figs. 4, 5) to provide an overview of their location in relation to the upper-slope habitat of each sector of the SESSF. The total area of each closure and the total area of the upper-slope habitat contained within each closure was also calculated and provided in Table 3. For example, the Gulper shark closure – Harrisson's dogfish (eastern Bass Strait), Schedule 19 of the closure direction (Table 3), that was designed and implemented to protect Harrisson's dogfish (closed to all hook and trawl methods) was estimated at 1231 km^2 in size; 971 km^2 of which occurs on the upper-slope habitat (Table 3).

In an attempt to identify the total area of the upper-slope habitat within the defined boundaries of each sector of the SESSF, both closed and open to fishing, we developed maps of the upper-slope for each sector of the SESSF (Appendix 5) and compared them with the closures identified in Table 3. The results are provided in Table 4. The proportion of the upper-slope habitat open to fishing varied by sector. For example, in the Commonwealth Trawl Sector 15.61 percent of the upper-slope is closed to fishing from Commonwealth trawl concession holders (Table 4), while in the GABT Sector 8.04 percent of the upper-slope habitat within the boundaries of the fishery are protected from trawling (Table 4).

However, most of the closures described in Table 3 are for one or two fishing gears only. In real terms, this means that the majority of the upper-slope habitat in the SESSF is open to at least one fishing gear capable of taking gulper sharks. Specifically, we determined that 3154 km^2 of the total 43 846 km^2 of upper-slope habitat in the SESSF is protected from all forms of fishing (7.19 percent; Table 4).

Based on international research that suggests closed areas need to be large and encompass 20 to 50 percent of a population's spawning stock biomass to be effective (e.g. Mangel 1998), the figure of 7.19 percent for the SESSF is insufficient for adequate protection. It should also be noted that the recommendation for 20-50 percent protection is for species and communities whose reproductive potential is much higher than those of the upper-slope habitat. Thus, a more precautionary approach should be taken for deepwater species with K-selected life history strategies.

Table 4. Total area (km^2) of the upper-slope habitat within each of the SESSF sectors and the corresponding total and percentage area that is currently defined in management arrangements as being closed to fishing (from Commonwealth concession holders). The corresponding area of the upper-slope habitat open to fishing is also provided.

SESSF Sector	Sub-Sector	Area of habitat (km^2)			Percent closed
		Upper-slope	Closed to fishing	Open to fishing	
Commonwealth Trawl	-	**17 504**	2 733	14 771	15.61
Great Australian Bight Trawl	-	**22 734**	1 828	20 906	8.04
East Coast Deepwater Trawl	-	**2 043**	2 043	0	100
Gillnet, Hook and Trap	Scalefish Hook	**28 947**	2 952	25 995	10.20
“	Gillnet and Shark Hook Sectors	**26 890**	26 890	0.00	100
SESSF Total	**-**	**43 846**	**3 154**	**40 692**	**7.19**

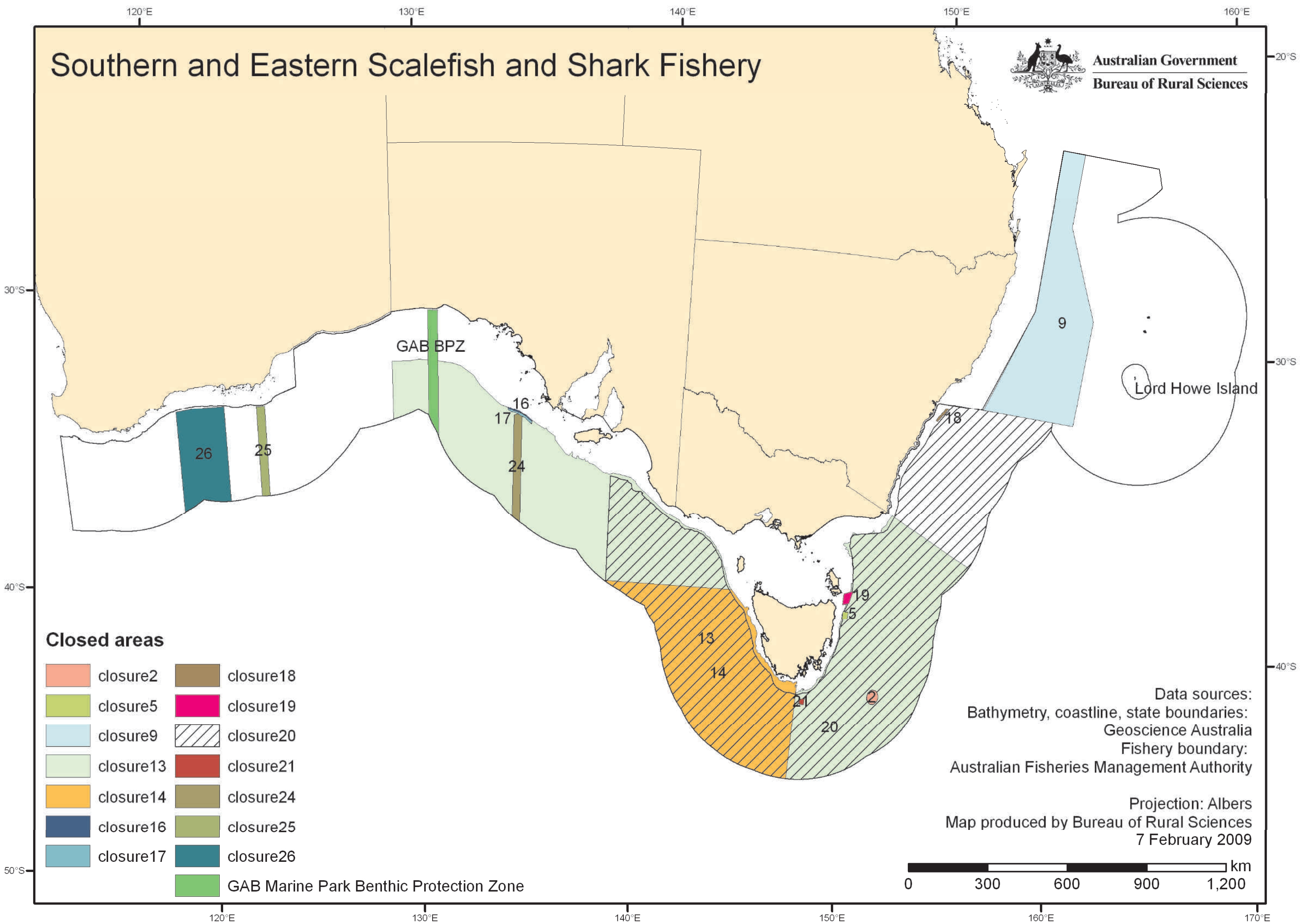

Figure 4. Current area closures in the SESSF that contribute either directly or indirectly to the conservation and sustainable use of upper-slope gulper shark species. Refer to Table 3 for a description of each closure (closure numbers refer to the schedule number in the SESSF closure direction (AFMA 2008a).

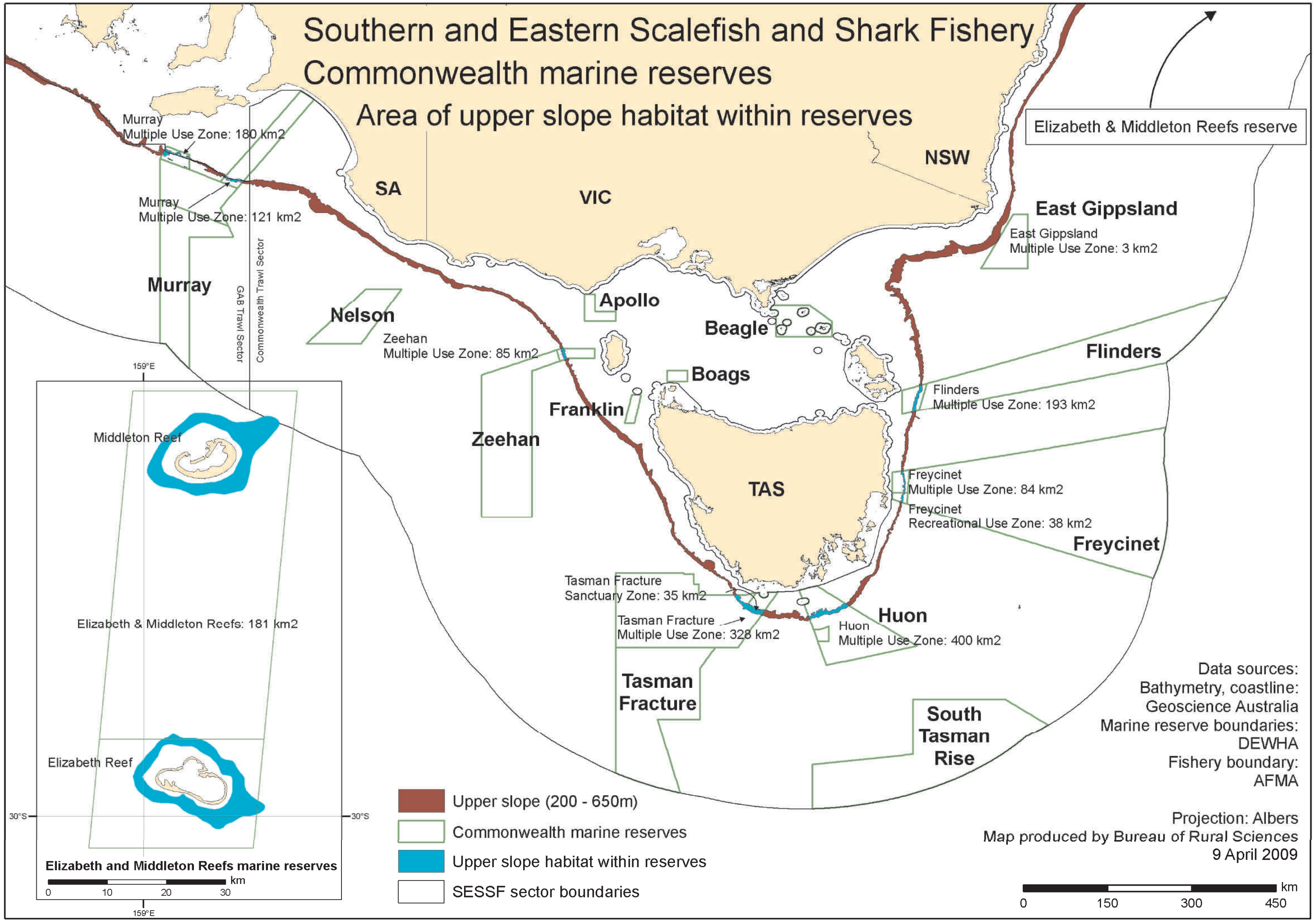

Figure 5. South-east Commonwealth marine reserve network and Elizabeth and Middleton Reefs marine national nature reserves, showing their interaction with the upper-slope habitat of the SESSF. Area of upper-slope contained within each reserve shown in km^2. Reserve types are described in Table 3.

6.4 International management of deepwater sharks

Objective 1 Review the success of management arrangements used elsewhere around the world to address the sustainability of fisheries catches involving similar upper-slope low productivity shark species.

International management arrangements were explored by identifying countries with gulper or other deepwater shark fisheries and investigating the management arrangements in place, if any, for those species. This involved carrying out literature searches for published journal documents, examining the grey literature for government reports, exploring the websites of fisheries management agencies such as the Ministry of Fisheries in New Zealand and contacting staff in those organisations directly. Only three countries/regions were relevant to gulper sharks, and identified as potentially having management arrangements in place that were accessible (North-East Atlantic, New Zealand and the United States, Table 5). Additional recommendations were sourced from an international workshop on the Conservation and Management of Deepwater Chondrichthyan Fishes, held in New Zealand in 2003 (Irvine 2005).

Table 5. Details of methods used to investigate international management arrangements for gulper sharks.

Fishery area	Literature search	Personal communication	Websites	Additional sources
North-East Atlantic	Web of Science, grey	-	www.ices.dk www.neafc.org www.ospar.org	ICES (2000, 2002, 2004a, 2004b, 2005a, 2005b, 2008) Gordon (1999, 2001)
New Zealand	Web of Science, grey	Andrew Hill, Ministry of Fisheries	www.fish.govt.nz	NZ NPOA-Sharks (2009)
United States	Web of Science, grey	Richard McBride, Karyl Brewster-Geisz, NMFS	www.nmfs.noaa.gov	USA NPOA-Sharks (2001)
Other Maldives Namibia	Web of Science, grey	-	www.mfmr.gov.na www.fishagri.gov.mv	Shotton (1999) Irvine (2005) Kyne and Simpfendorfer (2007) NATMIRC (2003) Anderson and Ahmed (1993) MOFAMR (2002)

6.5 SESSF review of data quality for gulper sharks

Objective 2 Consider the historical identification of Harrisson's dogfish including catch statistics and scientific surveys.

A qualitative analysis of historic information and consideration of the adequacy of this information was undertaken to address the objective, provide management advice and identify data gaps. A review of information on deepwater dogfish was completed by CSIRO in 2002 (Daley et al. 2002: Fisheries Research and Development Corporation (FRDC) Project 1998/108). The information sourced for this report was examined in light of recent developments in the SESSF, such as spatial/area closures (AFMA 2008a), trip limits (AFMA 2008b) and the Commonwealth Harvest Strategy Framework (AFMA 2007b). A review of the data quality and interpretation was also carried out for this and other relevant, previous studies. In addition, there are other data sources that have become available since the completion of the FRDC report by Daley et al. (2002). These sources include additional research undertaken by CSIRO, a FRDC project on rapid assessment of shark species undertaken by PIRVic (Walker et al. 2008), data from the Integrated Scientific Monitoring Program (ISMP), data compiled as part of AFMA's Ecological Risk Assessment project, improved logbook data, and CSIRO research characterising the benthic ecosystem in areas closed to provide protection for gulper sharks.

6.6 SESSF data investigation and improved estimates for gulper sharks

Objective 3 Investigate and improve estimates on the extent and nature of interactions with Harrisson's dogfish and other similar upper-slope gulper sharks in all sectors of Australia's SESSF.

Our report used data on daily catches of gulper sharks from several sources such as daily logbooks, ISMP observer data and other information submitted to the NSW Department of Primary Industries (DPI).

6.6.1 Data investigation

6.6.1a Logbooks

Prior to 1985, state agencies had used catch-recording systems of varying detail, with little standardisation among agencies. Trawlers in the SESSF have been required to maintain a detailed log of operations and catches since October 1985 (trawlers and Danish-seine; Grieve and Richardson 2001). Logbooks are used when fishing in all sectors of the SESSF. They are designed to provide a continuous record of fishing operations undertaken by Commonwealth fishing concession holders. Accurate data recording in the logbooks is essential to provide information for research into and management of Australian fisheries. Logbooks must be completed for every day that the fishing concession is in force, regardless of whether or not fishing takes place on that day. All logbook information is recorded on a shot by shot and daily basis and details for the last day of the trip are recorded before the vessel docks at the end of each trip.

Prior to March 2000, catch and effort data were recorded in the Australian Fishing Zone Information System (AFZIS) database by AFMA. The Bureau of Rural Sciences (BRS) holds a copy of this database. From March 2000 onwards, catch and effort data have been recorded in the Daily Logs Database by AFMA. BRS receives a download of this database several times a year and have developed routine scripts to join these two datasets to produce continuous time series data, modifying codes as required.

These databases were interrogated to obtain results from the AFZIS data for the Great Australian Bight Trawl (GABT) Sector, South East Trawl/Commonwealth Trawl Sector (SET/CTS), Southern Shark Fishery (SSF) and South East Non-Trawl (SEN) Fishery and Gillnet, Hook and Trap (GHAT) Sector codes. Additional detail on historical data collected for the GAB Trawl Sector is provided in Lynch and Garvey (2003).

Effort

The Commonwealth Trawl Sector logbook dataset from 1985 to present comprises 645 776 records. This was converted into a GIS data set of points representing the start points of the operations. It had been originally intended to create a dataset of trawl tracks by joining the start and end points of each track but this was abandoned because of technical difficulties relating to resolving the validity of trawl track lengths and allocation of catch and effort between different sectors crossed by the tracks.

The points representing operations were intersected with a GIS dataset of the upper-slope habitat within the Commonwealth Trawl Sector area (Fig. 2). Intersect is an Arc/INFO routine that intersects two datasets, merging their features and attribute tables. A total of 206 101 points fell within this zone, so 439 675 points were excluded. The data used to represent this habitat were the bathymetric contours generated by Geoscience Australia (GA 2005).

The same process was used for the Great Australian Bight Trawl Sector, East Coast Deepwater Trawl Sector and the Gillnet, Hook and Trap Sector.

Catch
Species codes searched for were: 37020000 (includes all commercial dogfishes), 37020001, 37020009, 37020010, 37020011, 37020050 and 37020902 (Table 2). Depths recorded in the database are average depths for each trawl shot in trawl fisheries (GAB, SET/CTS) and minimum and maximum depths for other fisheries.

For the Daily Logs data, that contains data for all Commonwealth fisheries, a search was carried out for the gulper shark codes to identify all fisheries where these species were caught. Depths recorded in the database were average depth for trawl fisheries (though this was recorded in the maximum depth field for the first part of the dataset) and maximum depth for the other fisheries. Depths recorded in fathoms (code “F”) were converted to metres.

6.6.1b Integrated Scientific Monitoring Program (ISMP) on-board sampling data (1992-2007)

The Australian Fisheries Management Authority (AFMA) established the ISMP to provide essential data on the SESSF that are not available through the quota monitoring and logbook systems. Specifically, the main objectives of the ISMP are to provide statistically robust estimates of:

- the total catch (retained and discarded) of quota species
- the total catch (retained and discarded) of other species
- the size/age composition of the total catch (retained and discarded) for selected species.

To achieve this, there are two components to the ISMP:

- at-sea monitoring of fishing activities, including the collection of data on total (retained and discarded) catches, the size composition of retained and discarded catches, collection of ageing material and other biological information
- port-based monitoring of landed catches at specified ports/markets/processors, including the measurement of the size composition of landed catches, collection of ageing material and other biological information.

The principal objective of the ISMP is to provide information on the quantity, size and age composition of the retained and discarded catch of quota species caught in the SESSF for use in the stock assessment process. In addition, the demand for information on non-quota species, discarded catch and catch composition has increased significantly. To meet these objectives, on-board field observers sample the retained and discarded catches taken by operators and fish-measurers sample the catches landed in the major SESSF ports.

The current ISMP has been ongoing in the CTS since 1998 and was expanded to the GABT and Scalefish hook sector in 2001; coverage in the gillnet sector began in 2006. In 2004, the scope of the ISMP was expanded to record interactions with Threatened, Endangered and Protected

(TEP) species and further information on fishing gear. Additional details regarding the ISMP program can be found in the ISMP annual reports (Koopman et al. 2006a, b, c).

In 2007, AFMA took over the operation of the ISMP from PIRVic. At this time PIRVic provided AFMA with the historical dataset. In 2008, BRS obtained a copy of this historical dataset together with the one year of AFMA collected data. It was this dataset that was used to extract ISMP data for this report. The dataset is divided into onboard sampling and port sampling. There were no occurrences of gulper shark species sampled during port sampling. Species codes used to search on-board sampling data were 37020010, 37020001, 37020011, 37020902, 37020050, 37020000 and 37020009. Conversion factors were determined for each of the processing codes and these were used to convert processed weights for retained and discarded catch to whole weights (Table 6).

Table 6. Conversion factors used to convert processed weights for retained and discarded catch to whole weight for all species of gulper shark (extracted from the AFZIS database).

Processing type	Code	Conversion factor
Finned	FIN	2.5
Filleted	FLT	2.33
Gutted	GUT	1.1
Headed and Gutted	HGT	1.5
Trunked (FIN + HGT)	TRK	1.5
Trashed fish	TSH	1
Unknown	UNK	1
Whole	WHO	1

6.6.1c Mapping

Spatial analysis was carried out in ESRI Arc/INFO (UNIX version 9.1) and mapping was done using ESRI ArcGIS (versions 9.2 and 9.3). AFMA logbook data was used to analyse and map catch and effort in the SESSF sectors. ISMP data was used to map observed gulper shark catch. It is not possible to show individual operations, for confidentiality reasons, so in all cases catch and effort data were aggregated into zones created along the upper-slope habitat and then filtered for fewer than five boats operating in each zone. In the area of the CTS, the upper-slope habitat was divided into zones approximately 55 km long along the upper-slope. In the area of the GABT sector, the upper-slope was divided into zones approximately 110 km long. It was not possible, within the scope of this project, to divide the upper-slope into equal areas. Operational data was intersected with these zones and then aggregated, filtered for fewer than five boats and total catch and effort calculated within each zone. These values were then mapped.

6.7 Alternative management options for gulper sharks

Objective 4 Provide an analysis, with supporting rationale, for alternative management options for reducing the ecological risk to Harrisson's dogfish and other similar upper-slope gulper sharks in Australia's SESSF.

Consideration was given to management changes that have occurred in recent years and the current harvest strategy and ecological risk assessments for the SESSF (Smith et al. 2007, 2008) that may have flow-on benefits for gulper sharks on the upper-slope. Data gaps and research needs were examined. This project drew on other work examining options for management of chondrichthyan species bycatch in Commonwealth fisheries. The information and knowledge generated by this project will be an improved understanding of the fishery for gulper sharks in south eastern Australia; an evaluation of the success of management arrangements for similar species elsewhere in the world; and a combination of these two elements to provide an objective basis for the selection of preferred management arrangements for these species in the SESSF.

7.0 Results

7.1 International management of deepwater sharks

Objective 1 Review the success of management arrangements used elsewhere around the world to address the sustainability of fisheries catches involving similar upper-slope low productivity shark species.

7.1.1 Background

Deepwater sharks (including gulper sharks) are routinely taken in fisheries around the world with a variety of fishing gear (Kyne and Simpfendorfer 2007). The majority of this catch is bycatch and fishing for gulper sharks is generally not targeted (Figueiredo et al. 2005; NZ NPOA-Sharks 2009; NMFS pers. comm.). As a result, fisheries management plans specific to, or pertaining to, gulper sharks are virtually non-existent. As these sharks are generally taken as bycatch, it also makes collecting information on them and elucidating issues of stock structure and status all the more difficult, as samples are low in number and likely not recorded accurately.

Given the slow recovery of deepwater shark species, any management measure is unlikely to have any measurable impact on stock recovery for several decades. This is an impediment to efficient and effective management as the measures cannot be altered accordingly if they are deemed inappropriate or ineffective, at least over the time scales at which government agencies and processes operate. It will therefore be very difficult to determine which measures will be the most effective and over what time scale they need to be in place before a measurable response is likely.

7.1.2 Case Studies

7.1.2a Northeast Atlantic deepwater fisheries

Of all the case studies examined, only the northeast Atlantic deepwater fisheries operating in the International Council for the Exploration of the Sea (ICES) area were identified as having in place any management measures specific for deepwater shark stocks.

Background

Location:	Northeast Atlantic, primarily in the northern ICES sub areas (sub areas V, VI, VII, XII) and particularly around the Rockall Trough and on the Porcupine Bank slopes which lay to the west of the British Isles.
Fishery methods:	Multi-species trawl, multi-species and directed longline, and historically some gillnet.
Major nations:	Spain, Portugal, UK, France, Iceland, Ireland, Norway.
Relevant species:	Primary: *Centrophorus squamosus* (Leafscale gulper shark) and *Centroscymnus coelolepis* (Portuguese dogfish). Secondary: *Centrophorus granulosus, Squalus acanthias* (Spiny dogfish), *Deania calcea* (Birdbeak dogfish), *Centroscyllium fabricii* (Black dogfish), *Etmopterus spinax* (Velvet belly), *E. princeps* (Great lanternshark), *Centroselachus crepidater* (Longnose velvet dogfish), *Scymnodon ringens* (Knifetooth dogfish), *Dalatias licha* (Kitefin shark).
Stock status:	Stocks reported as depleted for *C. squamosus* (Leafscale gulper shark) and *C. coelolepis* (Portuguese dogfish). There is evidence of declines for other species.
Conservation body:	Oslo and Paris (OSPAR) Commission (www.ospar.org). The OSPAR Convention is the current legal instrument guiding international cooperation on the protection of the marine environment of the northeast Atlantic. Work under the Convention is managed by the

	OSPAR Commission, made up of representatives of the Governments of 15 Contracting Parties and the European Commission, representing the European Community. OSPAR is the mechanism by which fifteen Governments of the western coasts and catchments of Europe, together with the European Community, cooperate to protect the marine environment of the northeast Atlantic. The fifteen Governments are Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.
Science body:	ICES is the organisation that coordinates and promotes marine research in the North Atlantic (www.ices.dk). ICES is the prime source of advice on the marine ecosystem to governments and international regulatory bodies that manage the North Atlantic Ocean and adjacent seas, and provides advice on individual deep water species every two years. The 20 member countries of ICES are: Belgium, Canada, Denmark, Estonia, Finland, France, Germany, Iceland, Ireland, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Russia, Spain, Sweden, the United Kingdom and the United States of America. The affiliates are: Australia, Chile, Greece, New Zealand, Peru and South Africa.
Management body:	The North East Atlantic Fisheries Commission (NEAFC) (www.neafc.org). NEAFC is made up of delegations from Contracting Parties (Denmark in respect of the Faroe Islands and Greenland, the European Union, Iceland, Norway and the Russian Federation) who have agreed to abide by the rules of the Convention on Future Multilateral Cooperation in North-East Atlantic Fisheries, which entered into force in its current form in November 1982. The Commission was formed to recommend measures to maintain the rational exploitation of fish stocks in the Convention Area, taking scientific advice from ICES. NEAFC is the organisation responsible for recommending measures to Contracting Parties to promote the rational exploitation of fisheries in the NEAFC area, but beyond areas under national fisheries jurisdiction of Contracting Parties. If Contracting Parties request, NEAFC will also recommend measures for areas under the fisheries jurisdiction of Contracting Parties.
Management history:	Table 7 provides a chronological history of management measures in the northeast Atlantic aimed at reducing adverse impacts of fisheries on deepwater shark species.

Table 7. Management history of northeast Atlantic fisheries - scientific advice and management measures relevant for deepwater sharks.

Date	Description	Organisation	Source
1988	Fishery for *Centrophorus squamosus* and *Centroscymnus coelolepis* began.	France/Spain	Heessen (2003) ICES (2006)
2000	NEAFC **noted**: • that most deep-sea species are being harvested outside safe biological limits. • stocks can be depleted quickly and recovery is slow. NEAFC **recommended**: • an immediate reduction in those fisheries that cannot be shown to be sustainable • any new development must progress slowly and be accompanied by programs for data collection that allow for the evaluation of stock status.	NEAFC	NEAFC (2000)
2000	ICES **indicates** to NEAFC that: • stock assessments for *Centrophorus squamosus* and *Centroscymnus coelolepis* combined, indicated that in 1998, the combined stock was below 50% of the initial biomass (pre-1988) • it does **not** consider the establishment of TACs and gear restrictions as effective management measures for deepwater species • experience from other areas has shown that no management measure implemented alone can provide an effective protection for deep-sea stocks.	ICES	ICES (2000)
2002	Basson et al. **noted**: • a declining catch trend reported for French trawl *C. squamosus* and *C. coelolepis* CPUE over a short time-series of 1990–1998 in ICES Sub areas VI and VII and Division Vb (the area to the West of the British Isles) • that production models used to undertake biomass estimates, with results indicating that the exploitable biomass of these two species in those regions was below 50% virgin biomass.	-	Basson et al. (2002)
2002	ICES **noted** that: • deep-water sharks can sustain only very low exploitation rates • they are taken in mixed fisheries, which makes it difficult to manage them in a single-species context. ICES **recommended** that: • due to the declining trends in CPUE, despite the mixed nature of the catches, that the overall exploitation be reduced • ICES further advises that species-specific landings data be collected for all deep-water sharks to allow better understanding and quantification of the status of exploited shark species • that reductions will likely need to be large (~50%) and sustained over a period of years in order to be effective.	ICES	ICES (2002)

Date	Description	Organisation	Source
2002	NEAFC **agreed** that: • ad-hoc and Temporary Conservation and Management Measures for Deep-Sea Species in the NEAFC Regulatory Area should be implemented as interim measures • each Contracting Party undertakes to limit the effort for 2003 put into the fishing for deep-sea species in the NEAFC Regulatory Area • the effort shall not exceed the highest level put into deep-sea fishing in previous years for deep-sea species • the effort should be calculated as aggregate power, aggregate tonnage, fishing days at sea or number of vessels which participated.	NEAFC	NEAFC (2002) Recommendation IV:2003
2003	As part of the European-wide DELASS project (Development of Elasmobranch Assessments) stock assessments were attempted for *Centrophorus squamosus* and *Centroscymnus coelolepis* for the northeast Atlantic as a whole. Although Heessen (2003) reports evidence of a decline in abundance (from CPUE data) for the two species combined in ICES Sub areas V, VI and VII, the stock assessment was unsuccessful due to a short time-series, a lack of species-specific data and a poor understanding of the stock structure of the species in the region.		Heessen (2003)
2003	NEAFC **agreed** that: • each Contracting Party undertakes to limit the effort for 2004 put into the fishing for deep-sea species in the NEAFC Regulatory Area • the effort shall not exceed the highest level put into deep-sea fishing in previous years for those species listed below • the effort should be calculated as aggregate power, aggregate tonnage, fishing days at sea or number of vessels, which participated.	NEAFC	NEAFC (2003) Recommendation V:2004
2004	NEAFC **agreed** that: • bottom trawling and fishing with static gear shall be prohibited in the following areas: a) The Hecate and Faraday seamounts, and a section of the Reykjanes Ridge b) The Altair seamounts c) The Antialtair seamounts. • this measure shall be in force for the period 1 January 2005 – 31 December 2007.	NEAFC	NEAFC (2004) Recommendation IV:2005

Date	Description	Organisation	Source
2005	ICES **noted**: • that stocks of Portuguese dogfish and Leafscale gulper shark are considered to be depleted. • that exploitation increased significantly from the commencement of fishing at the end of the 1980s while CPUE declined considerably for French, Irish, Norwegian, Portuguese and Scottish trawlers and longliners from 1994 to 2005 in the northern region (ICES Sub areas VI, VII and XII) • longline CPUE Status: stocks of the most commonly caught species, the Leafscale gulper shark *Centrophorus squamosus* and *Centroscymnus coelolepis*, are depleted • little data on other species, but some declines are also evident. ICES **recommended** that: • a **zero catch limit** for *C. squamosus* and *C. coelolepis* in ICES areas (i.e. the Northeast Atlantic) • a zero catch will require that means are found to **avoid any bycatch** of deep water sharks. If this is not possible, **effort needs to be reduced** to the lowest possible level in mixed fisheries taking deep-water sharks as bycatch.	ICES	ICES (2005a)
2005	NEAFC **agreed** that: • each Contracting Party undertakes to limit the effort for 2006 put into the directed fishing for certain deep-sea species in the NEAFC Regulatory Area • the effort shall not exceed 70 per cent of the highest level put into deep-sea fishing in previous years for the relevant species • the effort should be calculated as aggregate power, aggregate tonnage, fishing days at sea or number of vessels, which participated • NEAFC agrees to ban gillnets in waters deeper than 200 m.	NEAFC NEAFC	NEAFC (2005) Recommendation IX:2006 -
2005	Jones et al. (2005) **indicates** that: • There were considerable declines for *Centrophorus squamosus* and *Centroscymnus coelolepis* in the ICES area, using fisheries-independent data • trawl surveys undertaken to the west of Scotland between 1998 and 2004 were compared with historical trawl survey data from 1970 to 1978 • the historical data are pre-exploitation of deepwater marine resources in the region • there were considerable declines in CPUE between the 1970s surveys and the recent surveys for *C. squamosus* and *C. coelolepis* as well as for *D. licha* and *D. calcea* (1998–2004 survey catches 62–99% lower than 1970s surveys).	-	Jones et al. (2005)

Date	Description	Organisation	Source
2006	NEAFC **recommended**: • the adoption of conservation and management measures for deep-sea species in the NEAFC regulatory area in 2007 • that in accordance with Article 5 of the Convention on Future Multilateral Cooperation in North-East Atlantic fisheries, the Contracting Parties recommend the following measure for the fisheries for deep-sea species for 2007 • that each Contracting Party undertakes to limit the effort for 2007 put into the directed fishing for deep-sea species as set out in Annex 1B of the Scheme in the NEAFC Regulatory Area • the effort shall not exceed 65 per cent of the highest level put into deep-sea fishing in previous years for the relevant species • the effort should be calculated as aggregate power, aggregate tonnage, fishing days at sea or number of vessels, which participated • banning the practice of shark finning.	NEAFC	NEAFC (2006) Recommendation VI:2007
2007	NEAFC **recommended** that: • each Contracting Party undertakes to limit the effort for 2008 put into the directed fishing for deep-sea species as set out in Annex 1B of the Scheme in the NEAFC Regulatory Area • the effort shall not exceed 65 per cent of the highest level put into deep-sea fishing in previous years for the relevant species • the effort should be calculated as aggregate power, aggregate tonnage, fishing days at sea or number of vessels, which participated • area closures for trawling be implemented.	NEAFC	NEAFC (2007) Recommendation XV:2008
2008	OSPAR **agreed**: • to add six species of shark to the OSPAR list of threatened and/or declining species and habitats (Angel shark, Gulper shark, Leafscale gulper shark, Spurdog, Portuguese dogfish, Porbeagle).	OSPAR	OSPAR (2008)

Difficulties experienced:
The northeast Atlantic deepwater fishery mainly targets monkfish and deepwater sharks (Gordon 2001; Hareide et al. 2005) using trawl gear, as gillnets were banned in waters greater than 200 m in 2005 (NEAFC 2005). However, the short time-period for which the fisheries have been operating, has limited the utility of assessments on trend data, until recently when ICES presented a series of CPUE trends for these species to advise that the stocks had been depleted (ICES 2005b). In 2005, ICES recommended a total halt to the take of two deepwater shark species (*Centroscymnus coelolepis* and *Centrophorus squamosus*; ICES 2005a). The IUCN regards *Centroscymnus squamosus* as Vulnerable on its Red List (www.iucnredlist.org). Similarly, *Squalus acanthias* (Spiny dogfish), a species that mainly inhabits the continental shelf, but has a range that extends to the upper-slope, is also listed as Vulnerable and has reportedly declined by as much as 60 percent from catches taken in the early 1990s (ICES 2004a).

Landing data in the northeast Atlantic suffer from similar problems to those in the SESSF. Specifically, sharks are grouped together under general categories such as “deep-sea sharks” or “elasmobranchs”, thus providing little detail on the diversity of species landed and inhibiting useful stock assessments from being carried out. However, from partial data for *C. coelolepis* and *C. squamosus* alone, catches reportedly increased from 486 tonnes in 1991 to 2184 tonnes in 2000 and to 5174 tonnes in 2003 (ICES 2004b). Historically, most of the sharks caught in the northeast Atlantic were not covered by a quota system (Kjerstad and Fossen 2001), leading to fishers targeting sharks when they reached their quotas for other species. This was partially remedied by the European Union in 2004 when they placed a generic quota of 3500 tonnes under the category “deep-sea sharks” (EC 2004). This was amended by the Council of Fisheries Ministers in 2005 to 7000 t.

ICES have repeatedly advised for a zero catch limit for all deepwater sharks in the ICES areas where they are caught (ICES 2002, 2005b). NEAFC, however, has failed to fully adopt the ICES advice, and fishing for deepwater sharks continues albeit at effort levels substantially reduced from the early 1990s (Table 7).

In 2007, ICES advised a zero catch limit for deepwater sharks in certain areas and noted that means to avoid bycatch of these species must be implemented (ICES 2007). While the Fisheries Commission proposed a 2007 bycatch quota for certain ICES areas that amounted to a 33 percent reduction from actual 2005 catches, the Council of European Union Fisheries Ministers agreed to a bycatch Total Allowable Catch (TAC) of 2472 tonnes, representing a 25 percent reduction. Additionally, for an ICES area where deepwater sharks have historically been caught, the ICES scientific recommendation also advocated a zero TAC. However, the Council ignored this advice and agreed to a 25 percent increase over 2005 catches.

Applicability of management arrangements to the SESSF:
There are many similarities in the biology and fishing history of species of deepwater sharks taken in the northeast Atlantic (Girard and Du Buit 1998, 1999; Clarke et al. 2001a c, 2002c; Crozier 2001; Girard 2001; Bañón et al. 2006) and the SESSF (Kyne and Simpfendorfer 2007; Last and Stevens 2009). Large decreases in reported catches and apparent stock biomass have led scientists in both areas to strongly recommend a zero catch for deepwater sharks. A zero catch would require that means are found to avoid any bycatch of deepwater sharks. ICES noted that if a zero catch is not possible, then managers should reduce effort to the lowest possible level in mixed fisheries taking deepwater sharks as bycatch. It is possible that gulper sharks in the SESSF can only be protected if a similar recommendation is adopted. Options for reducing the catch of gulper sharks in the SESSF are discussed in subsequent sections of this

report, and include area and gear closures affecting a zero catch on large areas of the upper-slope.

7.1.2b New Zealand deepwater fisheries
Background
Deepwater sharks in New Zealand (NZ) are managed with a Quota Management System (QMS) or are open access. QMS species include: Spiny dogfish (*Squalus acanthias),* Rig shark (*Mustelus lenticulatus)* and Ghost shark (*Hydrolagus* spp.), among others. Open access sharks include Bramble sharks, deep sea sharks, Leafscale gulper shark (*Centrophorus squamosus*), Portuguese dogfish (*Centroscymnus coelolepis*) and unspecified deepwater dogfish. Spiny dogfish are also taken by recreational fishers, mainly as bycatch and are often regarded as a pest species. Key management measures include:

- 11 species are managed under the QMS and account for ~80 percent of the commercial landings in NZ. Of these 11 species, six have dominated the landings and are taken primarily as bycatch
- QMS species are managed at or above a biomass that can sustain maximum sustainable yield (MSY)
- as part of the New Zealand National Plan of Action for the Conservation and Management of Sharks (NZ NPOA-sharks 2009), several actions have been proposed including: producing a field identification guide, reducing the use of generic shark reporting codes and initiating research to address issues such as stock status and important habitats.

Applicability of management arrangements to the SESSF: New Zealand's arrangements for deepwater shark have limited additional utility to management arrangements for gulper sharks in the SESSF. While several of their deepwater sharks are targeted species and under their quota system, most are bycatch and do not have any quota or direct management associated with them. As part of the NZ NPOA-Sharks (2009), there are numerous proposed actions. These actions are very similar to what has been discussed or what is currently being undertaken in Australia.

7.1.2c United States (U.S.) fisheries
Background
U.S. fisheries interact with deepwater sharks, including gulper sharks (e.g. *Centrophorus acus*, *C. granulosus* and *C. uyato*). These sharks are taken primarily as bycatch and no directed fisheries target deepwater sharks. While these sharks are mentioned in formal management plans, such as the Final Fisheries Management Plan for Atlantic Tuna, Swordfish and Sharks (NMFS 2003), there are no actual management measures that pertain to these species (with the exception of the prohibition on finning put in place by the Shark Finning Prohibition Act). Other key aspects of the fishery include:

- there is no permitting or quota system, and no retention limit or management plan that formally includes deepwater sharks
- the catch of deepwater sharks is incidental, not targeted, therefore, there is little information on the status of these species
- they are included as "deepwater" sharks in research plans, although it is unclear how much research is directed to deepwater sharks
- the National Marine Fisheries Service (NMFS) is currently undertaking a scoping study regarding potential amendments to management plans and, given their life history and

potential vulnerability, deepwater sharks are being considered as a potential amendment to the plans.

Applicability of management arrangements to the SESSF: Given that currently there are no specific management arrangements for deepwater sharks in the U.S., it is not possible to review these arrangements or apply them to gulper sharks in the SESSF, except to note the stance on the take of these species. As noted above, the U.S. has identified that gulper sharks are likely to be at risk due to their life history characteristics, and are currently reviewing whether new management arrangements will be implemented for this group. Future communication with U.S. fisheries managers may then prove useful.

7.1.2d Management and research recommendations from the Workshop on Conservation and Management of Deepwater Chondrichthyan Fishes, New Zealand 2003 (Irvine 2005): Background

A meeting of shark specialists was held in New Zealand from 27–29 November 2003. The meeting was convened within the context of the FAO IPOA-Sharks (FAO 1999) with one of the main aims being the development of recommendations for the conservation and management of deep-sea fisheries (Irvine 2005). The following five requirements for management were recommended by the working group.

- Effective management requires good baseline data and this rarely exists for chondrichthyan fishes and therefore a significant increase in investment in research for this purpose is needed. Although research needs to increase, management should follow the precautionary approach and implement appropriate regulations immediately.
- Ideally, deepwater fisheries should not be initiated until baseline data are obtained from fisheries-independent surveys. Human and funding resource limitations make this approach difficult in many nations, thus managers and scientists need to work in conjunction with fishers to obtain the maximum data for all exploratory fisheries so fish stocks can be monitored.
- Closed fishing areas and marine protected areas are an important fisheries management and biodiversity conservation tool. However, it is important to identify candidate areas that offer the greatest benefit. This requires an understanding of species composition, stock structure and movement patterns. Managers may use this information to determine critical habitat size and location and to decide whether there are any benefits from seasonal closures. Larger areas should be allocated in those areas where collection of this information is not possible, especially if fisheries are not yet established.
- Adequate catch monitoring is essential for effective management. Education programs aimed at managers and stakeholders are required to outline the vulnerability of these fishes compared to other taxa. Workshops can be used to transfer expertise to managers and scientists including through the teaching of appropriate monitoring tools and methods.
- The species composition of the catch is currently impossible to determine if the fish are processed at sea, e.g. by removal of fins, tails and head. Regulations for chondrichthyan fisheries should require the retention of heads, fins and tails and prohibit the landing of fins, skate wings and livers without the accompanying carcass.

In addition, the working group made a number of research recommendations that included data gathering on:

- taxonomy
- life history (e.g. longevity and age-at-maturity)

- reproductive biology (e.g. annual fecundity, maturity/maternity, birth size)
- stock structure (e.g. depth distribution including possible depth-dependent segregation by sex)
- bycatch survivability.

The working group concluded that "*deepwater chondrichthyans may not sustain the current levels of exploitation due to their low fecundity, late attainment of sexual maturity, long life and extended gestation periods (some with a resting stage between pregnancies). Management should follow the precautionary approach and implement regulations immediately*."

Applicability of management arrangements to the SESSF: All of the recommendations made by the 2003 working group are applicable to the SESSF. Of particular note is that the working group recommended that in areas where collection of information on species composition, stock structure and movement patterns is not possible, larger areas should be allocated for closure from fishing. This is particularly important where this information does not already exist or will take an extended period to collect. In addition, the working group recommended that "management should follow the precautionary approach and implement regulations immediately". These two key elements, recommended in 2003, have clear applicability to the current situation in the SESSF for upper-slope gulper sharks.

7.1.2e Mitigation recommendations from the AFMA Chondrichthyan Technical Working Group (CTWG), Australia 2008 (Patterson 2009):

Background

The AFMA Chondrichthyan Technical Working Group (CTWG) met 4–7 November 2008 to discuss mitigating chondrichthyan bycatch in Commonwealth fisheries. Gulper sharks and other dogfishes were discussed and noted as being the highest priority, given their vulnerability to overfishing. The group discussed several mitigation options that would be applicable for trawl and demersal longline (including auto-longline) and rated these options against several criteria. While no one option is a panacea for the problem of bycatch, several options appeared plausible. These options and their rankings for each fishing gear type are given in Appendix 6. Briefly, the options determined for demersal longline include:

- spatial/area and temporal closures
- a reduction in fishing effort
- a reduction in the TAC of the target species
- stricter depth closures
- a prohibition on landings
- bait restrictions
- the use of rusting or corrodible hooks
- the use of rare earth metals/chemical repellents
- a reduction in soak time
- the adoption of better handling practices.

Of these options, several were identified that could be implemented by AFMA immediately. These options include handling practices, depth closures, a reduction in effort and a reduction in the TAC. Handling practices, such as returning captured sharks back to the water as quickly as possible, was noted as an especially desirable option and one that industry would likely readily accept. The other options all required at least some further work and some options (i.e. rare earth metals/chemical repellents; Stoner and Kaimmer 2008) required a great deal more directed research before such a measure could be considered further.

The options determined for trawl were similar to those noted above for demersal longline, with the addition of a few measures. Such measures include:

- gear modifications (i.e. smaller nets, reduced headline length)
- shorter shots (similar to a reduction in soak time).

Applicability of management arrangements to the SESSF:
All recommendations made by the CTWG on mitigating bycatch of gulper sharks are applicable to the SESSF. Indeed, the recommendations were developed with the SESSF specifically in mind. Key recommendations that could be immediately implemented were:

- depth closures
- a reduction in effort
- a reduction in TAC of target species
- the adoption of better handling practices.

7.2 SESSF review of data quality for gulper sharks

Objective 2 Consider the historical identification of Harrisson's dogfish including catch statistics and scientific surveys.

Background
A recent examination of the genus *Centrophorus* in southern Australian waters by White et al. (2008) resulted in the classification of two new species of gulper sharks: *C. westraliensis* and *C. zeehaani*.

C. westraliensis
C. westraliensis had previously been identified as a different colour morph of *C. harrissoni*. However, White et al. (2008) revealed that the two forms were clearly morphologically distinct. *C. westraliensis* is endemic to WA waters from Shark Bay to south of Cape Leeuwin (White et al. 2008), while *C. harrissoni* occurs further east (see Appendix 4).

C. zeehaani
White et al. (2008) indicated that *C. zeehaani* was previously considered to be conspecific with *C. uyato*. However, based on an examination of morphology, it was determined to be a different species, endemic to Australian waters from Forster (NSW) to Shark Bay (WA). *Centrophorus uyato* is now considered not to occur in Australian waters (White et al. 2008).

Noting these two new species and the fact that *C. zeehaani* should replace *C. uyato* in records from Australian waters, the following considerations were taken into account when interpreting catch data from the various sectors of the SESSF, including logbook, ISMP and fishery-independent survey data.

- *C. westraliensis* would occur in catch records from the western section of the GAB and other WA fisheries
- *C. zeehaani* replaces all records of *C. uyato*.

Over the past 35 years there have been a number of fisheries-independent research surveys recording data on gulper sharks. Fishery-dependent surveys have generally been limited to logbook and scientific observer data. Tables 8-11 provide summaries of all reports/publications we identified as including data on gulper sharks from the SESSF. The information sourced from each study was examined in light of recent developments in the SESSF including:

- additional research undertaken by CSIRO
- an FRDC project on rapid assessment of shark species undertaken by PIRVic (Walker et al. 2008)
- data from the ISMP
- CSIRO research characterising the benthic ecosystem in areas closed to provide protection to gulper sharks.

Additional reports were identified during our study, however we were unable to access the raw data for those reports. Thus, they were not included in this report.

7.2.1 Fishery-dependent catch records

7.2.1a Logbook Statistics

On 1 April 2000 the daily logbook system was implemented for the SESSF. A review of logbook records for SESSF sectors revealed only two CAAB codes in use, the family code for all commercial dogfishes (37020000) and the code for Endeavour dogfish (*C. moluccensis*: 37020001). The code 37020000 may include not only all gulper shark species (as shown in

Table 2), but also other species in the family Centrophoridae (e.g. *Deania* spp.), and dogfishes of several genera belonging to other families. Thus, the use of the general dogfish code does not facilitate the accurate determination of species-specific fishery interactions for gulper sharks.

Similarly, although the code for Endeavour dogfish is meant to represent a single species (*C. moluccensis*), previous surveys of how fishers report in the SESSF logbooks indicates that the code for Endeavour dogfish is frequently used as a group code to cover all gulper shark species (*Centrophorus* spp.) (Daley et al. 2002; Walker and Gason 2007). Thus, for the purposes of this report, when the code 37020001 appears in logbook records it is deemed to represent a genus code for *Centrophorus*. The correct code for the genus is 37020902.

The requirement to record all discards was not introduced into the SESSF management arrangements until late 2002. Surveys by Daley et al. (2002) of SESSF skippers revealed that few operators recorded discards prior to the introduction of the 2002 management arrangement. Thus, logbook records prior to 2002 cannot be considered to accurately represent total catch of deepwater sharks, including gulper shark species, in the SESSF. Even now it is unclear how accurately operators record discards.

Given that most gulper shark catch records are imprecise, with multiple species frequently grouped under one category (e.g. Endeavour dogfish), we conclude that current and historical logbook data does not provide a reliable/accurate representation of gulper shark (*Centrophorus* spp.) catch levels in the SESSF. The group codes used are likely to obscure differences in community structure (species composition) and any reductions in population size of the less productive species. Therefore, we determined that the daily logbook records for the SESSF are of little use in determining species-specific gulper shark interactions in their current form.

7.2.1b Observer records – ISMP

CAAB codes identified in ISMP records for gulper sharks are as follows:

- 37020000 (includes species other than gulper sharks)
- 37020001
- 37020009
- 37020010
- 37020011
- 37020902.

Substantial data deficiencies were identified in the scientific observer (ISMP) data sets. Generally, observers used the same CAAB codes, with the same errors noted above for logbook records, when recording interactions between SESSF gear and gulper sharks. This included the use of the generic “Endeavour dogfish” category (37020001) that consisted of three species of gulper sharks grouped together rather than just *C. moluccensis*, the true Endeavour dogfish. Given the difficulties in identifying gulper sharks, and the tendency for observers to use the generic *Centrophorus* spp. CAAB code in their records, it is unlikely that the observer data can be regarded as accurate at the species level and undoubtedly suffers from the same problems of misidentification and species groupings as the commercial logbook data. Such data needs to be interpreted with caution.

We conclude that the code 37020000 used in scientific observer records must be considered as representing catches of unspecified dogfishes which may include species of *Centrophorus*. The code 37020001 cannot be considered as only representing the species *C. moluccensis*, but rather, it should be considered to represent catches of all species within the genus

Centrophorus. The actual code for the genus is 37020902. Similarly, in instances where observers recorded catches against the codes for *C. harrissoni* (37020010) and *C. zeehaani* (37020011), we believe this information can be considered accurate only for *C. zeehaani*, as records for *C. harrissoni* are certainly incorrect given that they were reported by observers outside the range of known distribution (Last and Stevens 2009). In addition, some captures of these two species are likely to have been lumped into either the family (37020000) or genus (37020902) codes. We did note, however, that since 2002, improvements have been made in the way gulper sharks are being recorded by scientific observers. This was largely due to the recommendations by Daley et al. (2002), who identified the paucity of information available on gulper sharks and their vulnerability to overfishing. We believe that once identification and recording skills are improved, that scientific observer data will fulfil its objective of providing a means to validate fishery catch records.

7.2.1c Market records

Deepwater sharks have historically been targeted for their liver oil and carcasses from southern Australia have been landed at markets for at least the last 20 years (Hudson and Knuckey 2007). Hudson and Knuckey (2007) compiled information from shark liver processing operations and from market data to derive estimates of historic deepwater dogfish catches, requiring the use of conversion factors to estimate shark catch weight from shark oil sale data and an assumption that 80-90 percent of deepwater dogfish livers went through a single processor. The AFMA Deepwater Shark Working Group (November 2007), a group formed initially to focus on the mid-slope (>650 m) demersal sharks, broadened its scope in 2007 to include the upper-slope gulper shark species and agreed that the market data broadly reflected historical catch trends. However, these data are of limited use as a time series for the assessment of the status of the resource because of the assumptions required, particularly about the species composition of the catch and the proportion of catch that was processed for liver oil (Fig. 6). Although large numbers of dogfish were caught before 1994, their livers were not utilised for oils and are not included in the processing data presented in Figure 6.

Due to the similar liver oil value of *Centrophorus* spp., livers from these species were generally bundled together and categorised under "Endeavour dogfish". Landings of gulper sharks recorded for liver oil extraction should be considered to represent partial landings at the genus level (37020902). Daley et al. (2002) provides a detailed summary of market data from 1992–2000. We therefore conclude that market records are likely to provide an accurate estimate of the numbers of *Centrophorus* spp. landed for their liver oil during the period 1994–2006. The primary justification for this conclusion is that the liver oil of species of *Centrophorus* have the highest squalene content (67–89 percent) and for this reason are unlikely to be mixed with other species of deepwater shark.

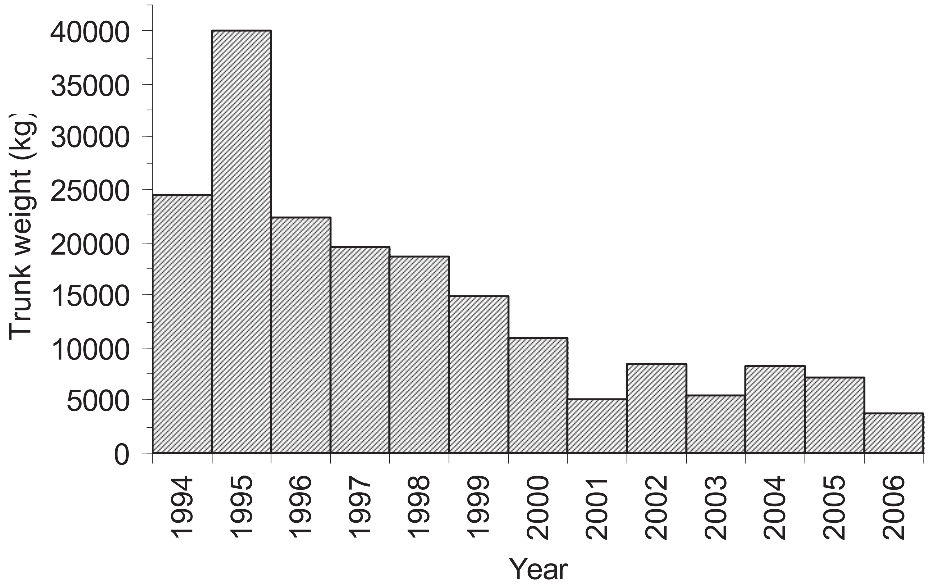

Figure 6. Combined landings of *Centrophorus* spp. recorded by shark liver oil processors in southern Australia. Trunk weights calculated by direct conversion of liver oil to trunks of 1:2 based on a conversion ratio liver oil to livers of 1:1.20 and livers to trunks of 1:1.67.

7.2.2 Fishery-independent catch statistics (scientific reports)

The following section provides a brief review of all major fishery-independent studies carried out in the SESSF. Although not exhaustive, Tables 8-11 provide a sector by sector listing of studies recording catches of *Centrophorus* spp. in the area of the SESSF.

Subsequent to the tables are brief reviews of each of the major studies outlining the key findings relevant to gulper sharks on the upper-slope of the SESSF.

Table 8. Mean catches (kg/hour) of gulper sharks (*Centrophorus* spp.) taken on the NSW upper-slope (200–650 m) by FRV *Kapala* during demersal trawling operations listed in Kapala Cruise Reports 24-117. Values shown are based on reworked datasets. Cen - *Centrophorus* spp., End - Endeavour dogfish, Harr - Harrisson's dogfish, Sth - Southern dogfish. Nets: FT – Fish Trawl; PT - Prawn trawl; HL - headline length (m).

Citation	Title	Survey period	Survey Area	Net-HL	No. Trawls	Trawl hours	End kg/h	Harr kg/h	Sth kg/h	Harr + Sth kg/h	Cen kg/h
Gorman and Graham 1975a	FRV Kapala Cruise Report No. 24	May-June 1975	Sydney - Ulladulla	FT-21m PT-20m	14	25.0	-	-	-	-	147.7
Gorman and Graham 1975b	FRV Kapala Cruise Report No. 25	Sept. 1975	Northern NSW	FT-21m	2	3.0	-	-	-	-	0.0
"	"	July-Sept. 1975	Crowdy Head – Gabo Is.	FT-21m PT-20m	24	42.8	-	-	-	-	126.7
Gorman and Graham 1975c	FRV Kapala Cruise Report No. 26	Oct. 1975	Northern NSW	FT-21m PT-20m	8	15.4	5.0	-	-	0.0	5.0
"	"	Oct. 1975	Cape Hawke - Ulladulla	FT-21m PT-20m	6	12.0	-	-	-	-	103.1
Gorman and Graham 1975d	FRV Kapala Cruise Report No. 28	Dec. 1975	Sydney - Ulladulla	PT-20m	7	12.5	-	-	-	-	102.8
Gorman and Graham 1976a	FRV Kapala Cruise Report No. 30	Apr.-May 1976	Sydney - Newcastle	FT-21m	27	53.0	12.9	-	-	5.0	17.9
Gorman and Graham 1976b	FRV Kapala Cruise Report No. 31	June-July 1976	Ulladulla - Batemans Bay	FT-21m	24	27.8	22.7	-	-	165.4	188.0
"	"	July 1976	Eden – Gabo Is.	FT-21m	3	3.0	0.0	-	-	180.0	180.0
Gorman and Graham 1976c	FRV Kapala Cruise Report No. 33	Oct. 1976	Sydney - Newcastle	FT-21m	24	24.5	35.1	-	-	102.7	137.7
Gorman and Graham 1976d	FRV Kapala Cruise Report No. 34	Nov.-Dec. 1976	Ulladulla - Batemans Bay	FT-21m	23	22.7	2.3	41.7	162.4	204.0	206.4
Gorman and Graham 1977a	FRV Kapala Cruise Report No. 35	Mar. 1977	Eden – Gabo Is.	FT-21m	23	22.0	0.1	20.7	297.7	318.4	318.5
Gorman and Graham 1977b	FRV Kapala Cruise Report No. 37	Apr.-May 1977	Ulladulla - Batemans Bay	FT-21m	22	22.5	1.6	11.1	34.1	45.2	46.8
Gorman and Graham 1977c	FRV Kapala Cruise Report No. 38	May-June 1977	Sydney - Newcastle	FT-21m	23	23.0	31.3	15.0	24.3	39.2	70.6
Gorman and Graham 1977d	FRV Kapala Cruise Report No. 39	July 1977	Eden – Gabo Is.	FT-21m	18	18.0	0.2	47.8	48.3	96.1	96.3
Gorman and Graham 1977e	FRV Kapala Cruise Report No. 40	Aug. 1977	Ulladulla - Batemans Bay	FT-21m	21	21.0	0.1	19.4	121.2	140.6	140.7
Gorman and Graham 1977f	FRV Kapala Cruise Report No. 42	Sept. 1977	Sydney - Newcastle	FT-21m	22	22.0	5.8	13.5	28.8	42.2	48.0
Gorman and Graham 1977g	FRV Kapala Cruise Report No. 43	Oct. 1977	Eden – Gabo Is.	FT-21m	22	22.8	0	65.1	115.3	180.4	180.4
Gorman and Graham 1979	FRV Kapala Cruise Report No. 53	Oct. 1978	Newcastle – Crowdy Head	FT-21m PT-20m	8	7.5	60.6	4.8	0	4.8	65.4

Citation	Title	Survey period	Survey Area	Net-HL	No. Trawls	Trawl hours	End kg/h	Harr kg/h	Sth kg/h	Harr + Sth kg/h	Cen kg/h
Gorman and Graham 1980a	FRV Kapala Cruise Report No. 56	Apr.-May 1979	Wollongong - Ulladulla	FT-56m PT-27m	6	5.7	0.8	8.3	39.2	47.5	48.3
KG data	Unpublished data, Ken Graham, NSW DPI	June 1979	Sydney - Newcastle	FT-21 PT-27m	7	7.8	8.7	16.4	2.9	19.3	28.0
Gorman and Graham 1980b	FRV Kapala Cruise Report No. 57	July 1979	Bermagui - Gabo Is.	FT-21m	22	21.7	0	10.9	24.0	34.8	34.8
Gorman and Graham 1980c	FRV Kapala Cruise Report No. 58	July-Aug. 1979	Port Stephens - Batemans Bay	FT-21 FT-56m	35	59.8	4.5	28.8	30.9	57.9	64.1
Gorman and Graham 1980d	FRV Kapala Cruise Report No. 59	Sept.-Oct. 1979	Port Stephens - Batemans Bay	FT-56 PT-27m	26	37.1	2.2	20.3	17.1	37.4	39.7
Gorman and Graham 1980e	FRV Kapala Cruise Report No. 60	Oct.-Nov. 1979	Ulladulla - Gabo Is.	FT-56m	21	27.5	0.2	6.2	17.6	23.8	24.0
Gorman and Graham 1980f	FRV Kapala Cruise Report No. 61	Dec. 1979	Sydney - Newcastle	PT-27m	7	7.5	2.9	44.1	0.4	44.6	47.4
Gorman and Graham 1980g	FRV Kapala Cruise Report No. 64	June 1980	Eden - Gabo Is.	FT-56m	14	16.2	0	9.5	11.4	20.9	20.9
Gorman and Graham 1981a	FRV Kapala Cruise Report No. 65	June-July 1980	Port Stephens - Batemans Bay	FT-56m	34	37.2	5.9	7.2	37.9	45.1	51.0
Gorman and Graham 1981b	FRV Kapala Cruise Report No. 67	Dec. 1980	Sydney - Newcastle	PT-24m	3	3.3	28.3	10.0	0	10.0	38.3
Gorman and Graham 1981c	FRV Kapala Cruise Report No. 68	Mar. 1981	Wollongong - Jervis Bay	FT-56m	4	4.8	0	0	0	0	0
Gorman and Graham 1981d	FRV Kapala Cruise Report No. 69	Mar. 1981	Port Stephens - Newcastle	FT-56m	2	2.0	95.0	0	0	0	95.0
Gorman and Graham 1981e	FRV Kapala Cruise Report No. 70	May 1981	Wollongong - Gabo Is.	FT-56m	18	18.3	1.4	4.2	35.9	40.1	41.6
Gorman and Graham 1981f	FRV Kapala Cruise Report No. 71	June 1981	Bermagui - Gabo Is.	FT-56m	20	20.0	0.5	10.3	8.4	18.6	19.1
Gorman and Graham 1981g	FRV Kapala Cruise Report No. 72	July 1981	Port Stephens - Bermagui	FT-56m	17	17.0	12.6	13.5	23.4	36.9	49.6
Gorman and Graham 1982a	FRV Kapala Cruise Report No. 73	Aug.-Sept. 1981	Sydney - Gabo Is.	FT-56m	18	18.0	0	11.6	80.8	92.4	92.4
Gorman and Graham 1982b	FRV Kapala Cruise Report No. 74	Oct.-Dec. 1981	Sydney - Batemans Bay	FT-56m	3	4.0	6.0	33.3	5.0	38.3	44.3
Gorman and Graham 1982c	FRV Kapala Cruise Report No. 75	Feb.-Mar. 1982	Port Stephens - Wollongong	FT-56m PT-27m	4	3.9	9.7	0	0	0	9.7
Gorman and Graham 1982d	FRV Kapala Cruise Report No. 77	May-June 1982	Newcastle - Ulladulla	FT-56m PT-27m	4	5.8	6.0	0	1.2	1.2	7.2
Gorman and Graham 1982e	FRV Kapala Cruise Report No. 79	July 1982	Northern NSW	FT-56m	2	3.0	5.0	0	0	0	5.0
“	“	Aug. 1982	SE of Gabo Is.	FT-56m	3	3.0	0	0	0	0	0
Gorman and Graham 1983a	FRV Kapala Cruise Report No. 82	Oct.-Dec. 1982	Sydney – Gabo Is.	PT-27m	8	8.8	0.7	6.9	5.3	12.2	12.9

Citation	Title	Survey period	Survey Area	Net-HL	No. Trawls	Trawl hours	End kg/h	Harr kg/h	Sth kg/h	Harr + Sth kg/h	Cen kg/h
Gorman and Graham 1983b	FRV Kapala Cruise Report No. 83	May 1983	Sydney - Wollongong	PT-27m	3	3.8	0	4.0	0	4.0	4.0
Gorman and Graham 1984a	FRV Kapala Cruise Report No. 86	Oct.-Dec. 1983	Sydney - Wollongong	PT-27m	3	5.8	0.5	0.7	1.4	2.1	2.6
Gorman and Graham 1985a	FRV Kapala Cruise Report No. 90	Aug. 1984	Ulladulla - Eden	FT-21m	5	9.4	0.2	12.3	42.8	55.1	55.3
Gorman and Graham 1985b	FRV Kapala Cruise Report No. 91	Sept. 1984	Sydney - Newcastle	PT-27m	4	7.9	0.6	2.1	0	2.1	2.8
Graham and Gorman 1988	FRV Kapala Cruise Report No. 103	July-Dec. 1987	Sydney – Jervis Bay	FT-30m PT-27m	6	8.6	2.9	8.0	3.5	11.5	14.4
Graham 1989b	FRV Kapala Cruise Report No. 106	Feb.-Mar. 1989	Shoalhaven – Gabo Is.	FT-3 m	13	11.9	0	0.2	1.1	1.3	1.3
Graham et al. 1997	FRV Kapala Cruise Report No. 117	May-June 1996	Sydney - Newcastle	FT-21m	24	24.0	0.6	0	0	0	0.6
“	FRV Kapala Cruise Report No. 117	July 1996	Eden – Gabo Is.	FT-21m	18	18.0	0	0	0.1	0.1	0.1
“	FRV Kapala Cruise Report No. 117	Aug.-Sept. 1996	Ulladulla – Batemans Bay	FT-21m	24	24.0	0	0.1	0.5	0.6	0.6
“	FRV Kapala Cruise Report No. 117	Sept.-Oct. 1996	Sydney – Newcastle	FT-21m	24	24.0	0.4	0.4	0	0.4	0.8
“	FRV Kapala Cruise Report No. 117	Oct. 1996	Eden – Gabo Is.	FT-21m	21	21.0	0	0	0	0	0
“	FRV Kapala Cruise Report No. 117	Nov.-Dec. 1996	Ulladulla – Batemans Bay	FT-21m	24	24.0	0	0.2	1.1	1.3	1.3
“	FRV Kapala Cruise Report No. 117	Apr. 1996	Eden – Gabo Is.	FT-21m	24	24.0	0	0	0	0	0
“	FRV Kapala Cruise Report No. 117	May 1997	Ulladulla – Batemans Bay	FT-21m	7	7.0	0.1	0	1.3	1.3	1.4

Table 9. Summary reports of mean catches (kg/hour) of gulper sharks (*Centrophorus* spp.) taken on the NSW upper-slope (200–650 m) by FRV *Kapala* during trawling operations listed in Kapala Cruise Reports 24-117. Cen - *Centrophorus* spp., End - Endeavour dogfish, Harr - Harrisson's dogfish, Sth - Southern dogfish. Methods: FT – Fish Trawl; PT - Prawn trawl; HL - headline length (m). For standard errors, see relevant citation.

Citation	Title	Survey period	Survey Area	Net-HL	No. Trawls	Trawl hours	End kg/h	Harr kg/h	Sth kg/h	Harr + Sth kg/h	Cen kg/h
Andrew et al. (1997) part 1	Changes after twenty years in relative abundance and size composition of commercial fisheries caught during fishery independent surveys on SEF trawl grounds.	1976-77 1996-97	Newcastle – Gabo Is. All depths	FT-21m	246 159	-	12.3 0.2	-	-	126.3 0.4	138.6 0.6
Andrew et al. (1997) part 2	As above	1976-77 1979-81 1996-97	As above 300-525 m only	FT-21m FT-21&56m FT-21m	130 150 81	-	18.0 2.3 <0.1	37.6 17.4 <0.1	146.3 26.7 <0.1	169.9 44.1 <0.1	187.9 47.4 0.1
Hodgson et al. (1997)	Kapala Upper Slope Survey data report.	1976-77 1996-97	As per Table 8	As above	-	-	-	-	-	-	-
Graham et al. (2001) part 1	Changes in relative abundance of sharks and rays on Australian SEF trawl grounds after twenty years of fishing.	1976-77 1979-81 1996-97	Newcastle – Gabo Is. All depths	As above	246 159	-	12.3 0.2	-	-	126.3 0.4	138.6 0.6
Graham et al. (2001) part 2	As above	1976-77 1979-81 1996-97	As above 300-525 m only	As above	130 150 81	-	18.0 2.3 <0.1	37.6 17.4 <0.1	146.3 26.7 <0.1	169.9 44.1 <0.1	187.9 47.4 0.1

Table 10. Mean catches (kg/hour) of gulper sharks (*Centrophorus* spp.) taken on the NSW mid-slope (650–1000 m) by FRV *Kapala* during demersal trawling operations listed in Kapala Cruise Reports 85-107. Values shown are based on reworked datasets. Cen - *Centrophorus* spp., End - Endeavour dogfish, Harr - Harrisson's dogfish, Sth - Southern dogfish. Nets: FT – Fish Trawl; PT - Prawn trawl; HL - headline length (m).

Citation	Title	Survey period	Survey Area	Net-HL	No. Trawls	Trawl hours	End kg/h	Harr kg/h	Sth kg/h	Harr + Sth kg/h	Cen kg/h
Gorman and Graham (1983c)	FRV Kapala Cruise Report No. 85	July-Aug. 1983	Sydney - Jervis Bay	FT-56m	7	14.5	0	1.0	0	1.0	1.0
Gorman and Graham (1984a)	FRV Kapala Cruise Report No. 86	Sept.-Nov. 1983	Port Stephens - Gabo Is.	FT-21m	15	26.8	0	1.8	0	1.8	1.8
Gorman and Graham (1984b)	FRV Kapala Cruise Report No. 88	Mar.-June 1984	Sydney - Gabo Is.	FT-21m PT-27m	20	39.7	0	39.7	2.0	41.7	41.7
Gorman and Graham (1985a)	FRV Kapala Cruise Report No. 90	July-Aug. 1984	Crowdy Head - Batemans Bay	FT-21m	5	9.3	0	3.0	0	3.0	3.0
Gorman and Graham (1985c)	FRV Kapala Cruise Report No. 92	Sept.-Nov. 1984	Sydney - Gabo Is.	FT-56m	20	39.9	0	18.5	2.2	20.7	20.7
Graham and Gorman (1988)	FRV Kapala Cruise Report No. 103	Feb. 1987	Cape Hawke - Batemans Bay	FT-30m	3	6.6	0	2.3	0	2.3	2.3
Graham and Gorman (1988)	FRV Kapala Cruise Report No. 103	Aug.-Dec. 1987	Cape Hawke - Batemans Bay	FT-30m	30	57.0	0	3.5	1.0	4.5	4.5
Graham (1988)	FRV Kapala Cruise Report No. 104	Feb.-Sept. 1988	Crowdy Head - Batemans Bay	FT-30m	32	50.5	0	0.3	0.1	0.4	0.5
Graham (1989a)	FRV Kapala Cruise Report No. 105	Dec. 1988	Port Stephens - Batemans Bay	FT-30m PT-21m	6	10.8	0	0	0	0	0
Graham (1990)	FRV Kapala Cruise Report No. 107	Apr.-Sept. 1989	Crowdy Head - Batemans Bay	FT-30m	35	48.8	0	9.7	4.7	14.4	14.4

Table 11. Mean catches (kg/hour) of gulper sharks (*Centrophorus* spp.) taken during research surveys in the area of the SESSF. Cen - *Centrophorus* spp., End - Endeavour dogfish, Harr - Harrisson's dogfish, Sth - Southern dogfish. Methods: FT – Fish Trawl; PT - Prawn trawl; HL - headline length (m).

Citation	Title	Survey period	Survey Area	Method-HL	No. Trawls	Trawl hours	End kg/h	Harr kg/h	Sth kg/h	Harr + Sth kg/h	Cen kg/h
May and Blaber (1989)	Benthic and pelagic fish biomass of the upper continental slope off eastern Tasmania	1984-85 Mar.-Apr.	East of Maria island, Tasmania 700-1200 m	FT-35.5m	41	N/A	N/A	N/A	N/A	N/A	N/A
Bulman et al. (1989) Bulman et al. (1994)	1988 Orange Roughy Survey Orange roughy surveys, 1988 and 1989	Mar.-Apr. 1988	South-western Victoria & Tasmania 700-1200 m	FT-35.5m	135 154	N/A	N/A	N/A	N/A	N/A	N/A
Newton and Klaer (1991)	Deep-sea demersal fisheries resources of the Great Australian Bight: A multi-vessel survey	July-Sept. 1988	Great Australian Bight	FT-various 35-50m	128	67	-	-	5.75	30.62 (Squaliformes)	
Liggins (1997)	Integrated scientific monitoring program for the SEF in 1996 (NSW component).	1996	NSW coast	FT-various	N/A	Total estimated catch of *Centrophorus* spp. in the SET in 1996 was 15 t +/-4 t					
Bax and Knuckey (2004)	Evaluation of selectivity in the South-East fishery to determine its sustainable yield	Aug.-Oct. 1999	Montagu Is. – Tathra	FT-35m	19	28.5	0	0	0.3	0.3	0.3
"	"	Feb.-Nov. 1999-2000	Montagu Is. – Tathra	FT-35m	41	114.5	0	0.1	0.2	0.3	0.3
"	"	Feb.-July 2001	Montagu Is. – Tathra	FT-35m	32	103.0	0	0.1	0.1	0.2	0.2
Klaer (2001)	Steam trawl catches from south-eastern Australia from 1918 to 1957: trends in catch rates and species composition.	1918–23 1937–43 1952–57	Various SESSF	Various	64,371	N/A	N/A	N/A	N/A	N/A	N/A
Daley et al. (2002)	Catch analysis and productivity of the deepwater dogfish resource in southern Australia.	2002	Data review - Various SESSF	Various	N/A	Reported average catch rate of 50.5 kg/h for *Centrophorus* spp. taken in 7 trawls off Gabo Is. in an average of 447 m. – by the FRV Soela in 1985. *C. harrissoni* and *C. zeehaani* have the highest catch rates at 35.3 k/h and 8.1 kg/h respectively.					
Walker et al. (2006)	SESSF scalefish abundance and spatial distributional trends from available ISMP data	1994-95 2000-06	Various SESSF	Various	N/A	Total estimated catch of *Centrophorus* spp. in the SESSF from 2000-06 was 56 t, consisting of: *C. moluccensis* – 30.2 t +/-5.6 *C. zeehaani* – 11.8 t +/-2 *C. harrissoni* – 0.17 +/-0.07 Unidentified *Centrophorus* spp. – 14 t +/-2.8					
Walker and Gason (2007)	Shark and other chondrichthyan byproduct and bycatch estimation in the Southern and Eastern Scalefish and shark fishery	1994-2006	Various SESSF	Various	N/A						

7.2.2a Commonwealth Trawl Sector
FRV Kapala surveys (Tables 8-10)

Key literature:
- Gorman and Graham (1975-1984)
- Graham (1989b)
- Andrew et al. (1997)
- Graham et al. (1997)
- Hodgson et al. (1997)
- Graham et al. (2001).

Background:
The New South Wales (NSW) Department of Primary Industries (DPI) carried out exploratory trawling (fishery-independent) on the upper-slope habitat (200–650 m depth) off NSW, using the same vessel (FRV *Kapala*), trawl gear and similar sampling protocols in 1976–77 (during the early years of commercial exploitation) and again in 1996–97 (Graham et al. 2001). Surveys were also done over a depth range of 300–525 m on the same grounds in 1979–81 (Andrew et al. 1997). Details of the 1996–97 survey are presented in Graham et al. (1997) and a more comprehensive analysis of the differences among surveys (relative abundance and size composition) and depths between the 1976–77 and 1996–97 periods was reported for important elasmobranchs (including gulper sharks) by Andrew et al. (1997). Graham et al. (2001) provided an analysis of the relative abundances of 15 species (or species groups) of sharks (including gulper sharks) and rays on the NSW upper-slope from the three survey periods between 1976 and 1997. The results described changes in relative abundance after 20 years of trawling on previously unexploited stocks.

Major findings:
- Graham et al. (2001) reported a dramatic decline in the abundance of sharks and rays from the NSW upper-slope over the 20 year period (1976–77 to 1996–97).
- Among all species, gulper sharks (*Centrophorus* spp.) showed the greatest change in catch rate in the 20 years since the inception of commercial trawling.
- In the 1976–77 surveys the mean catch-per-unit-effort for all gulper sharks was reported as 139 kg/hr; (126.3 kg/hr for Harrisson's and Southern dogfish combined; 12.3 kg/hr for Endeavour dogfish; Andrew et al. 1997; Graham et al. 2001).
- In the 1996-97 surveys, the catch-per-unit-effort for gulper sharks was reported as 0.6 kg/hr (0.4 kg/hr and 0.2 kg/hr for Harrisson's and Southern and Endeavour dogfish, respectively).
- The reported declines in the relative abundances of *C. harrissoni*, *C. moluccensis* and *C. uyato* (now *C. zeehaani*) off the upper-slope of NSW between 1976–77 and 1996–97 represent declines of 98.4–99.7 percent (Graham et al. 2001).
- In 1976–77, a total of 173 tows yielded over 5000 kg of *C. harrissoni*, equivalent to over 1100 sharks (see length-frequency data, Graham et al. 1997).
- In contrast, only 15 kg (a total of 8 sharks) of *C. harrissoni* were caught in 165 tows in the 1996–97 surveys (Graham et al. 1997). In 1976–77, *C. harrissoni* occurred in nearly 50 percent of the tows (84 of 173), in comparison with only three percent of tows (5 of 165) in 1996–97 (Graham et al. 1997).

Data accuracy:
The accuracy of species identification was assessed through the descriptions in the reports by Gorman and Graham (1975–84), by validation of specimens of *C. harrissoni* and *C. uyato* (now

C. zeehaani) that were deposited in the Australian Museum by the authors (Reg. Nos. I.19376-003 and I.19376-004) and through discussions with K. Graham (NSW DPI) who was aboard all but one of the FRV *Kapala* research cruises from 1973 to 1997, a period of approximately 25 years.

Data accuracy was further assessed by extracting the raw data from the FRV *Kapala* Cruise Reports (Gorman and Graham 1975–84, Graham 1989b, Graham et al. 1997) and comparing them to the reworked data sets (provided by K. Graham, NSW DPI) used in the preparation of the FRDC Project 96/139 Final Report (Andrew et al. 1997) and Graham et al. (2001). We reviewed the species identifications, the depth and location of each trawl, and extracted data from the upper-slope habitat. This reworked data are provided in Tables 8 and 9 with additional cruise data from waters deeper than the upper-slope (>650 m) presented in Table 10 for comparison. Although the data presented in Tables 8 and 9 were not standardised for the various types of trawl gear used, we assumed, as did Andrew et al. (1997), that the fishing power of the trawls used during the 1979–81 and 1996–97 surveys was equal to or greater than that of the trawls used in the 1976–77 surveys.

Following the assessment of available data, the following conclusions were drawn.

- Gulper shark catches reported until mid-1975 (Cruise Report Nos. 24, 25) were not separated to species level; all “Endeavour” dogfish should be considered to represent catches at the genus level (*Centrophorus* spp.).
- From mid-1975, Endeavour dogfish (*C. moluccensis*) was recorded separately from the other two species. However, as a precautionary measure, these should be combined with catches recorded as Harrisson's and Southern dogfish, despite the fact that catches recorded for these two species are likely to be more accurate than previous identifications.
- *C. harrissoni* and *C. zeehaani* were reliably separated from Cruise Report No. 34 onwards (Gorman and Graham 1976d). Thus, identification of the three species of gulper sharks from Cruise Report No. 34 are considered to be accurate (near the start of the 20 year survey period comparison) and reported by Andrew et al. (1997) and Graham et al. (2001).
- Specimens of gulper sharks collected during the FRV *Kapala* surveys and deposited at the Australian Museum were validated as being correctly identified as *C. harrissoni* and *C. zeehaani*.
- Early *Kapala* data analysed by Andrew et al. (1997) and Graham et al. (2001) were reworked by the authors in that numbers and weights were reassessed by going back through the raw data sheets, checking species lists for each trawl and recalculating weights from improved length/weight conversion factors.
- Thus, the data presented in Andrew et al. (1997) and Graham et al. (2001) are considered more accurate than the summary data provided in the early Cruise Report Nos. 30–43 (Gorman and Graham 1976a–1977g).
- We conclude that the data gathered and analysed is accurate and provides a realistic summary of the status of gulper shark species in the areas surveyed.

Conclusion:

We agree with the position taken by Andrew et al. (1997) and Graham et al. (2001) that there is a strong basis for inferring that sustained fishing over the 20 year period from 1976–77 to 1996–97 is the most likely and predominant cause of the observed changes (declines of between 98.4–99.7 percent) in the relative abundance and size structure of gulper shark species on the NSW upper-slope, noting the assumptions made in Graham et al. (2001). In addition, we note that Graham et al. (2001) also reported severe and very severe declines in the abundances of several other species/groups over the 20 year sampling period (1976/77 and 1996/97). These include the following:

- 97.3% decline – Greeneye dogshark
- 83.2% decline – Skates
- 96.4% decline – Silver ghost shark
- 91.4% decline – Sharpnose seven-gill shark.

FRV *Soela* surveys (Table 11)
Key literature:

- May and Blaber (1989).

Background:
The CSIRO's FRV *Soela* began a southern-temperate-fish program in 1984 to study the biology and ecology of fishes on the upper-slope off Maria Island on the east coast of Tasmania (Blaber 1984; Young and Blaber 1986; Young et al. 1987; May and Blaber 1989). The area surveyed was along the 420 to 550 m depth contour. The main aim of the project was to quantify the entire fish community by combining estimates derived from both demersal and pelagic trawling. The project provided data on the abundance, and bi-monthly and diurnal variations in the biomass of fishes captured in commercial-sized fish trawls.

Major findings:

- A total of 4 867 205 fish of 115 species were collected during the surveys.
- Eight species of squaliform sharks were caught during the study.
- *C. uyato* (now *C. zeehaani*) was identified as being present in demersal trawls 5 percent of the time.
- No absolute numbers or weights caught were provided in the report.

Data accuracy:
It seems likely that the identifications provided in this study are correct given that voucher specimens have been validated. The only change would be listing the primary species of gulper shark captured as *C. zeehaani* rather than *C. uyato*.

Conclusion:
This study surveyed a small area of eastern Tasmania but encountered a wide variety of species. The presence of *C. zeehaani* in catches five percent of the time suggest that this species was sparsely distributed on the upper-slope habitat off eastern Tasmania in 1988.

CSIRO catch analysis (Table 11)
Key literature:

- Daley et al. (2002).

Background:
The study assessed market, fishery-dependent (logbooks, industry questionnaire/port visits, observer data) and fishery-independent (FRV *Soela*, FRV *Southern Surveyor*, FRV *Kapala*) data from a range of sources. Much of the information reviewed by Daley et al. (2002) was from sources predating 2000. The aims of the study were as follows:

- Estimate the annual retained and discarded catch of deepwater dogfish by geographical area and depth strata within the Southern Shark, Western Australian Shark, South East Trawl, Great Australian Bight Trawl and dropline fisheries.

- Examine dogfish catch and effort data by region and depth strata for changes in catch rate with time.
- Determine population structure (size distributions and sex ratio) of principal dogfish species by region and depth strata.
- Assess the biological productivity of the major upper and mid-slope dogfish species from data on age, growth and reproduction.
- Obtain qualitative estimates of the mortality of the discarded component of the dogfish catch.
- Survey wholesale markets, retail markets and processors for information on species composition and marketing practices.
- Estimate the annual dogfish catch by analysing wholesale market sales data.

Major findings:

- The total landed catch of dogfish (Squaliformes) in the year 2000 was estimated to be 1500 t (whole weight).
- Fishery logbook data alone was determined as inadequate to assess stocks of dogfish for management purposes.
- Very limited species-specific data were available with common names frequently used.
- Discards were seldom recorded in logbooks.
- Weights recorded in logbooks were unclear in terms of whether they were live weights or carcass weights (processed).
- Some improvements in dogfish data quality occurred in 2000, including better recording of gulper shark species separate from dogfishes.
- Fishery, market and independent survey data indicated that some upper-slope species have been depleted.
- Upper-slope species (primarily *Centrophorus* spp.) were targeted in the Southern Shark Fishery for their livers from 1993–98. Targeting subsequently ceased when catch rates rapidly declined. The carcasses were generally discarded because of high mercury content. Upper-slope species remain a valuable byproduct in the South East Trawl Fishery where most (70–90 percent) of the catch is taken off southern NSW.
- Since 1986, catch rates of upper-slope dogfish by SET trawlers declined by 75 percent.
- Industry logbook data from 1993–99 indicated that catches of *Centrophorus* spp. off NSW decreased by 59 percent during that period. These reduced catches were reflected in Sydney Fish Market data for Endeavour dogfishes (note that this should be interpreted as a genus code: *Centrophorus* spp.) which showed a significant decline in sales from 1993–98 (discussed in section 7.2.1c above).
- The decline in the *Centrophorus* spp. market volumes was correlated with the overall decline in dogfish catches in the SET off southern NSW.
- The relatively high price paid for Endeavour dogfish carcasses and for their livers indicates that demand has remained steady and the reduced volume was because of declining abundance.
- Commercial fishery, market and research data suggest upper-slope dogfish, particularly *Centrophorus* spp., have declined off NSW, Victoria and South Australia.
- It is unlikely that catch restrictions alone would enable *Centrophorus* spp. to recover.
- Other measures such as seasonal closures or closed areas may be considered as part of recovery programs.
- Recovery measures need to be of an appropriate scale as species differ in their depth and topographic distribution and there is evidence that some species migrate. It would be difficult to develop effective recovery plans without further study of movements and critical habitat.

Data accuracy:

- Data accuracy was assessed by accessing raw data used in the report and validating them against raw datasets held by BRS and other entities (e.g. AFMA, Ocean Oils).
- Data used in the report were found to be accurate and analysed appropriately.

Following the assessment of available data, the following conclusions were drawn:

- Individuals recorded as *C. uyato* in the report should be considered *C. zeehaani*.

Conclusion:
The report by Daley et al. (2002) provides a comprehensive review of the commercial fishery, market and research data pre-2001. We believe that the recommendations by Daley et al. (2002) are valid and based on reliable, accurate and comprehensive information up until 2001. However, it should be noted that datasets (excluding logbook data) have been improved since the writing of the report by Daley et al. (2002) and include the following:

- Additional ISMP data, which now extend from 1994 to 2007 in the CTS (formerly the SETF) and from 2000 to 2007 in the GABT Sector (see Walker and Gason 2007).
- Age, growth and reproductive data compiled for a PhD (Irvine 2004) and MSc thesis (Whiteley 2004).

7.2.2b Great Australian Bight (GAB) research

Multi-vessel trawl surveys (Table 11)
Key literature:

- Newton and Klaer (1991).

Background:
The aims of the survey were to:

- assess the distribution of commercial and 'potentially commercial' fish species across the GAB continental slope, and gain some insight into their comparative catch rates.
- increase knowledge of the trawlable status of grounds across the GAB.
- investigate the biology of the major commercial species.
- investigate the composition of the demersal slope fish community.

Major findings:

- Approximately 13 species of dogfish (including species of gulper shark) were caught using demersal trawl across the entire GAB from the south-western tip of Western Australia (Cape Leeuwin) to south of Kangaroo Island, with the highest catches recorded from the central sector of the GAB.
- 1854 kg of mixed dogfish (including gulper sharks) were taken from 128 trawl shots for a total of 67 hours of trawling.
- The maximum catch rate for the mixed dogfish category was 240 kg/hr, with a mean of approximately 30 kg/hr.
- Commercial dogfish (including gulper sharks) were taken at all depths sampled (400 to 1200 m) but were predominantly collected from depths of 500 to 1100 m.
- Gulper sharks caught were recorded as 'Endeavour dogfish' (*C. moluccensis)*.
- 'Endeavour dogfish' were one of the three dominant species of 'dogfish' caught and occurred in depths from 300-1100 m, with catches peaking at 400 m.

Data accuracy:
Data accuracy was assessed by accessing raw data used in the report and validating them against raw datasets held by BRS. The accuracy of the identification of Endeavour dogfish (*C. moluccensis*) in the surveys is questionable, as this species has never been definitively recorded from the south coast of Australia. Validated distributions of *C. moluccensis* extend down the east coast of NSW to about Gabo Island but are unlikely to extend further south or west. During the FRV *Kapala* surveys (Gorman and Graham 1975–84) relatively large quantities of *C. moluccensis* were caught off Ulladulla in the first 1976 survey, but only a few individuals were taken in the later 1976–77 surveys, and only two specimens off Gabo Island in 1977. None was caught south of Batemans Bay in the ensuing 20 years (Graham et al. 2001). On the west coast of Australia, *C moluccensis* has only been recorded as far south as Perth (Last and Stevens 2009).

Following the assessment of available data, the following conclusions were drawn:

- It is highly likely that the generic recording name 'Endeavour dogfish' used by Newton and Klaer (1991) was erroneously ascribed to *C. moluccensis*, which does not occur in the study area.
- Given the known distributions of gulper sharks in Australia's southern waters, the catches recorded as Endeavour dogfish (*C. moluccensis*) in the GAB are likely to be mostly *C. zeehaani* with possibly some *C. westraliensis* from the western GABT.

Conclusion:
The study area for these surveys covered almost the entire area of the GAB fishery using industry vessels and trawl gear. The study established that dogfish (including gulper sharks) were mainly taken in depths of 500–1100 m and had a mean catch rate of approximately 30 kg/hr. No species specific information was provided in the report. However, we were able to access the original database for this report and extracted the records under the species code "Endeavour dogfish". As noted above, this is likely to be an incorrect identification and is most likely *C. westraliensis* and *C. zeehaani*. We determined from the database that 385.3 kg of *C. westraliensis* and *C. zeehaani* combined were caught at a rate of 5.75 kg/hour across the GAB during the survey period.

7.2.2c Gillnet, Hook and Trap (GHAT) Sector

Monitoring Database (Table 11)
Key literature:

- Walker and Gason (2005).

Background:
The report presents summary monitoring data collected from the former Southern Shark Fishery for the period 1970–2002, the former South East Non-Trawl Fishery 1997–2002, and from the GHAT sector for 2003 and 2004. It also includes data on GHAT quota species from state-managed fisheries.

Major findings:

- Data for gulper sharks is presented at the generic 'dogfish' category level, combining all species of dogfish and gulper sharks.
- The highest recorded landings of dogfish were taken between 1990 and 1994, with a peak of 383 t in 1992 (Walker and Gason 2005), and are provided in Figure 7 below.
- Few 'dogfish' were recorded in catches after 1997.

- Detailed catches by state can be found in the report.

Data accuracy:
- Data accuracy was assessed by comparing the findings in the report against raw datasets held by BRS and AFMA.
- Catches are only recorded as a ‘dogfish’ category that includes many species of squalids, including gulper sharks.
- No species specific inferences can be made.
- Prior to 1985, limited information was recorded in any form for ‘dogfish’.

Following the assessment of available data, the following conclusions were drawn:
- Catches of ‘dogfish’ declined sharply prior to the basket quota and trip limits being introduced in the SESSF in 2000 and 2003.
- Highest catches were taken in the years 1992–94.
- 95 percent of the catch was recorded by three vessels; two from South Australia (SA) and one from Victoria.
- The SA vessels were targeting *C. zeehaani*. Independent identification of the species taken, involving specimens being collected by AFMA and identified by the CSIRO (P. Last and J. Stevens), were confirmed as primarily consisting of *C. uyato* (now *C. zeehaani*). Specifically, *C. zeehaani* was estimated as comprising 88 percent of the catch.

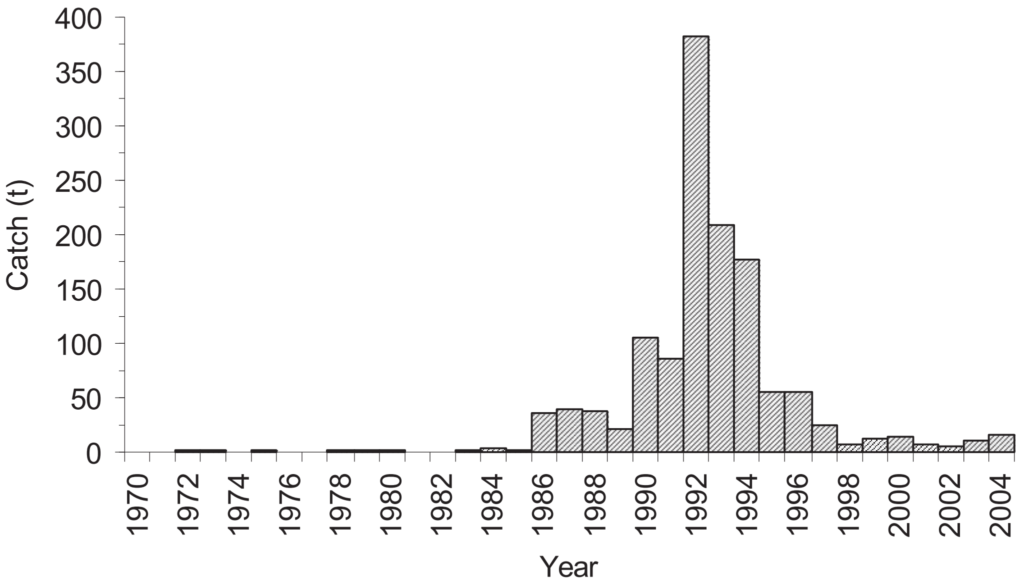

Figure 7. Total catch of ‘dogfish’ (including gulper sharks) from state (1970–2002) and Commonwealth (2002–2004) licensed vessels (Walker and Gason 2005).

Conclusion:
Although the data sets are incomplete, they provide a general overview of the level of catches taken from 1992 onwards, with peak catches being taken in the early 1990s.

7.2.2d SESSF wide research

Integrated Scientific Monitoring Program (ISMP) (Table 11)

Key literature:

- Liggins (1997)
- Walker et al. (2006)
- Walker and Gason (2007).

Background:

The relevant aims of the reports were to:

Liggins (1997)

- conduct at-sea monitoring of fishing activities from specified ports (Ulladulla and Eden), including the collection of data on the total (retained and discarded) catches, the size composition of retained and discarded catches and the collection of biological information.

Walker et al. (2006)

- estimate retained and discarded catch of scalefish bycatch species from available ISMP observer data and fisher-logbook effort data for the period 1994–2005
- estimate spatial and temporal trends in relative abundance of target, byproduct and bycatch scalefish species using available observer data from the ISMP for 1994–2005.

Walker and Gason (2007)

- summarise retained and discarded catches and length-frequency data on sharks, rays and holocephalans from the ISMP database
- estimate spatial and temporal trends in catches and abundance of sharks, rays and holocephalans using data from the ISMP database and from the SEF catch and effort database
- identify implications and requirements for species management, fishery bycatch action plans and FAO's IPOA-Sharks
- evaluate impact on the ISMP data and catch and effort data collection following adoption of the field guide to sharks and rays caught in Australian waters.

Major findings:

Liggins (1997)

- Estimates of annual retained catch of *Centrophorus* spp. was 23 t (± 5 t SE) with no discarding of this species group recorded.
- 65 percent of the total estimated catch came from the survey area off Ulladulla while the remaining 35 percent came from off Eden.
- *Centrophorus* spp. were the 29th most abundant species in retained catches during the study period.
- Estimates of other squalid (dogfish) species retained during the study (*Deania* spp. and *Squalus megalops*) totalled 379 t (± 314 t SE) and 213 t (± 41 t SE), respectively.
- Estimates of other squalid (dogfish) species discarded during the study (*Deania* spp. and *Squalus megalops*), totalled 63 t (± 62 t SE) and 101 t (± 27 t SE), respectively.
- 95 percent of the *Deania* spp. caught were taken off Eden, with only two percent taken off Ulladulla.
- 79 percent of *Squalus megalops* caught were taken off Eden, with only 21 percent taken off Ulladulla.

Walker et al. (2006) and Walker and Gason (2007)

- Risk of future population decline from the effects of fishing was classified as 'high', 'medium', or 'low'; this was determined from standardised CPUE trend analysis based on post-2000 decline.

- Gulper shark species (*Centrophorus* spp.) were identified as being at 'high' and 'medium' risk from fishing.
- Analysis for the gulper sharks, mostly Endeavour dogfish (*C. moluccensis*) and Southern dogfish (*C. uyato*, now *C. zeehaani*), with negligible quantities of Harrisson's dogfish (*C. harrissoni*), and Leafscale gulper shark (*C. squamosus*), indicated that they are at a higher risk in the eastern region than in the western region of the SET Fishery (note: no justification provided in the report).
- Reported that an estimated 56 220 kg of gulper sharks were caught in the SESSF during the seven year period from 2000 to 2006 (approximately 8031 kg/year), and consisted of 30 197 kg of *C. moluccensis*, 11 826 of *C. uyato* (now *C. zeehaani*), 169 kg of *C. harrissoni*, 33 kg of *C. squamosus* and 13 995 kg of unidentified gulper sharks (*Centrophorus* spp.) (for standard errors see Walker and Gason 2007).
- Found very low catch rates of gulper sharks per tow in all sectors of the SESSF.
- Identified gulper sharks (*Centrophorus* spp.) as requiring stock rehabilitation.
- Analysis of pooled data indicated that the total population of *Centrophorus* spp. is relatively stable at a low level.
- Indication that most of the depletion occurred before the ISMP began.
- No information was available (due to species identification problems) on whether the least abundant species (*C. harrissoni* and *C. squamosus*) are continuing to decline.

Data accuracy:
Data accuracy was assessed by accessing raw data used in the report and validating them against raw datasets held by BRS and AFMA. Observers encountered difficulties separating gulper sharks to the species level, thus data were grouped to the genus level for analysis (*Centrophorus* spp.). However, some data in the reports by Walker et al. (2006) and Walker and Gason (2007) are presented at the species level. Of the total number of gulper sharks observed caught during the ISMP sampling period, almost a quarter were reported at the genus level (*Centrophorus* spp.), thereby introducing substantial possible error for the rarer species such as *C. harrissoni* and *C. squamosus*. In addition, it is likely that the estimated catch of *C. moluccensis* was actually *C. zeehaani* due to the known distribution of these two species. Similarly, *C. harrissoni* is thought not to occur west of Tasmania.

Following the assessment of available data, the following conclusions were drawn:

- Identifications of *C. moluccensis* are likely to be incorrect due to the known distribution of this species and are most likely to be *C. zeehaani* and/or *C. harrissoni*. However, as this cannot be confirmed, the estimated catches of *C. moluccensis* in the report should be considered at the genus level (*Centrophorus* spp.).
- *Centrophorus* spp. were more abundant on the upper-slope off Ulladulla than Eden.
- Individuals recorded as *C. uyato* should be considered as *C. zeehaani*.
- If the species-specific data are used for *C. harrissoni* and *C. squamosus*, then caution should be taken when interpreting catch data in the reports by Walker et al. (2006) and Walker and Gason (2007) due to the large portion (approximately 25 percent of total gulper shark catch) of individuals identified only to the genus level (*Centrophorus* spp.), and the relatively high estimated catch of *C. moluccensis* that is likely to be *C. zeehaani* but may contain other species.

Conclusion:
We support the findings detailed in the report by Walker and Gason (2007) that call for a stock rebuilding strategy to be urgently developed and implemented for gulper sharks (*Centrophorus*

spp.). Other conclusions relating to gulper sharks cannot be supported due to the lack of species resolution (misidentification of species).

7.3 SESSF data investigation for gulper sharks

Objective 3 Investigate and improve estimates on the extent and nature of actual interactions with Harrisson's dogfish and other similar upper-slope gulper sharks in all sectors of Australia's SESSF.

7.3.1 Data investigation

7.3.1a Logbooks

Examination of logbook records from each sector of the SESSF identified two categories of entries that included landings of gulper sharks. These were CAAB codes 37020000 and 37020001. The code 37020000 represents landings for all commercial dogfishes (Table 2), while the CAAB code 37020001 is considered to be a genus code for *Centrophorus* for the purposes of our study due to the lack of consistency in its use, both as a genus and species code (*C. moluccensis*) across the SESSF (Daley et al. 2002). Table 12 provides a breakdown of catches recorded in logbooks under CAAB codes 37020000 and 37020001 by depth and fishing sector. The majority of catches were recorded from the upper-slope habitat for the CTS, GHAT and ECDWT Sectors, while only 21.3 percent was recorded from the upper-slope in the GAB Sector.

Table 12. Percent total catch recorded in logbooks as codes 37020000 and 37020001, by depth and sector. Dates in brackets represent the period of logbook records available. Records for the ECDWT are for code 37020000 only.

Sector	<200 m Combined	200-650 m Combined	>650 m Combined	200-650 m 37 020 001 only
CTS (1985-08)	12.7	56.7	30.6	84.0
GAB (1987-08)	77.1	21.3	1.6	74.1
GHAT (1988-08)	12.1	83.1	4.8	91.6
ECDWT (2000-08)	0	88.7	11.3	N/A

Commonwealth Trawl Sector (CTS)

Effort. In 2007, relative fishing effort was greatest in areas off Portland, NW Tasmania, and from Eden to eastern Bass Strait (Larcombe and Begg 2008). Review of historical fishing effort distribution (Fig. 8) revealed a similar pattern to that shown in Larcombe and Begg (2008). Over the period 1985 to 2008, 47.8 percent (680 585 hrs) of the total trawl effort in the CTS (1 423 858 hrs) occurred in depths less than 200 m, while 40.7 percent (579 693 hrs) was recorded on the upper-slope (200-650 m), and only 11.5 percent (163 580 hrs) in waters deeper than 650 m. Over the period 1985 to 2008, the percentage of total effort on the upper-slope increased until 1999, before gradually decreasing until 2006 (Fig. 9). In 2007, 43.6 percent (17 360 hrs) of trawl effort was recorded on the upper-slope (Fig. 9).

Catch. The reported catches of sharks under the CAAB code 37020000 that includes all dogfishes (including gulper sharks) in the CTS since 1985 is shown in Figure 10 as whole weight (raw annual catches are provided in Appendix 7). Since 1985, only 12.7 percent of the total catches of sharks under the codes 37020000 and 37020001 combined have been taken from waters less than 200 m deep, while 56.7 and 30.6 percent were reported from waters 200–650 m and waters greater than 650 m deep, respectively (Table 12). However, since catches began to be recorded under the code 37020001 in 1999–2000, 84 percent of catches were recorded from the upper-slope (200–650 m) (Fig. 11).

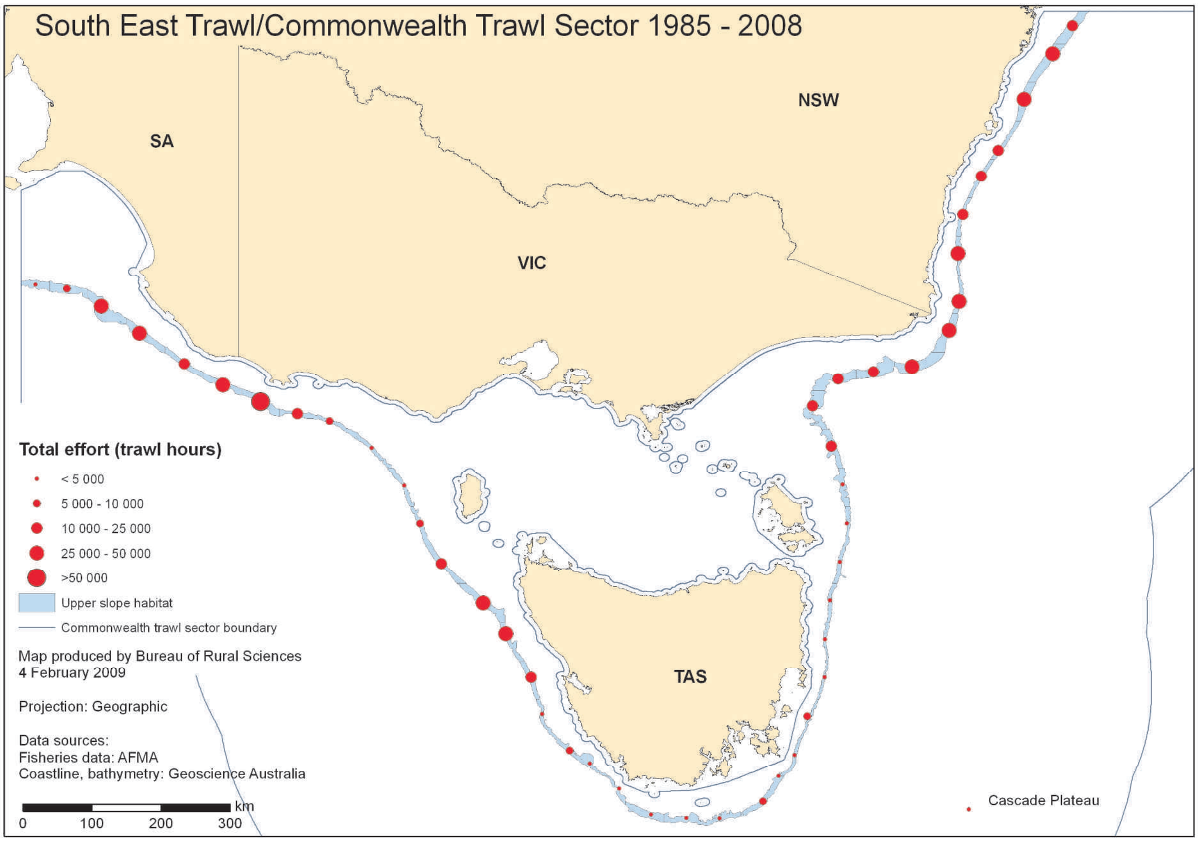

Figure 8. Aggregated total effort (hours trawled) recorded in daily logbooks on the Commonwealth Trawl Sector upper-slope habitat from 1985 to 2008.

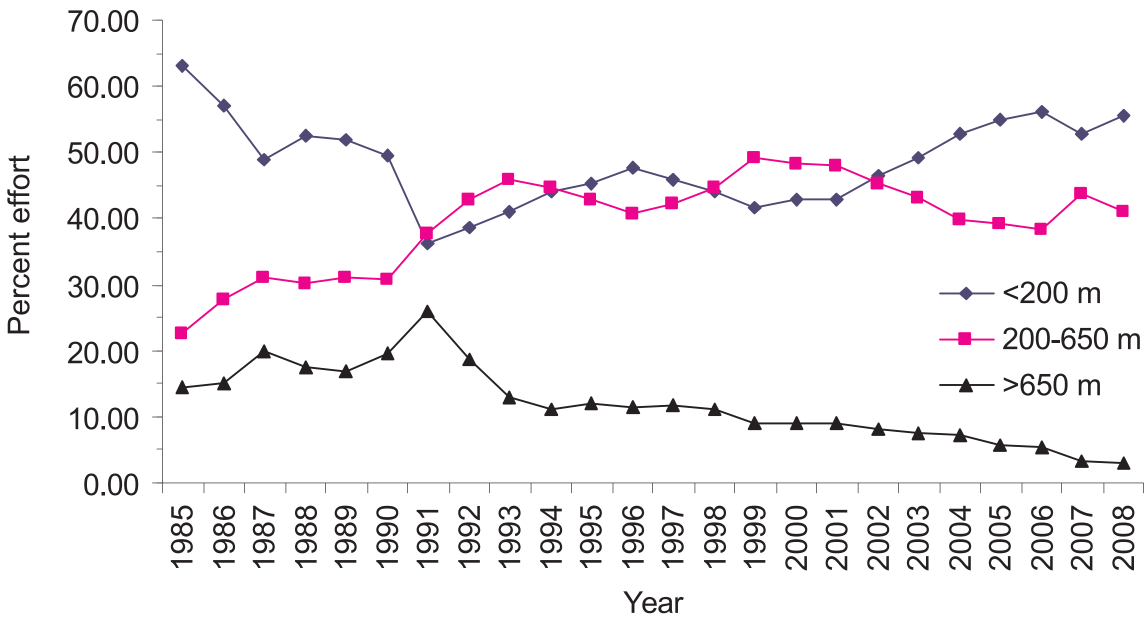

Figure 9. Commonwealth Trawl Sector annual percentage effort (hours trawled) recorded in daily logbooks by depth zone from 1985 to 2008.

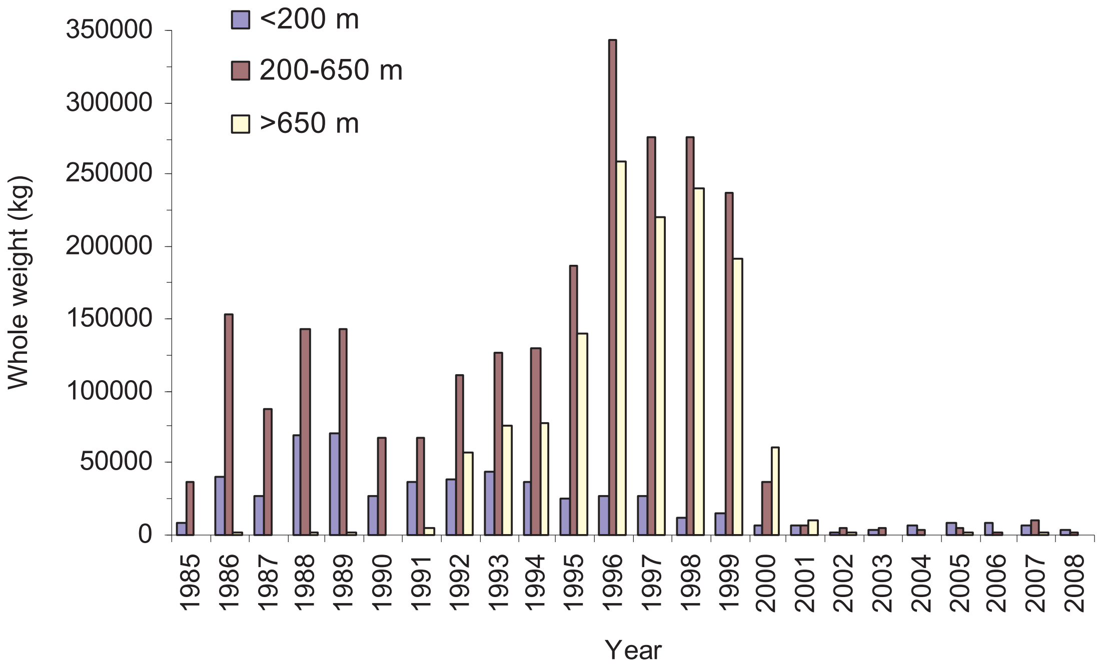

Figure 10. Commonwealth Trawl Sector total catches (kg whole weight) reported in logbooks under the code 37020000 (for all commercial dogfishes including gulper sharks).

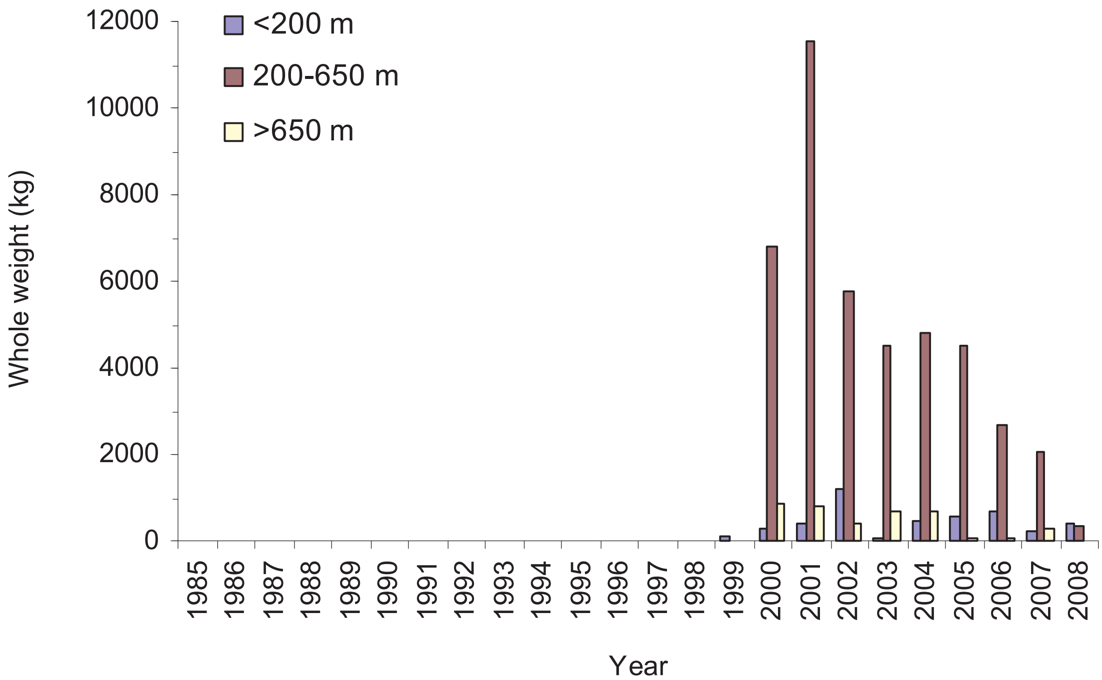

Figure 11. Commonwealth Trawl Sector total catches (kg whole weight) reported in logbooks under the code 37020001, but interpreted to represent *C. moluccensis* (Endeavour dogfish), *C. harrissoni* (Harrisson's dogfish) and *C. zeehaani* (Southern dogfish).

The catch distribution of the CAAB code 37020000 (including all commercial dogfishes and gulper sharks) as recorded in daily logbooks from 1985 to 2008 shows the greatest catches were reported from NSW (Fig. 12). Compared to the NW coast of Tasmania and the coast off western Victoria that had similarly high total effort (Fig. 8), the NSW catch is disproportionately high. However, due to the lack of species resolution in logbook reporting data, we are unable to interpret these data further.

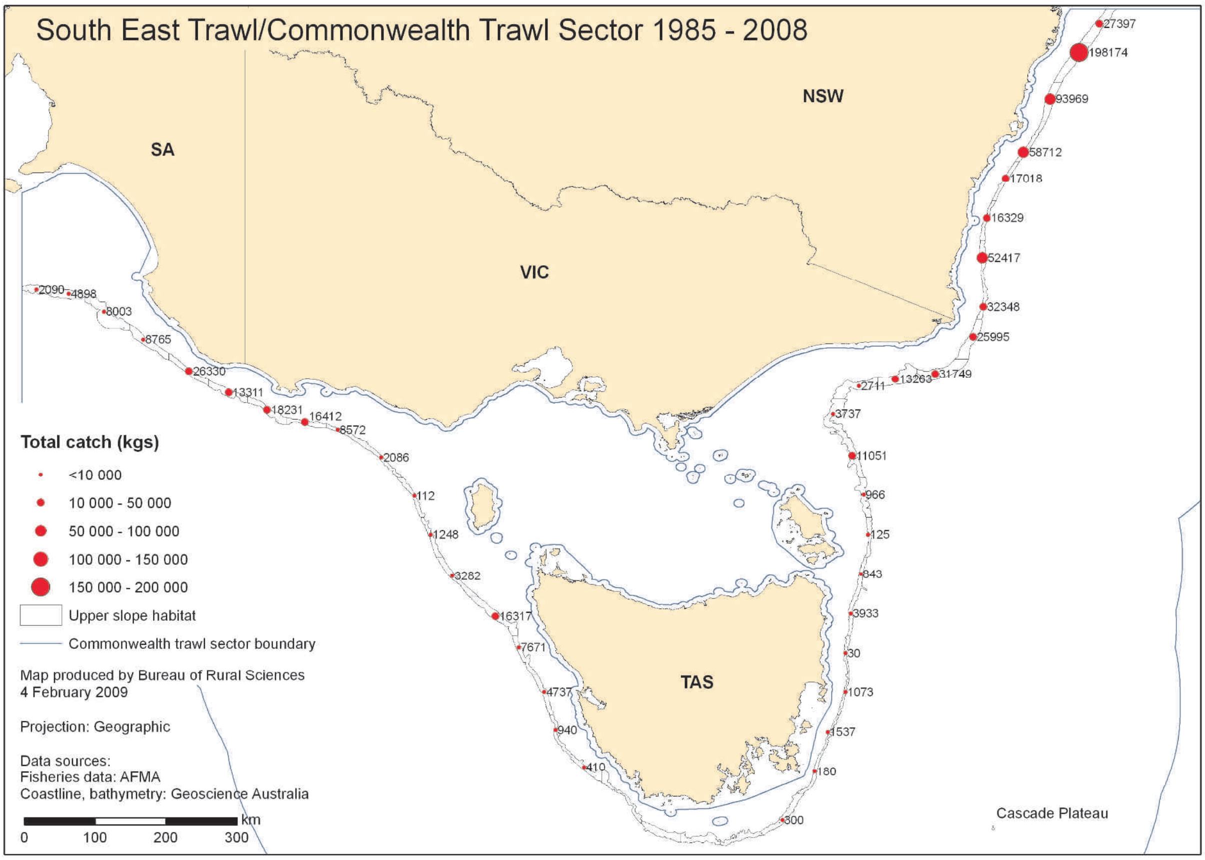

Figure 12. Catch distribution of all commercial dogfishes (CAAB codes 37020000 and 37020001; including gulper sharks) recorded in daily logbooks for the Commonwealth Trawl Sector upper-slope habitat from 1985 to 2008.

Great Australian Bight (GAB) Trawl Sector
Effort. Relative fishing effort has historically been highest in the centre of the Great Australian Bight and off Kangaroo Island, South Australia, with little or no effort recorded from the western GAB Sector (Fig. 13).

Catch. The reported catches of sharks under the CAAB code 37020000 (that includes all commercial dogfishes and gulper sharks) in the GAB since 1985 are shown in Figure 14 as whole weight (raw annual catches are provided in Appendix 8). Since 1985, 77.1 percent of the total catches of sharks under the codes 37020000 and 37020001 combined, have been taken from waters less than 200 m deep, while 21.3 and 1.6 percent were taken from waters 200–650 m and waters greater than 650 m deep, respectively (Table 12). However, since catches began to be recorded under the code 37020001 in 1999–00, 74.1 percent of catches recorded were from the upper-slope (200–650 m) (Fig. 15).

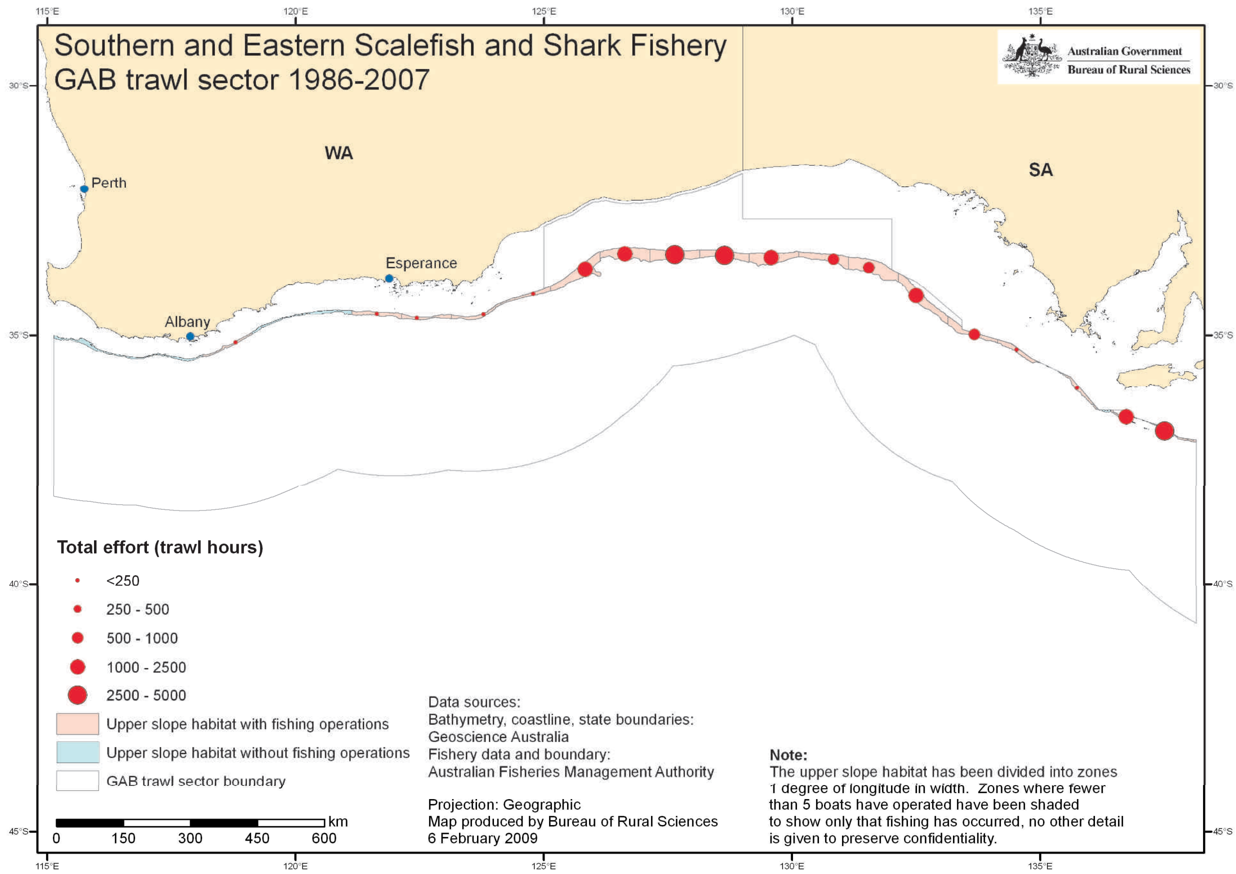

Figure 13. Fishing effort on the upper-slope habitat recorded in daily logbooks, by one degree grid for the Great Australian Bight Trawl Sector in 2000–08.

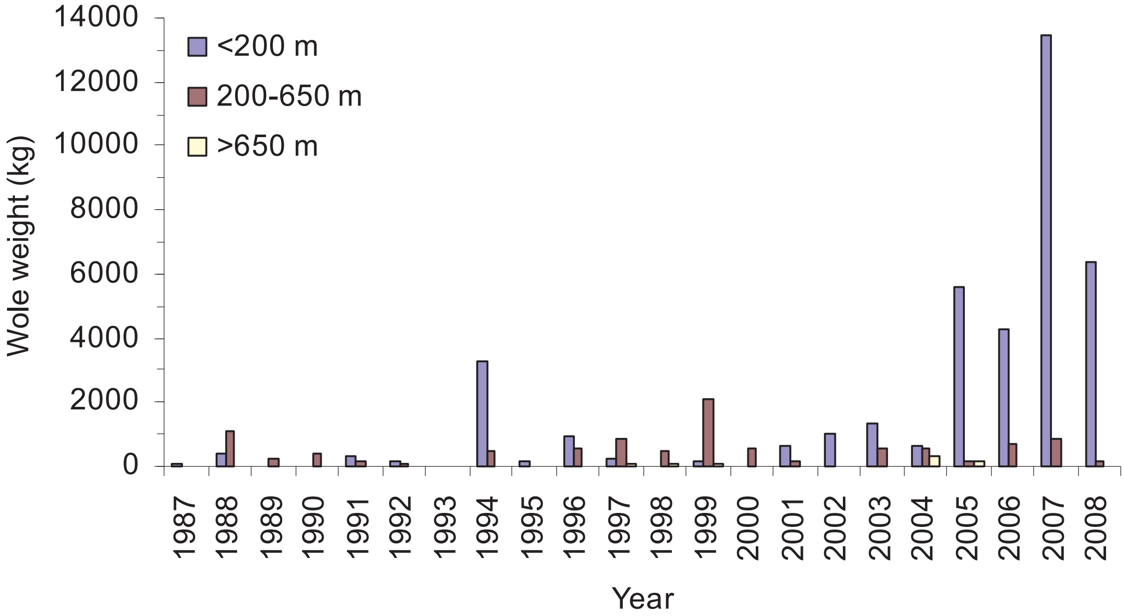

Figure 14. Great Australian Bight Trawl Sector total catches (kg whole weight) reported in logbooks under the code 37020000 for all commercial dogfishes including gulper sharks.

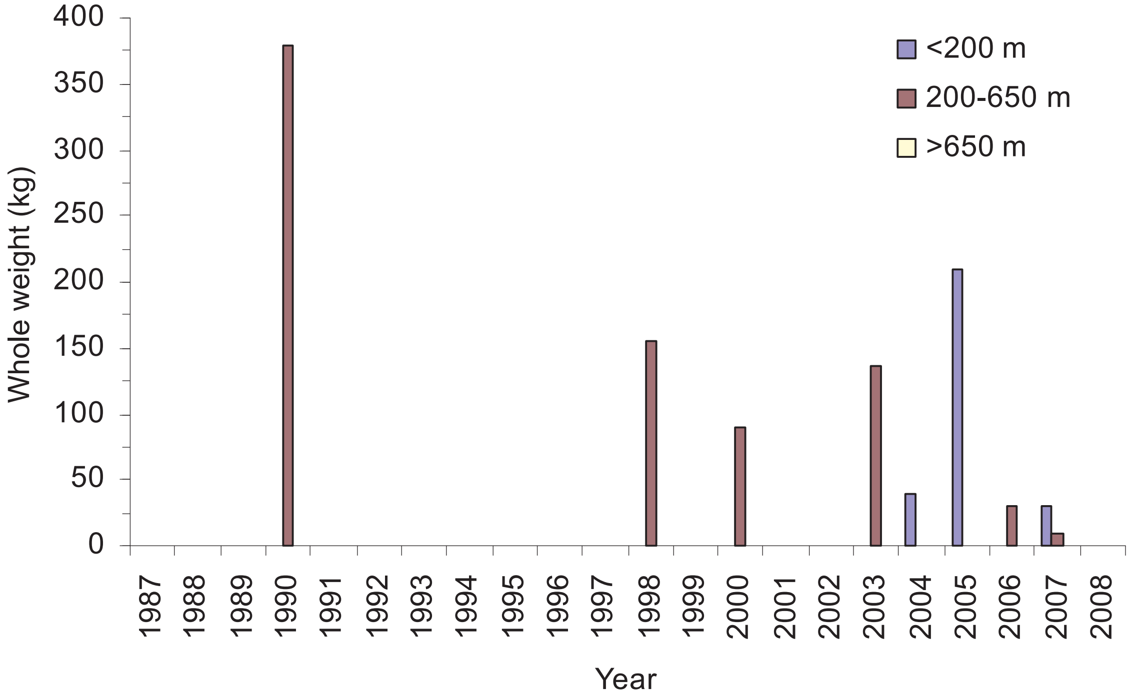

Figure 15. Great Australian Bight Trawl Sector total catches (kg whole weight) reported in logbooks under the code 37020001, interpreted to represent *C. zeehaani* and possibly *C. westraliensis*.

Catches reported under the code 37020000, that includes all commercial dogfishes including gulper sharks, recorded in logbooks from 1988 to 2008 are presented in Figure 16. Due to data confidentiality reasons (less than five vessels operating in a given area) data is presented for three areas only. However, relatively small catches were reported from most of the GAB except the far western zone (Fig. 16). Due to the lack of species resolution in logbook reporting data, and the sporadic nature of interactions, we are unable to interpret these data further.

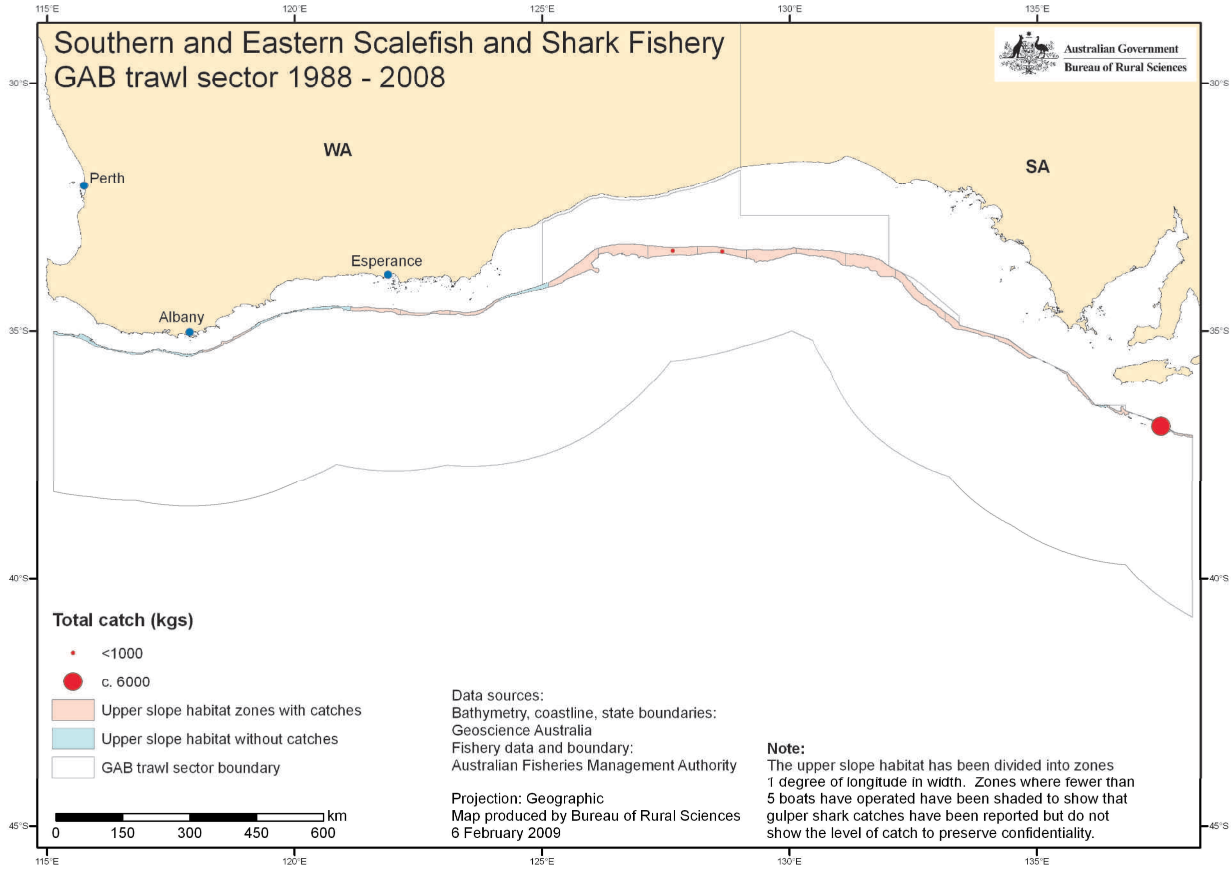

Figure 16. Catch distribution of all commercial dogfishes (CAAB codes 37020000 and 37020001; including gulper sharks) recorded in daily logbooks for the Great Australian Trawl Sector upper-slope habitat (1985–2008).

Gillnet, Hook and Trap (GHAT) Sector
Includes the Scalefish and Shark Hook Sectors, and the former South-East Non-Trawl Fishery and Southern Shark Fishery.
Effort. In 2007, only two areas received fishing effort, east of St Helens and south-east of Hobart (Figs. 17, 18). Effort in the hook sector of the GHAT rose sharply from 665,000 hooks set in 2001 to 8 504 902 in 2004 and 8 967 241 in 2006. Effort decreased in 2007 with 6 732 100 hooks set, a decrease of approximately 25 percent from 2006 (Larcombe and Begg 2008). The majority of this effort occurs on the upper-slope habitat (Fig. 17).

Catch. The catches of sharks reported under the dogfish code (37020000) in the GHAT since 1985 are shown in Figure 19 as whole weight (raw annual catches are provided in Appendix 8). The increase in recorded catches in 1997 reflects the fact that the Commonwealth assumed management responsibility for deepwater sharks from state agencies. Since 1985, only 12.1 percent of the total catches of sharks under the codes 37020000 and 37020001 combined have been taken from waters less than 200 m deep, while 83.1 and 4.8 percent were taken from waters 200–650 m and waters greater than 650 m deep, respectively (Table 12). However, since catches began to be recorded under the code 37020001 in 1999–2000, 91.6 percent of catches were recorded from the upper-slope (200–650 m) (Fig. 20). As with the CTS and GABT Sector, logbook records do not accurately report catches at the species level and are therefore not discussed further.

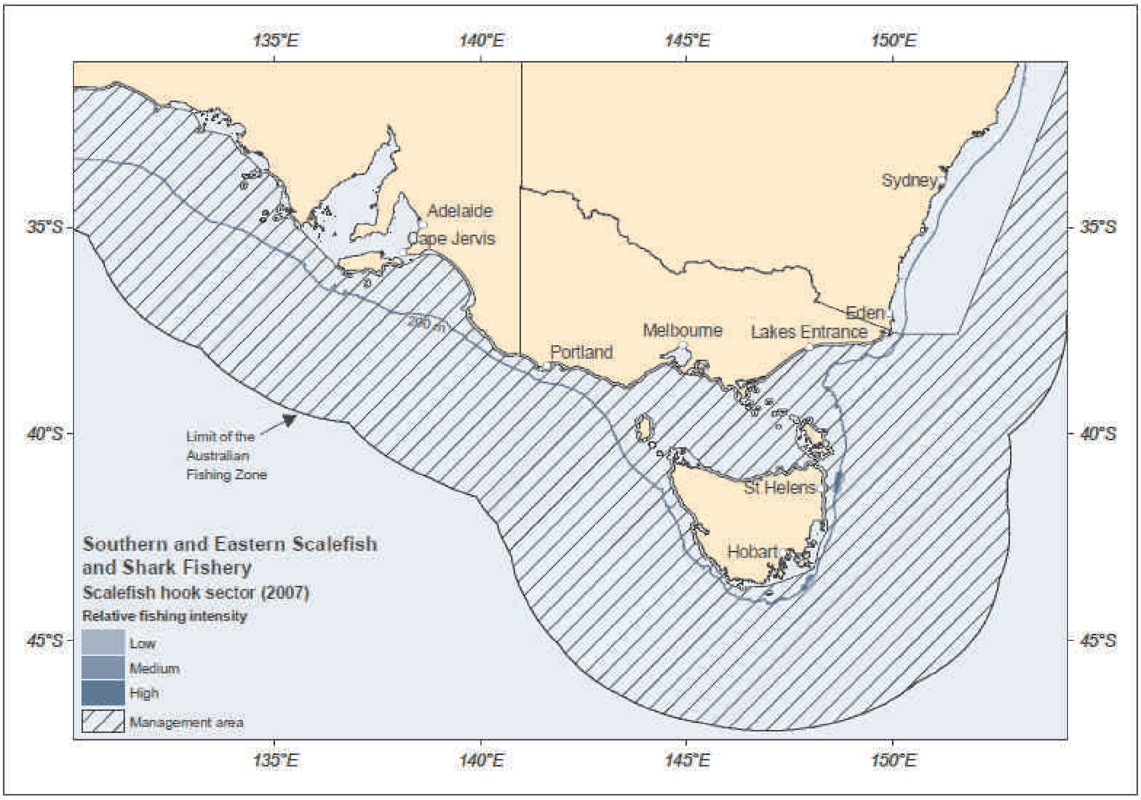

Figure 17. Relative fishing intensity for the Scalefish Hook Sector in 2007 (Larcombe and Begg 2008).

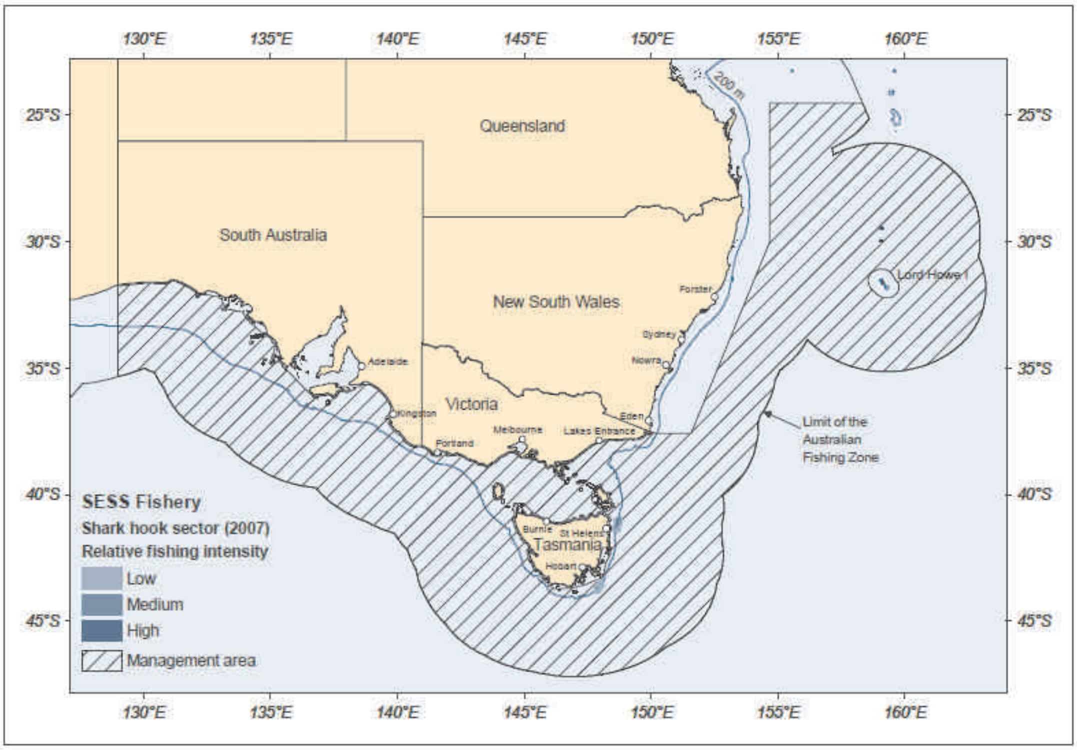

Figure 18. Relative fishing intensity for the Shark Hook Sector in 2007 (Larcombe and Begg 2008).

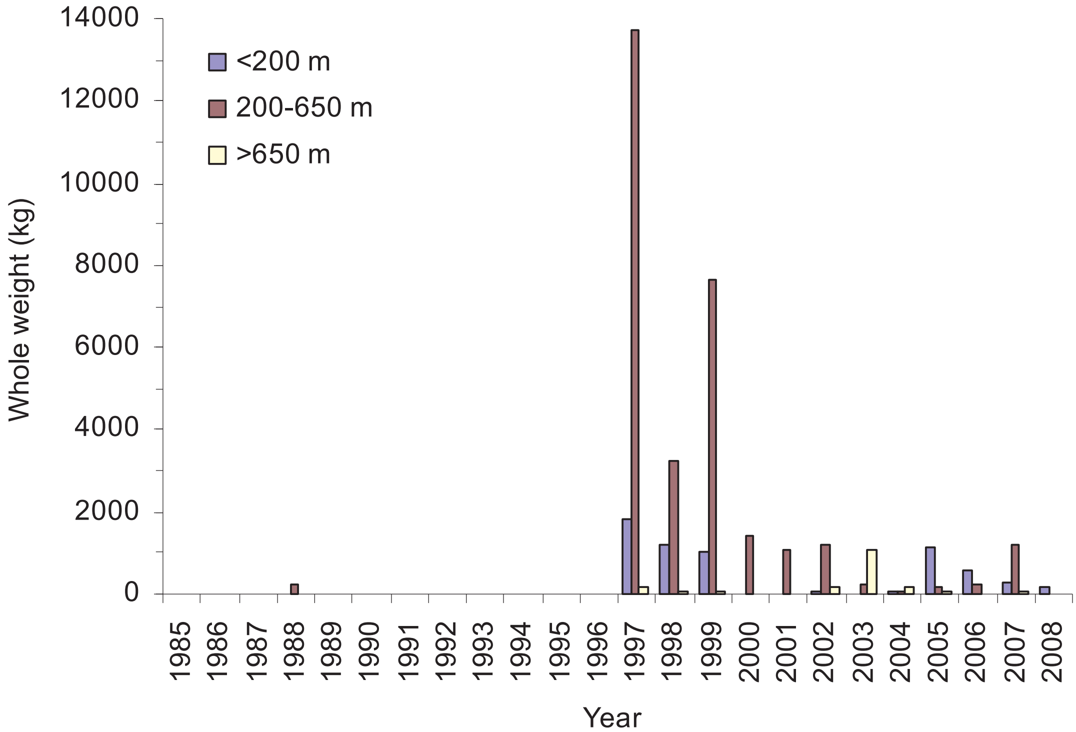

Figure 19. Gillnet, Hook and Trap Sector total catches (kg whole weight) reported in logbooks under the code 37020000 for all commercial dogfishes including gulper sharks.

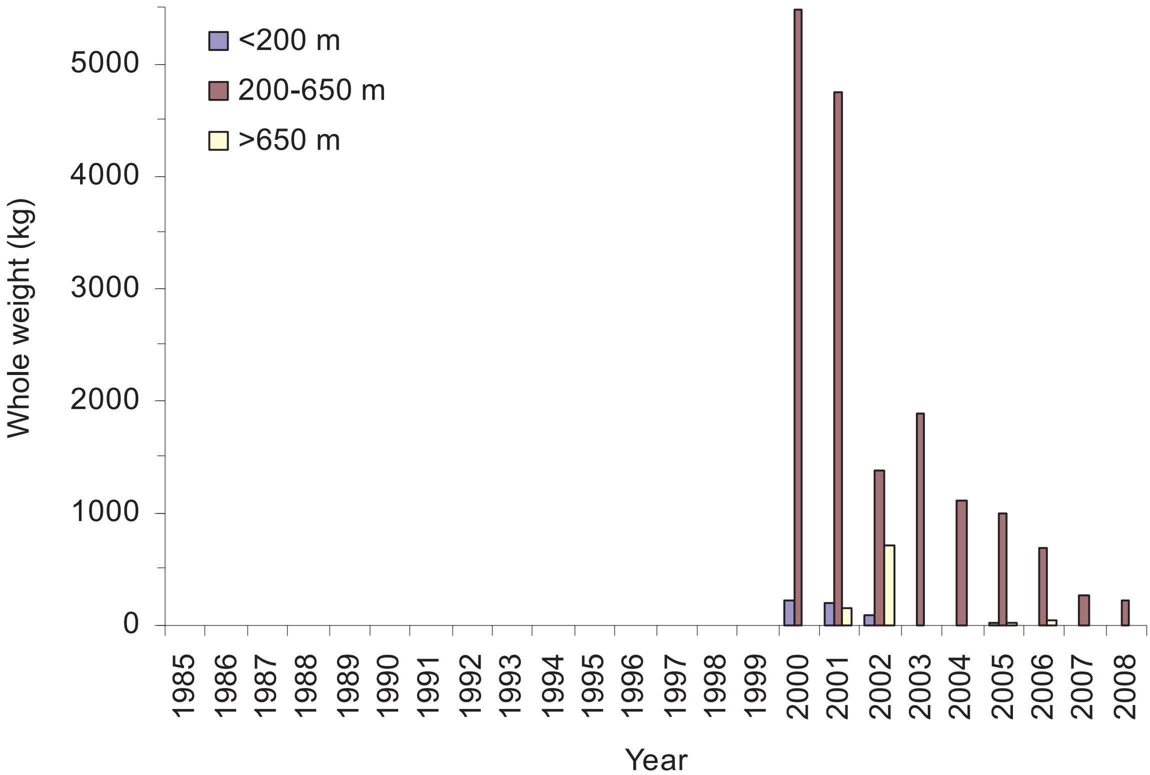

Figure 20. Gillnet, Hook and Trap Sector total catches (kg whole weight) reported in logbooks under the code 37020001, interpreted to represent all *Centrophorus* spp.

East Coast Deep Water Trawl (ECDWT) Sector

Effort. Limited fishing effort has occurred in the ECDWT since 2003 and only three vessels have reported effort in logbooks where gulper shark catches were reported. Due to confidentiality reasons (less than five vessels operating), the location of this effort cannot be reported. However, due to the relatively small area of upper-slope habitat open to trawling by Commonwealth concession holders in the ECDWT, this is not considered detrimental to this study.

Catch. Catches of sharks in the ECDWT Sector since 2000, reported under the code 37020000 that includes all dogfishes (including gulper sharks) are shown in Table 13 as whole weight. Since 2000, 88.7 percent of the total landings of sharks under the code 37020000 have been taken from waters 200–650 m deep, while the remaining 11.3 percent were taken from waters greater than 650 m deep (Table 12). Waters shallower than 200 m have been closed to fishing in the ECDWT since December 2004.

Table 13. Total catches (kg whole weight retained and discarded) of deepwater sharks (including gulper sharks) from the ECDWT (2000–08), from logbooks (CAAB code 37020000). *Confidential data, less than five vessels operating.

Year	<200 m	200-650 m	>650 m
2000	0	1450	0
2001	0	265	0
2002	0	0	0
2003	0	2639	0
2004	*	*	*
2005	*	*	*
2006	*	*	*
2007	*	*	*
2008	*	*	*

7.3.1b Integrated Scientific Monitoring Program (ISMP) on-board sampling data (1992–0707)

Observed effort. Scientific observer coverage varied widely within each sector and year in the SESSF (Table 14). Table 14 details scientific observer coverage rates from 1992–2008 by gear type within each sector of the SESSF. AFMA provided the raw data by generic categories such as trawl shot, or longline lift rather than by actual effort (trawl hours, hooks set). For example, observer coverage for the CTS otter trawl method in 2001 was 2.56 percent of the number of trawl shots in that year. In real terms this represents 906 observations from a possible 35 336 trawls in that year (Appendix 8). However, the duration of the 906 trawls where catch was examined by observers was not available, and this increases the level of uncertainty of actual coverage rates as the trawls observed may have been of a shorter duration than the average trawl duration in that year.

Similarly, for the line methods, effort used in calculating coverage rates is by longline lifts rather than by the number of hooks deployed in a given year. For example, in 2001 a total of 1.79 percent of demersal longline lifts in the GHAT were reported as being observed. This represents 14 observed lifts from a total of 784 that were reported in logbooks in 2001 (Appendix 8). No information was provided on the number of hooks on each of the 14 observed lifts in comparison to the total hooks deployed in 2001. Deficiencies in data reporting of this nature lead to increased uncertainties when extrapolating the observed catches of gulper sharks to the fishery as a whole, thereby greatly reducing the utility of the observer program.

Of the four SESSF sectors, only the CTS (otter trawl and Danish seine methods) received any observer coverage prior to 1999. Since then, coverage rates have been low in all but the ECDWT and GHAT auto-longline sectors (Table 14).

Table 14. Levels of scientific observer coverage (as a percentage of total effort) by year for each sector of the SESSF. Percentage coverage calculated using total effort (recorded from logbooks) and total observations (ISMP data) as provided in Appendix 8.

Year	CTS Otter Trawl	CTS Danish Seine	GABT Otter Trawl	ECDWT Otter Trawl	GHAT Auto-longline	GHAT Demersal longline	GHAT Drop-line	GHAT Fish Trap	GHAT Gillnet
1992	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	1.94	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	2.02	2.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	1.38	2.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	1.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	2.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	2.18	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	2.75	0.43	0.00	0.00	0.00	4.69	1.24	0.13	0.40
2000	2.11	0.27	4.90	80.88	0.00	0.00	1.26	0.00	0.22
2001	2.56	0.43	5.35	9.78	0.00	1.79	0.89	0.61	0.00
2002	2.30	0.36	5.99	69.61	17.99	0.64	2.49	0.15	0.03
2003	2.44	1.23	2.93	0.00	20.33	4.65	2.13	0.00	0.00
2004	2.34	0.58	3.10	10.04	14.16	1.81	0.12	0.00	0.00
2005	3.04	0.94	3.47	0.00	10.13	0.79	0.24	0.00	0.00
2006	3.04	2.04	2.96	0.00	7.92	0.58	0.79	0.00	0.00
2007	2.86	0.37	3.20	1.00	30.92	0.00	0.49	0.00	0.49
2008	3.60	0.61	5.04	2.00	51.09	4.79	0.00	0.00	0.72

Source: AFMA data section (2008 data preliminary)

Observed catch. ISMP data indicated that species of gulper shark appear to have been caught in very small numbers by all sectors in the SESSF since the program's inception in 1992 (Appendix 7). Total catches of all commercial dogfish (including gulper sharks) recorded under the CAAB code 37020000 by the ISMP are provided in Figure 21. The largest number observed caught was off Portland, Victoria and corresponds to the location of highest observer coverage levels. Given the deficiencies in the use of the generic family code discussed in previous sections, we conclude that the data presented in Figure 21 provide a presence/absence indication only.

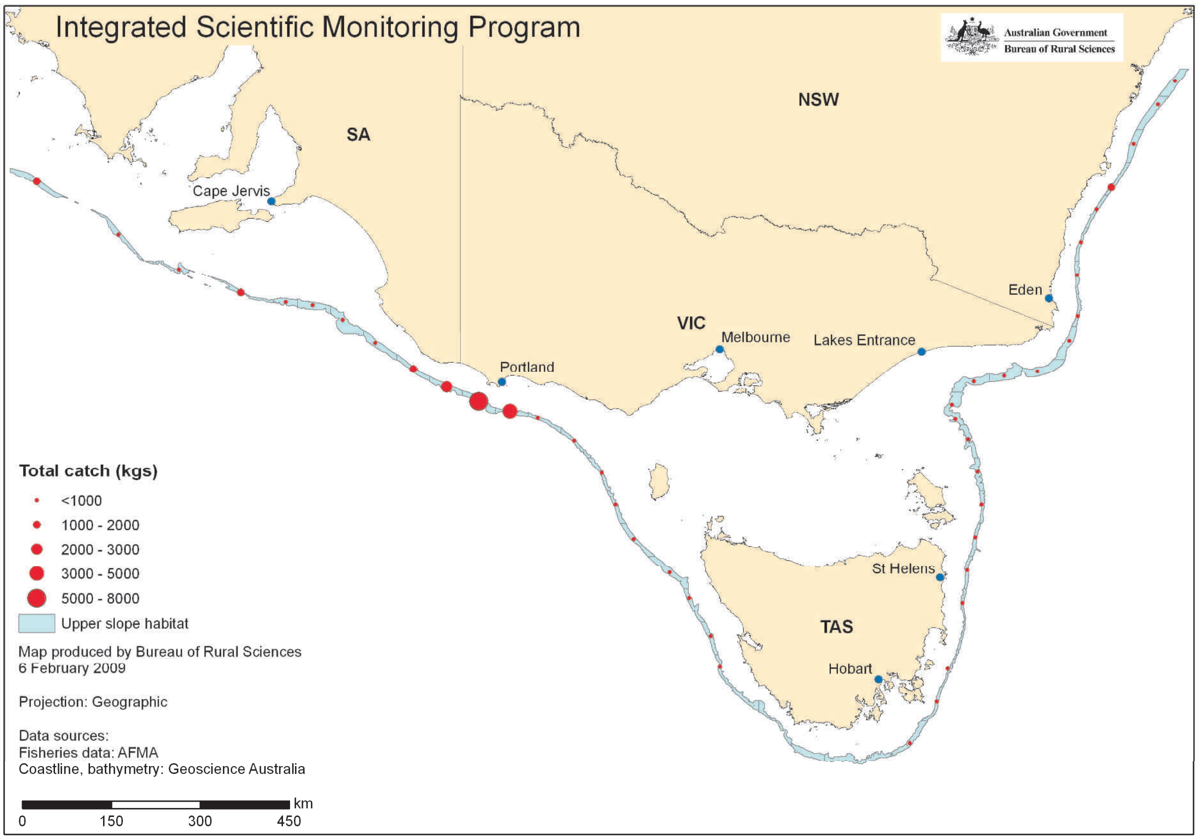

Figure 21. Distribution of commercial dogfish catches (CAAB code 37020000), including gulper sharks, reported by the Integrated Scientific Monitoring Program (1992–2007) from the upper-slope habitat.

Observed catches of *C. harrissoni* (Fig. 22), *C. moluccensis* (Fig. 23) and *C. zeehaani* (Fig. 24) show similar distributions with the exception of *C. harrissoni* that has not been reported off the coast of central NSW by the ISMP since its inception in 1992. None of the three gulper shark species has been reported from south-west Tasmania indicating that this habitat may be unsuitable for gulper sharks, or that it is unsuitable for trawling (e.g. rough benthic habitat). The largest catches were observed off Portland, Lakes Entrance, Kangaroo Island and South of Sydney (Figs. 22-24). However, it should be noted that the reported observations of *C. harrissoni* (Fig. 22) and *C. moluccensis* (Fig. 23) by the ISMP observers are likely to be incorrect as neither of these two species have been validated as occurring off western Tasmania or the Victorian coast, and should therefore be considered at the genus level only.

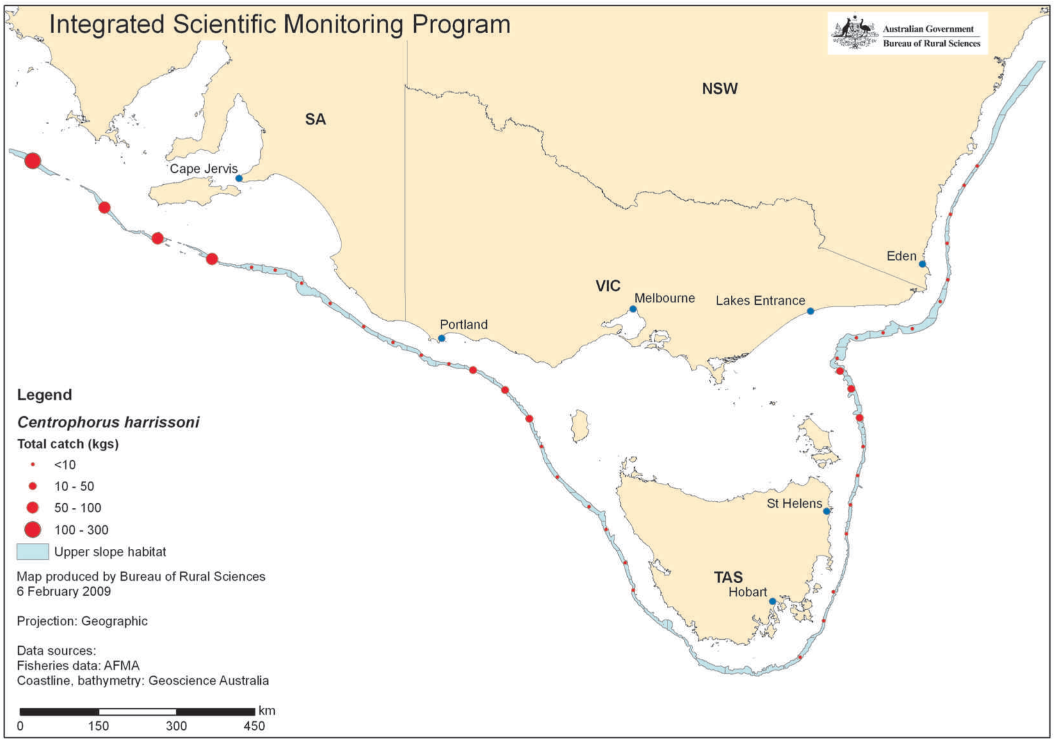

Figure 22. Reported distribution of *Centrophorus harrissoni* (CAAB code 37020010) by the Integrated Scientific Monitoring Program (1992–2007) from the upper-slope habitat.

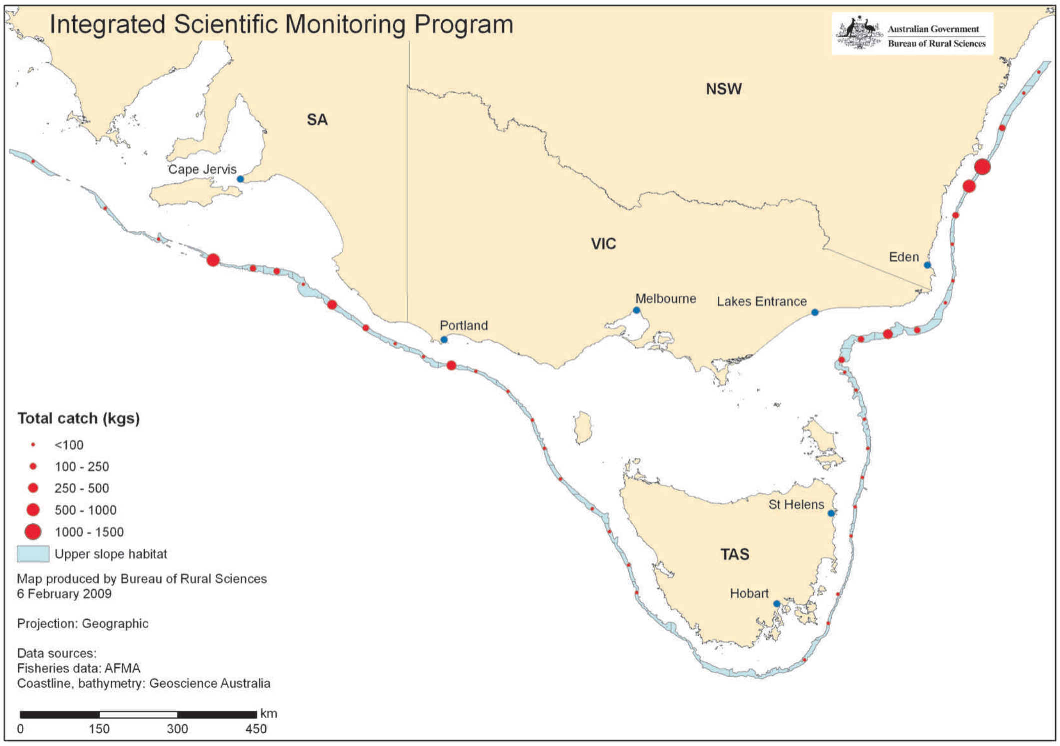

Figure 23. Reported distribution of *Centrophorus moluccensis* (CAAB code 37020001) by the Integrated Scientific Monitoring Program (1992–2007) from the upper-slope habitat.

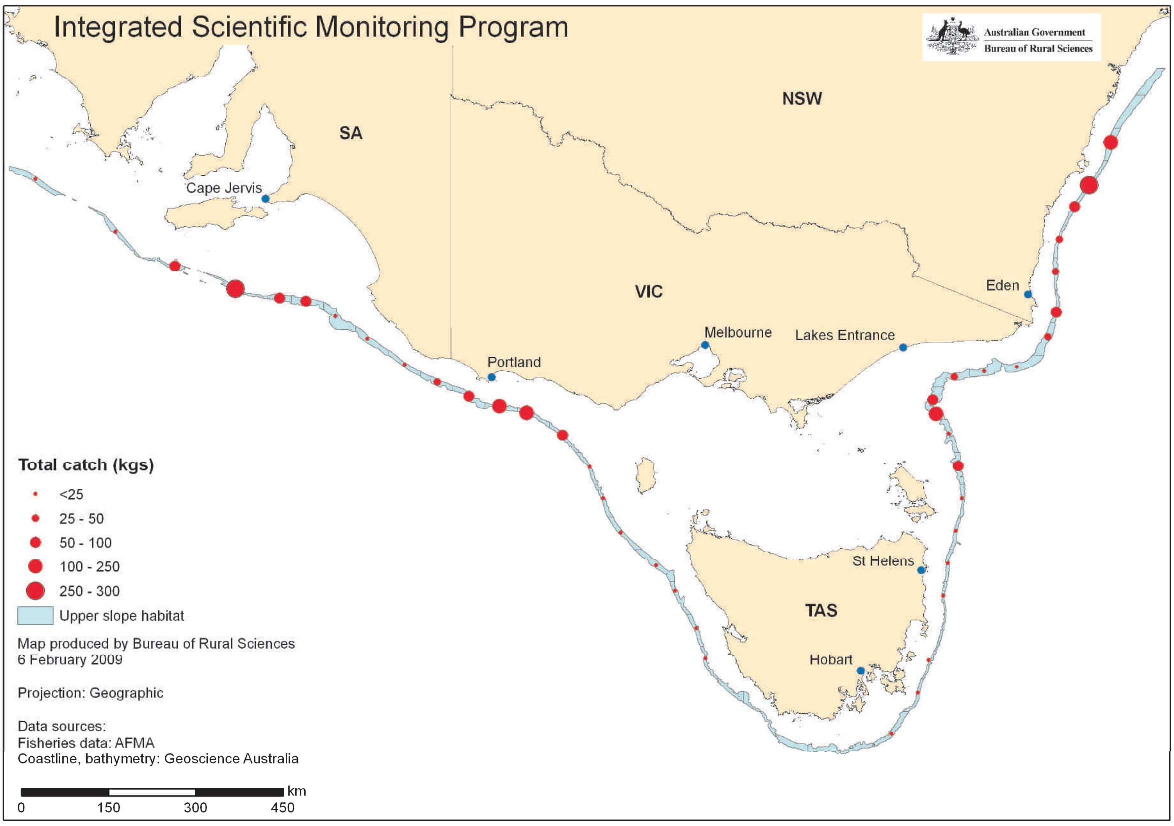

Figure 24. Reported distribution of *Centrophorus zeehaani* (CAAB code 37020011) by the Integrated Scientific Monitoring Program (1992–2007) from the upper-slope habitat.

7.3.2 *Data improvements*

Characterising the nature and extent of interactions with gulper sharks, the ongoing monitoring of those interactions, and the mitigation of any impacts, will be critical if impacts of the SESSF are to be minimised to a level that will ensure gulper shark populations are viable. The following sections provide a brief discussion of the areas we have identified as requiring improvement in terms of the quality of data collected.

7.3.2a Improved identification and recording of gulper shark interactions

To facilitate the collection of meaningful catch and effort data in commercial logbooks and observer reports, there is an urgent need to improve the accuracy of onboard identification of gulper sharks caught in the SESSF. Recent taxonomic studies by White et al. (2008) have resolved issues surrounding the identification of gulper sharks occurring in the SESSF, and the preparation of accurate identification keys and guides for field identification of gulper sharks to the species level, necessary for accurate data collection, should be developed. Training of observers and crew across all sectors of the SESSF, should then be a priority, with the addition of a longer-term review/maintenance program put in place to ensure the accurate identification of gulper sharks is maintained over time. The use of genetic techniques should also be explored as a means to periodically validate both logbook and ISMP data, but not for day-to-day identifications.

In addition, all current documentation relating to the fishery, such as the Management Arrangements booklet (AFMA 2008b) and SFR/permit conditions, needs to be updated to reflect the accurate identification of gulper sharks. Specifically, the use of the common name 'Endeavour dogfish', which has frequently been used to refer to all gulper sharks, should be avoided. Where possible, species names should be used in tandem with the common name (i.e. *C. harrissoni* (Harrisson's dogfish), *C. moluccensis* (Endeavour dogfish), *C. squamosus* (Leaf-scale gulper shark), *C. westraliensis* (Western gulper shark) and *C. zeehaani* (Southern dogfish)). It will be critically important for common names to be paired with the scientific name so that fishers' awareness of the number of gulper shark species and their known distribution in the SESSF and the correct species level identification is reinforced, thereby reducing confusion or ambiguity as to which species is being referred to, particularly when recording interactions in logbooks. Fishers should be encouraged to use the genus code (37020902) for gulper sharks if they are uncertain about the identity of species (*Centrophorus* spp.).

Note: The options made throughout this report are summarized and prioritised in Appendix 9.

Option 1: Develop a gulper shark identification key and field guide suitable for use onboard SESSF vessels.

Option 2: Train scientific observers and SESSF crew on how to use the key/guide effectively in the field.

Option 3: Develop and maintain a regular program of training/review on using the key/guide for gulper shark identification.

Option 4: Explore the use of genetic techniques as a means to periodically validate identifications of both logbook and scientific observer data.

Option 5: Update all fishery documentation, including the SESSF Management Arrangements booklet and SFR/permit conditions, to reflect the correct use of species names.

Option 6: Voucher specimens to be periodically taken from industry vessels, ISMP and all future research surveys, and lodged at an appropriate facility, so that periodic validation of species identifications can be made.

7.3.2b Improved observer coverage and reporting

Despite attempts by BRS, AFMA and PIRVic staff to produce accurate observer coverage rates for the SESSF, we found it extremely difficult to obtain the necessary information. Partial information was obtained from a number of sources. However, the reliability of the actual observer coverage rates is questionable as much of the information is provided as observer coverage by sea days, shots or sets, rather than by the number of trawl hours or hooks observed. Given that the determination of observer coverage rates is a critical element to the scientific monitoring and validation of logbook data for the SESSF; this anomaly needs to be rectified as a matter of urgency. Observer coverage must be accurately calculated in terms of coverage by actual effort (trawl hours, dropline hooks etc.), rather than by generic effort levels such as days or shots that can be of differing duration, and drop-line lifts that can have varying numbers of hooks. During the study, concern was raised by AFMA that this would not be possible to measure; however, we disagree as the duration of each trawl shot is recorded by the vessels skipper, as is the approximate number of hooks per longline lift. Scientific observers should record both the catch sorted/observed and the details of the trawl shot or longline lift (hours or hooks) provided by the vessels skipper. This will then provide managers and researchers with an optimal measure of observer coverage for comparison and extrapolation of gulper shark catch rates.

As noted in Table 14 above, the highest observer coverage rate for the CTS since the observer program commenced in 1992 was only 3.60 percent in 2008. Coverage rates for other sectors has varied. As a target, the scientific observer program should strive to achieve a coverage range of 20 to 30 percent of individual fishing operations (tows or sets) each year (10% as a minimum), noting that actual coverage by trawl hours and hooks set must be recorded. In addition, observer coverage must be representative of different sectors, vessel-types, areas and months. In order to achieve the required observer coverage rates in some vessel/area strata, (e.g. specific vessel-types in certain areas and times), it may be necessary to have higher than 20 to 30 percent coverage in other strata.

Another option would be to implement zones within the SESSF where observer coverage must be higher or compulsory if gulper sharks are likely to be caught. Similar zones are in use in the Eastern Tuna and Billfish Fishery when southern bluefin tuna migrate up the east coast of Australia. The difference for the SESSF is that gulper shark interactions are likely to occur year round. The determination of whether the entire upper-slope or specific areas are to be considered ‘high risk’ in terms of the potential for gulper shark interactions would need to be determined via research. Full (100 percent) observer coverage may be required to detect any effects of fishing on gulper sharks, and research to determine the suitability of electronic monitoring should be considered as a means to supplement physical scientific observer presence.

Option 7: Ensure that the levels of scientific observer coverage for each SESSF sector are accurately recorded, by ensuring that catch observations are paired with actual effort in the fishery, such as trawl hours or hooks set as appropriate.

Option 8: Ensure that scientific observer coverage rates (by hour or hooks set as appropriate) are made publically available on a regular (at least annual) basis.

Option 9: Temporarily increase scientific observer coverage rates to 20-30 percent of actual effort (hours trawled, hooks set) for all vessels fishing the upper-slope habitat, while a long-term coverage rate is determined (Option 10), as previous ISMP data was determined as being of little use in estimating species specific gulper shark catch and discard rates.

Option 10: Facilitate research aimed at statistically determining optimal scientific observer coverage levels for each sector of the SESSF, with the aim of facilitating a robust assessment and quantification of the effects of fishing on gulper shark populations.

Option 11: Ensure that scientific observer coverage is representative of each sector of the SESSF by vessel-types, areas and months.

7.4 Alternative management options for gulper sharks

Objective 4 Provide an analysis, with supporting rationale, for alternative management options for reducing the ecological risk to Harrisson's dogfish and other similar upper-slope gulper sharks in Australia.

In December 2005, AFMA was directed by the Minister for Fisheries, Forestry and Conservation to cease overfishing, recover overfished stocks, avoid further species becoming overfished, and to manage the broader environmental impacts of fishing. Commercial trawling and droplining are continuing threats to gulper sharks within most of their distributional range and trawling was recently nominated, and accepted for consideration by the Department of Environment, Water and the Arts, as a key threatening process to the marine ecosystem in the SESSF under the relevant section of the Environment Protection and Biodiversity Conservation (EPBC) Act.

The information reviewed in this report clearly demonstrates that gulper sharks, and most likely other deepwater species, have suffered very severe population declines as a result of relatively few years of exploitation (Graham et al. 2001; ICES 2002, 2005a), and that now depleted, populations have a reduced capacity to recover. Specifically, we conclude that gulper sharks on the upper-slope of the SESSF are:

- overfished and overfishing is occurring
- show no signs of recovering and are unlikely to recover under current management measures.

The literature reviewed suggests that many deepwater species are unable to endure catches exceeding five percent of their biomass (e.g. Morato et al. 2004, Forest and Walter in press). Forrest and Walters (in press) have shown that, under reasonable assumptions about the age at which gulper sharks in the genus *Centrophorus* become vulnerable to fishing gear (<10 years old), the largest possible hypothesis for maximum sustainable harvest rate that can be considered possible is somewhere on the order of five percent of their virgin biomass, although the actual figure may be lower given uncertainty in their recruitment potential. Even assuming that gulpers do not become vulnerable until 15 years old, these authors found the maximum possible sustainable harvest rate likely is to be less than 10 percent for all three species. The very conservative life history strategies of upper-slope gulper sharks from south-eastern Australia indicate a very low resilience to fishing pressure. As a sustainable harvest level for gulper sharks in the SESSF is currently unknown, we believe that harvest, either targeted or incidental, must be dramatically reduced or halted. For the existing fisheries of the SESSF, fishing pressure on the upper-slope should be reduced considerably to low levels and only be expanded again once reliable estimates of sustainable catches of gulper sharks are identified. If the status quo is maintained, it is highly likely that *C. harrissoni* and possibly *C. zeehaani* will become biologically unviable within the range of the upper-slope in the SESSF.

It is worth highlighting that the continued take of gulper sharks in any quantity in the SESSF is not consistent with a precautionary approach and will prevent the overfished stocks of *Centrophorus* spp. from recovering. Thus, we conclude that there is an urgent need for effective fishery management of upper-slope gulper shark species in the SESSF and strongly advise that the following measures be considered when developing both **immediate** and **long-term** management strategies. As gulper sharks are usually caught in association with other species in the multi-species fisheries of the SESSF, any management measure aimed at reducing the interaction of gulper sharks and fisheries will have major implications for other species within the fishery.

Option 12: Implement both immediate and long-term management strategies to recover the severely depleted (overfished) stocks of gulper sharks on the upper-slope habitat of the SESSF.

7.4.1 Immediate management measures

The following are a series of management measures that should be considered by fisheries management for immediate implementation while further research is carried out to determine appropriate long-term stock recovery measures, detailed in section 7.4.2 below.

7.4.1a. Cessation of auto-longline and associated methods of fishing on the upper-slope habitat

The AFMA Chondrichthyan Technical Working Group (CTWG) noted that longlining may now be more of a threat to gulper sharks in the SESSF due to the ability of fishers to reach all habitats, including deepwater canyons where remnant populations of gulper sharks are likely to remain. In addition, the automated de-hooking practice employed by auto-longline operators frequently results in the mutilation of gulper sharks (and other species), thereby limiting the chance of post-release survival (Patterson 2009). Specifically, anecdotal reports indicate that the use of automatic de-hooking machines frequently results in the jaws of sharks being broken by the de-hooking machines, before being returned to the water (R. Daley pers. comm.). Prohibiting the use of auto-longlining on the upper-slope (and deeper waters) as an interim measure would eliminate the harvest of a significant portion of the gulper shark catch currently taken in the SESSF, particularly in and immediately around deepwater refuge areas such as canyons. While this is negotiated with industry, the use of automated de-hooking machines should be prohibited.

Option 13: Prohibit the use of longline and auto-longline methods of fishing on the upper-slope habitat of the SESSF until research has determined the size of long-term closures necessary to ensure the viability of gulper sharks on the upper-slope.

Pros:

- would eliminate a substantial proportion of the current interactions of the SESSF with remaining gulper sharks on the upper-slope habitat
- would result in effective precautionary protection of remnant gulper shark populations in deepwater canyons that are unavailable to trawl methods
- relatively easy to enforce using current Vessel Monitoring System.

Cons:

- prohibiting auto-longlining will be strongly opposed by operators using this fishing method (currently ten permits) and potentially shore-based processors
- these operators will have to move back to standard longline methods
- industry may be unlikely to it support unless assurances could be made to reopen specific areas of the upper-slope habitat once research had determined the size of long-term closures necessary to ensure the viability of gulper sharks on the upper-slope.

Option 14: Prohibit the use of automated de-hooking machines in the SESSF.

Pros:

- prohibiting the use of auto de-hooking machines will likely receive substantial support from other sectors of the SESSF, not involved in auto-longlining
- NGO’s will also see this as a positive move for management and industry

- modification or abandonment of the automated de-hooking machines would likely increase survival of discarded gulper sharks
- could be implemented relatively quickly in consultation with industry.

Cons:

- may be opposed by operators using this fishing method (currently ten permits)
- these operators will have to move back to standard longline methods
- additional expense for industry if de-hooking machines require modification or removal
- increased processing time when hauling longlines if manual de-hooking is required.

7.4.1b. Increased scientific observer coverage for all fishing operations on the upper-slope

We found that one of the main issues hindering our determination of the extent of interactions with gulper sharks was the relatively low rates of scientific observer coverage, particularly for the CTS. The low coverage rates combined with limited resolution of species identifications will continue to hamper efforts to accurately determine interactions by species and gear. An immediate increase in scientific observer coverage rates on the upper-slope, on the order of 20–30 percent, would be required until sufficient information has been gathered on the impacts of each fishing gear type on gulper sharks. This measure would need to be implemented in tandem with **options 1–11** above, aimed at improving the species identification skills of scientific observers and crew, and how observer coverage is recorded. If implemented, the much needed information on fishery interactions with gulper sharks could be achieved. Additional benefits of increasing coverage rates may include the identification of areas of remnant populations of gulper sharks that could then be used in determining areas for long-term closure. The determination of appropriate long-term observer coverage rates would be aided by increased coverage in the short-term.

Pros:

- detailed information on the interactions between each fishing gear type and gulper shark species would be determined
- information on other upper-slope species could also be gathered
- logbook records could be verified, thereby aiding in determining if serial depletion is occurring, which is likely to be concealed if precise fishing location information and accurate catch composition data are not being recorded in logbooks
- will aid in identifying gulper shark remnant populations, either for protection or for continued higher levels of observer coverage in the long-term.

Cons:

- a substantial increase in costs for industry in the short term while sufficient information is gathered to assess the impacts of each fishing gear type on gulper sharks
- long-term observer coverage rates are likely to be between 10 and 20 percent, and will incur increased costs to industry.

An increase of scientific observer coverage is recommended (see Option 9).

7.4.1c. Implementation of interim area closures on the upper-slope

Large continuous areas of the upper-slope would need to be immediately closed to all forms of fishing capable of interacting with gulper sharks if the ecological risk to gulper sharks is to be reduced, while research is undertaken to determine appropriate long-term closure size and placement. The total size of these initial, precautionary closures should reflect current scientific understanding of marine protected areas. As determined in this report, the current proportion of the upper-slope habitat of the SESSF that is currently protected from all forms of fishing capable of taking gulper sharks is only 7.19 percent. We would propose that the size of the short-term closures should protect at least 30 percent of the upper-slope in the SESSF from all fishing methods. This figure is based on international research that suggests closed areas need to be large and encompass 20 to 50 percent of a population's spawning stock biomass to be effective (e.g. Mangel 1998). For example, when the Great Barrier Reef Marine Park was rezoned in 2004, the percentage of no-take areas (NTAs) increased from 4.5 to 33 percent (Fernandes et al. 2005). This was based on scientific advice for tropical R-selected species (fast growth, high reproductive output). Indeed, several modelling studies have indicated that at least 30 percent of the world's coral reefs should be declared NTAs if maximum sustainable yield of exploited stocks is to be achieved (e.g. Roughgarden and Armsworth 2001; Hastings and Botsford 2003). This option is for species and communities whose reproductive potential is much higher than those of the upper-slope habitat, particularly the K-selected life history strategies of gulper sharks. Thus, it could be argued that a more precautionary approach is warranted for upper-slope habitat species.

The interim network of closures proposed for the SESSF upper-slope should consist of a series of replicated closures along the upper-slope within the area of each sector of the SESSF. Replicated closures would then provide the basis for a large-scale evaluation of the efficacy of closures to aid in the recovery of gulper shark stocks, while also immediately reducing the risk of further depletion of gulper shark populations. The placement of these closed areas should increase the size of the current gulper shark specific closures such as the Harrisson's closure off eastern Bass Strait (Direction 19; AFMA 2008a). The area of the upper-slope habitat in the GABT sector, west of Albany would be an ideal precautionary closure aimed at protecting *C. westraliensis*. This area should be considered for immediate closure.

Option 15: Place large temporary area closures on the upper-slope habitat of the SESSF, prohibiting all forms of fishing capable of taking or negatively interacting with gulper sharks, while long-term measures are developed. Noting the area west of Albany, WA, is an ideal area for closure due to the presence of unfished populations of *C. westraliensis*.

Pros:

- would ensure a precautionary approach is taken by managers, while research is being undertaken to determine the size and placement of long-term closures in the SESSF
- would increase the area protected to meet internationally recognised standards for the protection of a population's spawning stock biomass.

Cons

- may result in the short-term closure of upper-slope areas that are determined as being of limited importance to gulper shark populations in the long-term
- may impact negatively on fishers depending on the areas closed
- given than only 7.19 percent of the SESSF upper-slope habitat is currently closed to all forms of fishing capable of taking gulper sharks, this option will require a substantial increase in the total area closed throughout the SESSF.

7.4.1d. No-take options for gulper sharks in tandem with improved compliance of discards being recorded in logbooks

Discard recording requirements were not introduced in the SESSF in late 2002. Daley et al. (2002), using an industry survey, determined that prior to 2002 most fishers did not record discards in their logbooks. Thus, records of total interactions prior to 2002 are inaccurate. In 2002 and 2003 AFMA, via permit conditions, introduced a trip limit for the CTS and GHAT, respectively. The trip limit allowed the taking and carrying of no more than a combined total of 150 kg trunked weight per trip of *Centrophorus* spp. However, no trip limit has ever been in place for GABT operators, but rather a 'voluntary' annual limit of two tonnes across the entire fishery. This is despite the SESSF management arrangements booklet's indication that in recognition of the longer length of trips in the Commonwealth GABT Sector, the bycatch allowance for GABT operators allows for landing of no more than 500 kg in a month. AFMA have advised that this is incorrect and that the 'voluntary' annual limit of two tonnes was adopted for the GABT in 2006 (S. Weekes pers. comm.).

In reviewing the trip and 'voluntary' annual limit for the SESSF sectors, we found no scientific basis for these measures as a means to conserve or protect gulper sharks on the upper-slope habitat. We examined all SESSF logbook and observer data and found that no one trip recorded gulper catches nearing the trip limit. We consider that the trip limit and voluntary annual limit serve little use in conserving gulper shark stocks and should be replaced with a no-take policy (zero TAC; as a permit condition) in tandem with improved compliance of the requirement to record gulper sharks as discards in logbooks. This could be facilitated through the scientific observer coverage from 7.4.1b above. The zero take policy would be consistent with international recommendations made by ICES (ICES 2005a). In addition, a zero take policy would need to be paired with a catch trigger whereby the fishery, or specific areas of the fishery, would be closed to all forms of fishing capable of taking gulper sharks once a pre-determined catch trigger was reached (see closure options section below for further discussion of this option). A zero take policy should be implemented in tandem with a network of closed areas.

Option 16: Replace the current gulper shark trip and voluntary annual limits with a no-take policy (zero TAC), in tandem with improved education and training on the requirement to record gulper shark discards in logbooks.

Pros:

- would result in all gulper sharks being returned to the water, thereby increasing the number of sharks returning to the water alive and eliminating any chance of targeted fishing for remnant populations.

Cons:

- gulper sharks would no longer be available to the fishery
- onshore operators currently receiving gulper sharks would be negatively affected
- industry have indicated that a no-take policy should not be implemented, but rather a reduced trip limit that requires operators to make all catches of gulper sharks available for scientific research, before it is sold commercially.

7.4.2 Long-term management measures

7.4.2a. Permanent area closures

The designation of adequately sized no-take reserves within the known range of each gulper shark species will be essential to ensure their conservation. Permanent closures may take several forms, ranging from total closure of the upper-slope, to closures preserving pre-determined percentages of critical or remnant habitat. Below we have provided descriptions for a number of options that would need to be researched before permanent placement of a network of protected areas could be implemented.

The following sections are provided as a series of **options** for managers, ranging in severity from a total closure of the entire upper-slope, to a spatial array of smaller closures determined from research and aimed at identifying and conserving remnant populations of gulper sharks while rebuilding depleted populations. Any additional closures are likely to have negative impacts on the income of SESSF operators. However, this may only be a short-term impact as closures are likely to incidentally assist the rebuilding of target species in the medium- and long-term. The greatest implication for industry is that they will lose important fishing grounds, resulting in them having to fish potentially less productive or more remote areas to catch their quota of target species. Closures may also result in increased fishing effort on traditional fishing areas left open, and will therefore require a reduction of fishing capacity. As such, any consideration of areas to be closed should be done in tandem with a consideration of the social, economic and wider ecological effects. Management may prefer to take a risk-based approach whereby closures are put in place as a precautionary measures, thereby reducing or eliminating the need for expensive research projects.

Option: Long-term closure of the entire upper-slope habitat (200-650 m) to all forms of fishing

All forms of fishing would be excluded from the upper-slope habitat (200–650 m) until research could prove that gulper shark stocks had recovered to a minimum biomass level, noting that literature reviewed during this study suggests that many deepwater species are unable to endure catches exceeding five percent of their virgin biomass.

Pros:

- gulper shark populations, as well as other species, may recover to biologically sustainable levels within several decades
- productivity increases for some species will likely spill over into nearby areas (continental shelf)
- once recovery was confirmed, the upper-slope could be reopened to fishing activity.

Cons:

- almost 50 percent of effort and total catch currently occurs on the upper-slope of the SESSF. Closure of the upper-slope will likely result in a halving of product being landed from the fishery
- an undetermined number of fishing operations will likely become unviable, likely to be at least half of the active fishing fleet
- recovery will likely take several decades
- would be strongly opposed by fishers and land-based processors targeting upper-slope species.

Option: Long-term closure of the upper-slope habitat from 500–650 m to all forms of fishing
Similar to the first option, all forms of fishing would be excluded from upper-slope waters below 500 m. This would include deepwater canyons and offshore seamounts where remnant gulper shark populations are most likely to occur. A buffer zone (450-500 m) may need to be implemented to ensure fishing gear is not set below 500 m.

Pros:

- gulper shark populations, as well as other species, may recover to biologically sustainable levels within several decades
- productivity increases will likely spill over into nearby areas
- allows access to areas of the upper-slope shallower than 500 m
- almost all fishing operations would remain viable as the majority of the catch from the SESSF is taken from the continental shelf and upper-slope habitat
- reduces fishery impact on upper-slope species while allowing access to the most productive area from 200–500 m.

Cons:

- industry consider that depth closures are unworkable on the upper-slope due to the difficulties in ensuring fishing gear does not drift/sink to closed areas
- compliance would be more difficult than a total closure of the upper-slope habitat
- relies on operators not fishing in areas where gear may sink deeper than 500 m
- would be opposed by fishers and land-based processors targeting deepwater species.

Option: Targeted area closures of the upper-slope to all forms of fishing
AFMA's Shark Research Assessment Group (SharkRAG) suggested that gulper sharks may rely on canyon ecosystems as refuge habitats from trawl gear in the SESSF. Research would need to be carried out to identify areas likely to be important for gulper shark recovery such as deepwater canyons and other critical habitats that would then need to be protected from all forms of fishing. This research should utilise previous work on benthic habitat mapping in the SESSF, such as Williams et al. (2006), and current work being undertaken by the CSIRO (R. Daley pers. comm.). The total area to be protected must be representative of areas fished and unfished, as per **Option 15**. The determination of appropriate areas for permanent closure should be examined in light of traditional fishing grounds, by mapping temporal fishing effort patterns over the area of the SESSF upper-slope habitat.

Pros:

- preservation of remnant populations
- many areas would be left open to fishing
- is likely to be the most feasible option for management.

Cons:

- areas left open to fishing are unlikely to experience any recovery of gulper shark populations, despite potential spillover effects. This is due to the limited resilience of gulper sharks to fishing pressure
- may result in localised extinctions
- may result in numerous closures, resulting in greater compliance risks and associated enforcement costs

- would require extensive research surveys of the upper-slope both inside and outside of current closures with subsequent costs being borne by industry and government.

Option: Closures when gulper shark catch trigger is reached
A catch trigger could be developed, similar to those currently in place for seabirds, whereby the area of the upper-slope would be closed to all forms of fishing once a pre-determined trigger was reached. For example, if it was determined (via research) that a maximum of three percent of the remaining population of *C. harrissoni* could be taken each year, and this trigger was reached in a given fishing season, then the entire upper-slope, or other pre-determined areas, would be closed to all forms of fishing.

Pros:
- as long as the trigger was set at an appropriate level (to be determined by area and species) it would ensure gulper shark catch would be minimised and maintained below a sustainable catch level
- the fishery would remain open if trigger is not reached during a given season.

Cons:
- would require high rates of scientific observer coverage to ensure accurate reporting of catch, resulting in increased cost to industry
- may result in a race-to-fish mentality.

Option 17: Develop a network of adequately sized area closures (determined from the research options described below, and from the range of closure options provided in this report), that prohibit all forms of fishing capable of taking or negatively interacting with gulper sharks on the upper-slope habitat of the SESSF, in tandem with a no-take/zero TAC policy in areas that remain open to fishing.

7.4.2b. Stock recovery strategy
The implementation of a stock recovery strategy for gulper sharks off southern and eastern Australia by mapping shark distribution, movement and developing non-extractive monitoring techniques such as acoustic tagging to estimate shark abundance, thereby providing the information necessary to protect adequate stocks of gulper sharks will be required. The need for non-lethal sampling methods follows directly from concerns about the already highly depleted state of these species in key parts of their range. Such monitoring techniques should be cost effective (ideally involving industry) and provide sufficient resolution to detect change. The development of a recovery strategy should be seen as a means to validate a precautionary approach over time, with the aim of easing management measures as evidence of recovery becomes available.

Option 18: Develop and implement a management strategy for gulper sharks on the upper-slope of the SESSF as a matter of urgency.

Option 19: Ensure the management strategy includes measures that will facilitate the recovery of gulper shark stocks to ecologically sustainable levels, via appropriate limit and target reference points.

Option 20: Ensure the management strategy considers the types of long-term management measures outlined in this report and the associated research required to improve the effectiveness of these measures.

Pros:

- a means to validate a precautionary approach over time
- will provide a detailed and quantifiable plan for the recovery of gulper shark stocks in the SESSF.

Cons:

- easing of management measures may not occur if evidence of recovery does not become available for several decades
- expensive to monitor any impact of the recovery strategy.

7.4.3 Research

Note: The CSIRO recently received funding to carry out some of the research outlined below.

7.4.3a Information on the distribution and abundance of gulper sharks within and beyond the area of the fishery

There is an urgent need to identify the remaining/remnant populations of gulper sharks, particularly on the east coast of Australia (Tasmania to northern NSW), but also out onto the seamounts in the Tasman and Coral Seas outside of the SESSF, and in the GABT. Identifying these populations will aid in the determination of suitable areas for protection/closure from all forms of fishing capable of interacting with gulper sharks. It will also help determine, to some extent, whether current spatial/area closures are appropriately sized and located. This may involve surveying areas within each sector of the SESSF that have received historically low or no fishing effort to determine if gulper sharks are present, in addition to highly fished areas. If populations are identified outside currently fished areas (including outside of the SESSF), then protecting them from possible exploitation may ease the need to close existing fishing grounds. However, this is only feasible if they are determined as being sufficient to ensure the sustainability of gulper shark populations on the upper-slope as a whole. A complicating issue may involve size and sex segregation of gulper sharks (Walker 1998). If gulper shark sex segregation within a species does occur on the upper-slope, then ensuring that adequate protection is given to the separate sub-populations, in addition to spawning areas, may be crucial to the success of a closed area network.

Option 21: Undertake research to determine the current distribution and abundance of gulper sharks in the SESSF and neighbouring areas, preferably using non-lethal techniques to minimise negative impacts on the remaining populations.

Option 22: Develop non-lethal sampling techniques to monitor gulper shark distribution and abundance.

Option 23: Determine if populations of gulper sharks are segregated by size and sex, and if so, ensure these spatially segregated sub-populations are adequately protected.

7.4.3b Rate of movement of gulper sharks

The determination of spatial and temporal movement rates, particularly into and out of current or proposed closed areas, and the ranges occupied by gulper sharks (discussed in 7.4.3a above), is essential if we are to be able to accurately assess the optimum size and location of closed areas. Specifically, we need to know how much time gulper sharks spend within a defined area (e.g. a current closure), what the seabed habitats are like (habitat preferences), and what role each of these factors play in the ecology of gulper sharks.

The CSIRO is currently undertaking research that involves fitting acoustic tags to gulper sharks in the overlapping Great Australian Bight Trawl and Scalefish Hook Sectors gulper shark closed areas (Table 3, Figs. 4, 5; R. Daley pers. comm.). The combined closures cover approximately 1200 km^2 and are mostly in 200 to 1000 m depths. A network of 24 moored acoustic receivers monitors the movements of the tagged gulper sharks. Some sharks were released at the surface while others were lowered to the seabed in large cages fitted with video surveillance systems to monitor their recovery (R. Daley pers. comm.). The sharks will be tracked by the CSIRO for the next three years. This study should be replicated on the east coast where the majority of gulper shark landings have been recorded from the SESSF.

An examination of diel vertical migrations should also be considered. For example, Baelde (2001) reported that trawlers in the SESSF fish throughout the night, usually making one or two long ‘scratch’ shots on shallow grounds on the continental shelf or deep grounds on the continental slope (below 500 m). Non-quota species (e.g. various species of sharks) are reportedly targeted during these operations (Baelde 2001). However, it is the first morning shot that is regarded as being the most productive due to diel vertical migrations of fish from depth. The diel cycle is driven by the migration of the ‘feed layer’, presumably a mixture of macroplankton and various species of fish, concentrated in a horizontal band ~200 m deep (Baelde 2001). This feed layer is believed to regulate vertical migrations of commercial fish species as well as predators such as gulper sharks on and off the sea floor and up and down the upper-slope benthic habitat daily. The feed layer is also likely to vary seasonally leading to an increased likelihood of fish moving into and out of fishing grounds and closures seasonally (Baelde 2001). The importance of similar diel patterns to fishing dynamics has been shown in other trawl fisheries (Dorn 1998). Thus, we recommend that research be undertaken to determine the degree to which gulper sharks may follow this pattern daily. If a substantial proportion of remaining gulper shark populations move into and remain in shallower water until just after dawn, depth closures by time may be an option to reduce interactions when gulper sharks are more vulnerable to fishing gear. For example, a depth closure at 200 m may be implemented from 10 pm to 10 am each day. Initial results from the tagging studies currently being carried out by the CSIRO (R. Daley pers. comm.) reported one gulper shark that was fitted with a depth sensor made vertical migrations into shallower depths before midnight and then back into deeper waters in the early hours of the morning. If this diel vertical migration pattern is consistent within and among species, closures by depth and time may be an effective means of protecting these species.

Option 24: Determine spatial and temporal movement rates, particularly into and out of current and proposed closed areas, and also the movement rates between different parts of the SESSF.

Option 25: Undertake research to determine the degree to which gulper sharks make daily vertical migrations in the water column, to assess whether temporal depth closures are a viable option.

7.4.3c Identification of suitable habitats for gulper sharks in the SESSF

The CSIRO is currently undertaking research that involves mapping the benthic habitat within the Great Australian Bight Trawl and Scalefish Hook Sectors gulper shark closed areas (Table 3, Fig. 4) from the Marine National Facility Research Vessel 'Southern Surveyor' (R. Daley pers. comm.). Multi-beam sonar was used to draw the contours of steep rocky banks, narrow muddy terraces and submarine canyons on a previously blank area of seabed (R. Daley unpublished data). A network of 24 moored acoustic receivers tracks the movements of the tagged gulper sharks which are then overlaid on the detailed habitat maps, thereby providing an estimate of the conservation value of areas closed to commercial fishing.

Demersal habitats of the upper-slope off NSW have previously been identified as critical habitat for gulper sharks (Graham et al. 2001). However, no qualitative or quantitative surveys of the habitat have been carried out to demonstrate any habitat preferences/associations. The current CSIRO surveys in the GABT should be replicated on the east coast where the majority of gulper shark interactions have been recorded. Research aimed at identifying preferred habitats may be less expensive than studies aimed at determining the actual abundance and distribution of individual species. The CSIRO has obtained funding to identify a suitable remnant population on the east coast to undertake such a study.

Option 26: Replicate the current CSIRO habitat mapping surveys taking place in the Great Australian Bight, on the east coast of Australia where the majority of gulper shark interactions have been recorded.

7.4.3d Improved understanding of gulper shark biology

Information on species longevity, age-at-maturity and natural mortality is currently limited for several species of gulper sharks (e.g. *C. westraliensis*). Ageing techniques have been applied, although band count periodicity in dorsal-fin spines (Tanaka 1990; Clarke et al. 1998; Clarke 2000) and vertebral centra (Polat and Gumus 1995) have not been validated. Dorsal-fin spines appear to yield better results than the poorly calcified vertebrae (Clarke 2000). Age validation may require investigation into the feasibility of radiocarbon dating or radiometric isotope analysis.

Knowledge of reproductive biology (e.g. annual fecundity, gestation period, resting period, maturity/maternity, size at birth) is central to understanding gulper shark life history. Reproductive cycles (seasonal trends) for gulper sharks remain undefined and are restricted to basic descriptions of the reproductive mode, with observations of litter size, monthly variations of gonad development and approximate size at birth and size-range at maturity yet to be determined.

The cue for growth in deepwater chondrichthyans may be influenced by seasonal food availability rather than seasonal temperature cycles, thus information on trophic ecology is also required.

Where feasible, biological research should be carried out in tandem with other research, such as the CSIRO surveys, thereby minimising the costs to industry and government.

Option 27: Undertake opportunistic research aimed at improving the understanding of the biology and life history, including the validation of ageing, determining the annual fecundity, gestation period, resting period, maturity/maternity,

birth size, and trophic ecology, for species of gulper shark where this information doesn't already exist.

7.4.3e. Gear restrictions/modifications (e.g. hook types, net sizes, use of BRDs)
There is little that can be modified on SESSF trawl gear to exclude gulper sharks from catches. However, the CTWG noted that survival of gulper sharks captured in both trawl and longline gear could likely be improved with better handling practices. One practice in particular is the redesigning of the de-hooking machine. Currently, the machine operates by driving the hooked animal into a board which releases the hook, but also damages the fish. Typically, the jaws of the animals are broken. Any discarded gulper sharks are thus returned to the ocean damaged. Although, some sharks have been known to survive, as evidenced by sharks with broken jaws being recaptured, it is likely that this treatment results in some level of mortality. Given the depleted state of gulper sharks on the upper-slope of the SESSF, any unnecessary mortality is unacceptable. The likely survival of damaged sharks is further compounded by the depth in which the animal is caught (i.e. sharks taken in deeper waters have higher mortality rates). If the de-hooking machine could be redesigned to decrease the impact on the animals, this would likely increase the survival of animals that are returned to the water alive. Alternatively, our preferred option is for de-hooking machines to be banned, requiring manual de-hooking, as per **Option 14.**

Bycatch Reduction Devices (BRDs) and Seal Excluder Devices (SEDs) are very similar to Turtle Excluder Devices (TEDs). Due to the relatively small size of gulper sharks (less than 120 cm for *C. harrissoni*, *C. zeehaani* and *C. moluccensis*), the CTWG felt it was unlikely that much benefit could be derived from these devices. However, research should be carried out to confirm that this is the case.

Option 28: Determine if bycatch reduction devices will reduce the take of gulper sharks from the upper-slope of the SESSF, and if so, implement such devices.

7.4.3f Discard survival
The survival rate of discarded gulper sharks is currently unknown. Research is required to determine the survival rates of discarded gulper sharks for each fishing method used in the SESSF. Different fishing methods are likely to result in different discard mortalities. In the northeast Atlantic, ICES (2008) indicated that survival of deepwater sharks released from longline fisheries is thought to be high, but is lower in trawl fisheries; trawling is likely to be more damaging than longlines. Most trawls are reported in logbooks as being around three hours in duration and almost all gulper sharks are reported as dead when landed (Daley et al. 2002). However, anecdotal evidence indicates that catch taken in shorter trawling tows in the CTS have a high proportion of gulper sharks that are landed alive (R. Daley pers. comm.), although no definitive research has been undertaken to determine how many of the sharks survive when returned to the water.

A telemetry study on an upper-slope dogfish off Japan, *Centrophorus acus*, caught using bottom dropline (at 500–600 m depth) by Yano and Tanaka (1986) reported that animals returned to the water in good condition would descend to a depth of about 375 m in 1.5 hours. However, the limited numbers of individuals used in this study (n=2) restrict the generalities that can be drawn.

If fishing is to continue on the upper-slope of the SESSF, assessments should be carried out to determine the survivability of gulper sharks that are released quickly.

Option 29: Undertake research to determine the rates of survivorship of gulper sharks that have been caught using various gear types deployed for differing times in the SESSF, and if necessary how survivorship can be improved.

7.4.3g Determine the efficacy of 'no take' provisions versus trip limits on gulper sharks

In January 2003, a trip limit was introduced in the SET (now CTS) Fishery that allowed a combined catch of 150 kg trunked weight of gulper sharks (*Centrophorus* spp.) to be taken. However, there appears to be no scientific basis for the 150 kg limit and research needs to be undertaken to determine if this, or any amount of take, is appropriate. For example, research trawls on the east coast in 1996–97 took 67 kg of gulper shark from a total of 159 hours of trawling (Graham et al. 2001). Thus, it is questionable whether the 150 kg trip limit places any effective constraints on the take of gulper sharks in this area. Similarly, for the GHAT Sector, a trip limit may be unnecessary given that anecdotal evidence suggests survivorship of individuals brought up from depth on hook is high. Thus, introducing measures to avoid interactions with gulper sharks, in combination with a system of accurately recording discards when interactions do occur, would appear to be a more logical approach. Noting that **Option 17** calls for an interim measure of zero take of gulper sharks while this research is undertaken.

Option 30: If trip limits are to be retained, determine the scientific basis and validity of the current 150 kg trip limit as a conservation measure to protect gulper sharks in the SESSF.

7.4.3h Determine the efficacy of deterrents

An effective means of reducing the catch rates of gulper sharks is to deter their interactions with fishing gear. Recent research indicates that rare earth metals or magnets may be effective deterrents for some species of shark (Rice 2008). For example, in both laboratory and field tests the catch of spiny dogfish (*Squalus acanthias*) was reduced when cerium mischmetal, a rare earth metal, was present or attached to the longline (Kaimmer and Stoner 2008; Stoner and Kaimmer 2008). Magnets comprised of neodymium-iron-boride were also tested in the laboratory but did not deter the sharks from attacking baits so they were not field tested. Neither the mischmetal nor the magnets appeared to have any effect on the target species of the longlines (Pacific halibut). This research followed the 2006 "Smart Gear" award from the World Wildlife Fund to Shark Defense for their work on rare earth magnets as shark deterrents (http://www.smartgear.org). However, more research is required before this method can be applied in fisheries as it is currently unknown how rare earth metals may impact target species or sharks over long time periods, nor is much known about the environmental safety of using such deterrents. It is also unknown if gulper sharks will respond to rare earth metals. However, given the promising recent research and the potential to eliminate or greatly reduce fishery interactions with gulper sharks, such research seems prudent.

Research aimed at determining the utility of deterrents in the SESSF could be carried out in tandem with other research currently underway, both to minimise costs and timelines for production of research results.

Option 31: Investigating the potential for deterrents, such as rare earth metals, to be effective in mitigating fishery interactions for gulper sharks.

8.0 Discussion

The management, data and research options made throughout this report are summarized and prioritised in Appendix 9, and were developed based on the primary objective of the study, that is, to reduce the ecological risk to upper-slope gulper sharks in Australia's SESSF. As such, the options should be considered in light of the broader management context for the fishery, including the likely social, economic and wider ecological effects. Increasing levels of information gathering will require substantial financial input, much of which will likely be drawn from industry and government. However, management may prefer to take a risk-based approach whereby conservative measures are put in place, such as large spatial/area closures and zero TAC's, to avoid expensive research surveys and increased scientific observer coverage.

We consider that gulper sharks (*Centrophorus* spp.) have clearly been harvested outside safe biological limits throughout most of their range in the SESSF, and this has led to a very severe population decline on the upper-slope in excess of 90 percent of virgin biomass. The dramatic decline combined with the conservative (K-selected) life histories of upper-slope gulper sharks leaves little doubt that gulper sharks have already been adversely affected by exploitation to a point where only substantial and immediate management intervention will result in a quantifiable recovery of populations. If the ecological risk to gulper sharks in the SESSF is to substantially reduced, then measures need to be urgently implemented to eliminate catches of gulper sharks in large areas of the SESSF. The implementation of a network of areas closed to all types of fishing simultaneously, in tandem with a fishery-wide zero TAC, is likely to be the most effective measure to achieve this goal given the multi-species nature of SESSF fishing methods (trawl and longline). Recovery of these species will be slow given their biological characteristics, including a reported fecundity of 1–2 pups every two years after a probable extended period of immaturity (Daley et al. 2002; Compagno et al. 2005). Recent age estimates also support a late age at first maturity and high longevity (Fenton 2001; Clarke et al. 2002a).

A long-term outlook on the order of several decades is therefore required to ensure recovery of these species, particularly *C. harrissoni* and *C. zeehaani* that are known to be restricted endemic species (Last and Stevens 2009). Until a sustainable catch is determined for each gulper shark species, large areas of the SESSF would need to be closed to all fishing activities in the short-term. Research to determine the level of movements and home range for gulper sharks would be necessary to ensure the suitability of subsequent long-term spatial/area closures.

A review of fishery-dependent logbook and observer data revealed incomplete and unreliable catch records at the species level. Where family or genus codes have been used, it is highly likely that catches have been spread across multiple codes, including species other than of the genus *Centrophorus*. As the level of data aggregation in logbooks cannot be determined from logbook records, we conclude that these data are of limited use. Compounding this problem is that until recently there was no requirement to record discarded individuals in logbooks. Although there have been some recent improvements in data acquisition for some aspects of the SESSF, a review of the data collection and validation system is urgently required. Data from commercial vessels relating to the catch of gulper sharks remains both limited and unreliable. The same is likely true of observer data, although the ISMP series is the most robust fishery-dependent dataset available. A comprehensive data collection and validation system (logbook and scientific observer) is therefore urgently needed. In order to obtain accurate data, fishers and observers need to be able to identify gulper sharks accurately and the data needs to be recorded in a manner that is efficient and easy to access for analysis. However, even with these data deficiencies and inaccuracies, recent logbook and ISMP data for deepwater sharks as a group confirm that relatively low numbers of individuals are now present on the upper-slope habitat of the SESSF compared to historical data (Daley et al. 2002; Walker et al. 2008).

A review of the available fishery-independent information confirms that a substantial decline of upper-slope gulper sharks has occurred over the past several decades, due to the effects of fishing (Graham et al. 2001; Daley et al. 2002; Walker et al. 2008). Graham et al. (2001) found that for *C. harrissoni* (Harrisson's dogfish) in 1976–77, a total of 173 tows yielded over 5000 kg of *C. harrissoni*, equivalent to over 1100 sharks (see length-frequency data, Graham et al. 1997). In contrast, only 15 kg (a total of 8 sharks) of *C. harrissoni* were caught in 165 tows in the 1996–97 surveys (Graham et al. 1997). In 1976–77, *C. harrissoni* occurred in nearly 50 percent of the tows (84 of 173), in comparison with only three percent of tows (5 of 165) in 1996–97 (Graham et al. 1997). In our study, we assessed the accuracy of the data described in Graham et al. (2001) by extracting the raw data from the FRV *Kapala* Cruise Reports (Gorman and Graham 1975–84, Graham 1989b, Graham et al. 1997) and comparing them to the reworked data sets (provided by K. Graham, NSW DPI) used in the preparation of the FRDC Project 96/139 Final Report (Andrew et al. 1997) and Graham et al. (2001). As a result, we confirmed and agree with the position taken by Andrew et al. (1997) and Graham et al. (2001) that there is a strong basis for inferring that sustained fishing over the 20 year period from 1976–77 to 1996–97 is the most likely and predominant cause of the observed changes in the relative abundance and size structure of gulper shark species on the upper-slope habitat.

Research on all upper-slope gulper shark stocks should be increased to provide the data necessary for assessment. Key uncertainties on the biology and ecology of gulper sharks remain and inhibit definitive management advice being developed. These uncertainties include: rates of movement between and among areas and natural mortality rates; the development of fishery independent estimates of abundance would be extremely valuable for providing a more robust assessment of the status of upper-slope gulper sharks in the future; and gaining an absolute estimate or index of abundance is central to assessing the status of an exploited species. However, it is likely that even with increased investment in research to improve our understanding of the points listed above, substantial gaps in our knowledge will remain, thereby requiring a precautionary, risk based approach be taken by managers, including developing strategies that will be robust to uncertainty.

Consequently, SESSF operators should not be permitted to expand into areas where they have not already fished, or not fished in the recent past, until those areas have been surveyed for species that may be at risk. If new areas are targeted, then programs to collect data to allow evaluation of stock status should be implemented in tandem with those operations. This would ensure that fishing would not expand faster than the acquisition of information necessary to provide a basis for sustainable exploitation.

Based on the very severe declines in catch-per-unit-effort that have been reported for some species of gulper shark in the SESSF, we conclude that these species are depleted in some areas to less than 90 percent of their virgin biomass and that current and previous quota management, trip limits, bycatch mitigation strategies and other management measures have failed to reduce bycatch of gulper sharks in the area of the SESSF. Consequently, we strongly advise a zero take/TAC for these sharks and urge management to ensure the implementation of this option as a matter of urgency. In addition, we note that these exceptionally slow growing species have been severely depleted by fisheries in several parts of the world and at least five populations of gulper sharks are considered threatened, according to the IUCN-World Conservation Union Red List. Included on the IUCN Red List are two species considered endemic to Australian waters: *C. harrissoni* (Critically endangered) and *C. uyato,* now *C. zeehaani* (Critically endangered). *C. squamosus* is listed as Vulnerable on the IUCN Red List. We advise that a network of adequately sized area closures that prohibit all forms of fishing capable of taking or negatively interacting with gulper sharks on the upper-slope habitat of the SESSF be urgently developed and implemented. The closed area network must be implemented in tandem with a zero take/TAC policy in areas that remain open to fishing, given the precarious state of gulper shark populations in the SESSF.

The following is a brief summary of the status of each gulper shark species taken on the upper-slope habitat of the SESSF based on the information identified in this report:

Harrisson's dogfish (*C. harrissoni*) and Southern dogfish (*C. zeehaani*). We confirm that *C. harrissoni* and *C. zeehaani* have undergone very severe reductions in numbers throughout their restricted ranges. Both species have geographic distributions that are precarious given that they are considered endemic to waters off south-eastern Australia and adjacent seamounts (*C. harrissoni*), and southern Australian waters (*C. zeehaani*), largely or wholly within the SESSF management area. The confirmed declines in catches of these two species of greater than 90 percent over the 20 year period from 1976–77 to 1996–97 (Graham et al. 2001) and continued low catches (Walker et al. 2008), combined with their K-selected life history strategy (slow growth, late age at maturity, low fecundity and low natural mortality), indicate that their viability is at risk given the very low numbers of mature individuals being caught by fishery-dependent and fishery-independent studies. This leads us to conclude that there is a very high risk of biological extinction for these two species within their geographic ranges.

Endeavour dogfish (*C. moluccensis*) and Leafscale gulper shark (*C. squamosus*). *C. moluccensis* and *C. squamosus* have undergone very severe reductions in numbers throughout the upper-slope of the SESSF (greater than 90 percent). However, as both of these species are known to occur extensively in areas outside the fishery, we conclude that the activities of the SESSF will not cause either to become extinct. However, as the number of individuals have undergone severe declines on the SESSF upper-slope, measures should be undertaken to ensure that further depletion within the SESSF does not occur, and where possible, begin to rebuild local populations. If measures are taken to rebuild stocks of *C. harrissoni* and *C. zeehaani*, a flow-on benefit for *C. moluccensis* and *C. squamosus* will likely occur.

Western gulper shark (*C. westraliensis*). Little is currently known about this species of gulper shark other than its highly restricted distribution from Shark Bay to Cape Leeuwin, Western Australia, its restricted depth distribution (616 to 750 m) and its K-selected life history strategy (White et al. 2008; Last and Stevens 2009). The combination of these factors make *C. westraliensis* highly vulnerable to overfishing. Given the experiences with other *Centrophorus* species in the SESSF, the fact that a sustainable harvest level for this deepwater species is currently unknown, and that the literature reviewed in this report suggests that many deepwater species are unable to endure catches exceeding five percent of their virgin biomass (e.g. Morato et al. 2004, Forrest and Walters in press), we advise that targeted fishing for this species should not be allowed (via a zero TAC) and measures are implemented to avoid incidental catch throughout its range (via area closures).

C. westraliensis appears to have received little impact from SESSF activities due to its far western distribution. However, current regulations permit 100 kgs (trunked weight) of this species (described as *C. uyato*), in combination with Harrisson's dogfish (*C. harrissoni*) and Endeavour dogfish (*C. moluccensis*) to be taken per day by Commonwealth concession holders in the Western and Deepwater Trawl Fishery (Patterson and Whitelaw 2007). We recommend that due to the susceptibility of this species to overfishing, substantial areas within its range must be permanently closed to all forms of fishing capable of taking gulper sharks, thereby protecting populations of *C. westraliensis* before they are depleted to biologically unviable levels.

The development of a strategy to recover populations of gulper sharks should be seen as a means to validate a precautionary approach over time, with the aim of easing management measures as evidence of recovery becomes available. This would be consistent with AFMA's legislated objective of '*ensuring that the exploitation of fisheries resources and the carrying on of any related activities are conducted in a manner consistent with the principles of ecologically sustainable development and the exercise of the precautionary principle, in particular the need to have regard to the impact of fishing activities on non-target species and the long term sustainability of the marine environment*'.

The management, data and research options made throughout this report are consistent with international management recommendations for deepwater species, that acknowledge the high vulnerability and low productivity of deepwater species and advise that harvest of such species should be prohibited unless this harvest can clearly be demonstrated as sustainable (NEAFC 2000; ICES 2002, 2005a). A zero take/TAC would require that means are found to avoid any bycatch of deepwater sharks. If a zero catch is not possible, then managers should reduce fishing effort to the lowest possible level in mixed fisheries taking gulper sharks as bycatch. As a sustainable harvest level for gulper sharks in the SESSF is currently unknown, and declines in excess of 90 percent in the relative abundances of these species have been reported (Graham et al. 2001), and validated in this report, all harvest, either targeted or incidental, must be dramatically reduced or halted. Without such substantial measures it is highly likely that populations of *C. harrissoni* and possibly *C. zeehaani* will become biologically unviable within the SESSF. Noting the points raised in this report, the continued take of gulper sharks in the SESSF is not consistent with a precautionary approach to fisheries management.

9.0 Benefits and adoption

The initial beneficiary of this work will be the Australian Fisheries Management Authority by facilitating their selection of preferred management arrangements for upper-slope gulper sharks and meeting requirements for Wildlife Trade Operation (WTO) conditions.

The data gathered and options made in this report will also contribute to other work underway to identify best-practice management arrangements for all chondrichthyan species in Commonwealth fisheries.

In the medium and longer term, concession holders in the fishery who wish to fish in the depths at which upper-slope gulper sharks are found will benefit if the sustainable management arrangements provided in the report are implemented in conjunction with additional research to refine each strategy.

The Australian community will also benefit if the SESSF is able to continue to provide fresh seafood without jeopardising the conservation status of upper-slope gulper sharks and without unnecessary restrictions on fishing activity.

The DEWHA will use the report during its assessment of upper-slope gulper sharks as threatened species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The assessment is due to be completed by 30 September 2010.

10.0 Further Development

A range of additional research options have been outlined in this report (section 7.4.3 above), some of which should be considered urgent if effective management strategies are to be implemented and monitored in the SESSF.

11.0 Planned outcomes

The report has determined that there is a strong basis for inferring that sustained fishing over the 20 year period from 1976–77 to 1996–97 is the most likely and predominant cause of the observed declines of in excess of 90 percent in the relative abundance and size structure of gulper shark species on the NSW upper-slope.

This project provides information that will allow the implementation of a range of management options for upper-slope gulper sharks to be assessed and compared.

12.0 Conclusion

The objectives of the study, as outlined below, were all fully met. As part of this process, a number of important conclusions were made, each of which is outlined below.

Objective 1. Review the success of international management arrangements to address the sustainability of fisheries catches involving similar upper-slope low productivity shark species.

- Large decreases in reported catches and apparent stock biomass of deepwater sharks in the northeast Atlantic have led scientists from the region to strongly recommend a zero catch of deepwater sharks.
- We believe that gulper sharks in the SESSF will only be adequately protected if a similar recommendation is adopted.
- A zero catch would require that means are found to avoid any bycatch of deepwater sharks.
- The most efficient method to achieve this in the SESSF would be via large area closures of the upper-slope habitat to all forms of fishing that take gulper sharks, affecting a zero catch on large areas of the upper-slope.
- We agree with the shark specialists who attended the workshop on conservation and management of deepwater Chondrichthyan fisheries in 2003 who concluded that in areas where collection of information on species composition, stock structure and movement patterns is not possible larger areas should be allocated for closure. This is particularly important where this information does not already exist or will take an extended period to collect. In addition, the working group recommended that “management should follow the precautionary approach and implement regulations immediately”. These two key elements recommended in 2003 have clear applicability to the current situation in the SESSF for gulper sharks.
- All recommendations made by the AFMA CTWG on mitigating bycatch of gulper sharks are applicable to the SESSF. Key recommendations that could be immediately implemented for demersal longline and trawl methods included a reduction in fishing effort, a reduction in the TAC of target species, depth closures and the adoption of better handling practices.

Objective 2. Consider the historical identification of Harrisson's dogfish including catch statistics and scientific surveys.

- Current and historical logbook data does not provide a reliable/accurate representation of gulper shark (*Centrophorus* spp.) catch levels in the SESSF. This is largely due to the fact that most gulper shark catch records are imprecise with multiple species frequently grouped under one category.
- The group codes used obscure differences in community structure (species composition) and any reductions in population size of the less productive species.
- Daily logbook records for the SESSF are of little use in determining gulper shark species interactions in their current form.
- Substantial data deficiencies were identified in the scientific observer (ISMP) data sets. Given the difficulties in identifying gulper sharks, and the tendency for observers to use the generic codes in their records, it is unlikely that the observer data can be regarded as accurate at the species level and undoubtedly suffers from the same problems of misidentification and species groupings as the logbook data. Such data needs to be interpreted with caution.
- Since 2002, improvements have been made in the way gulper sharks are being recorded by scientific observers. When identification and recording skills are improved, scientific observer data will fulfil its objective of providing a means to validate fishery catch records.
- We agree with the position taken by Andrew et al. (1997) and Graham et al. (2001) that there is a strong basis for inferring that sustained fishing over the 20 year period from 1976–77 to 1996–97 is the most likely and predominant cause of the observed declines of in excess of 90 percent in the relative abundance and size structure of gulper shark species on the NSW upper-slope.

Objective 3. Investigate and improve estimates on the nature and extent of interactions with Harrisson's dogfish and similar upper-slope gulper sharks in all sectors of Australia's SESSF.

- Due to the poor quality of logbook data from the SESSF, the nature and extent of interactions with *C. harrissoni* and other gulper shark species was difficult to determine, with general patterns being all that could be identified.
- Interactions at the family level have declined substantially since logbook records were first introduced, suggesting population depletion.
- Data quality must immediately be improved and maintained, including the training and continual retraining of both scientific observers and crew.
- Scientific observer coverage should be increased if accurate interactions are to be determined for vessels fishing on the upper-slope habitat.
- Scientific observer coverage must be representative of each sector of the SESSF by vessel-types, areas and months.

Objective 4. Provide an analysis, with supporting rationale, for alternative management options for reducing the ecological risk to Harrisson's dogfish and similar upper-slope gulper sharks in Australia's SESSF.

- Urgent action needs to be taken by fishery managers if the heavily overfished and very severely depleted stocks of gulper sharks on the upper-slope habitat of the SESSF are to recover.

- A recovery strategy must be developed to include both immediate and long-term management strategies aimed at ensuring the stocks of gulper sharks recover to a sustainable level.
- Research is required to determine the current distribution, abundance and movement patterns of gulper sharks in the SESSF and neighbouring areas.

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Appendix 1: Intellectual Property

No intellectual property has arisen from the research that is likely to lead to significant commercial benefits, patients or licences. Intellectual property associated with information produced from the project will be shared equally by the Fisheries Research and Development Corporation and by the Bureau of Rural Sciences.

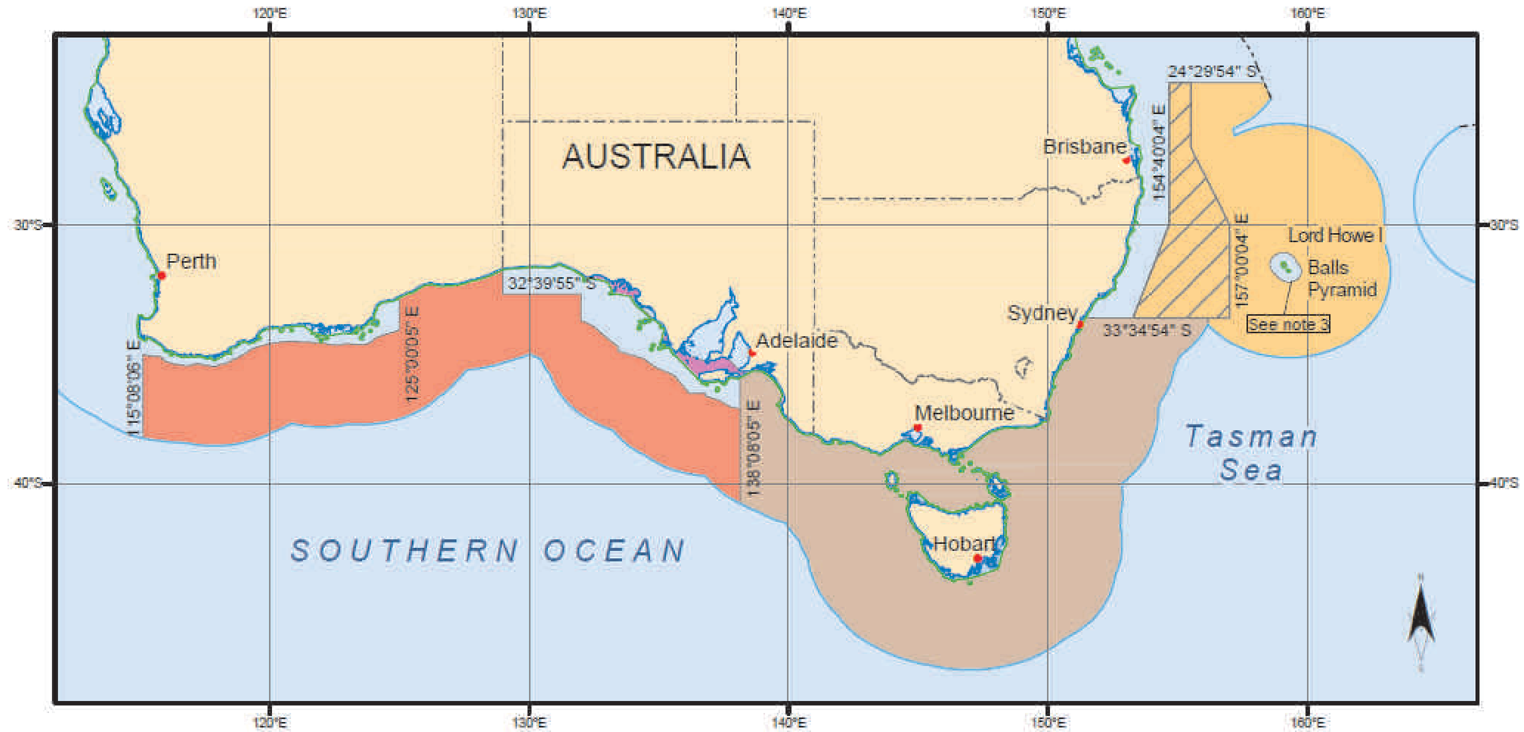
Appendix 2: Staff List

Dr. David T. Wilson, Senior Scientist, BRS
Dr. Heather M. Patterson, BRS
Rupert Summerson, BRS
Patricia I. Hobsbawn, BRS

Appendix 3: Sectors of the SESSF

Southern and Eastern Scalefish and Shark Fishery

Commonwealth Trawl Sectors and South Australian Coastal Waters Sector



LEGEND

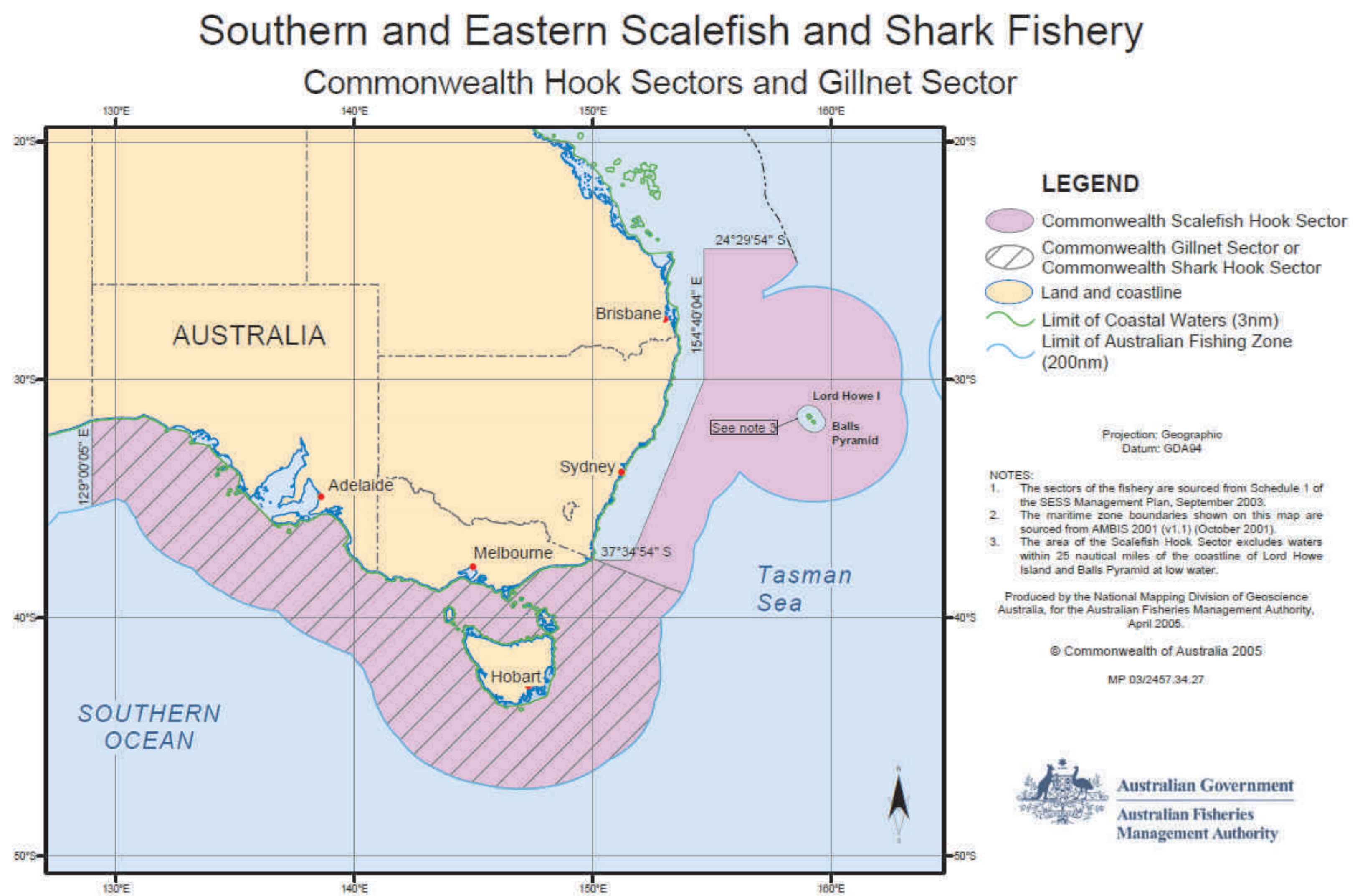
- East Coast Deepwater Trawl Sector
- Trawl Exclusion Zone (closed by permit conditions)
- Commonwealth GAB Trawl Sector
- Commonwealth Trawl Sector
- South Australia Coastal Waters Sector
- Limit of Coastal Waters (3nm)
- Limit of Australian Fishing Zone (200nm)

Projection: Geographic
Datum: GDA94

NOTES:
1. The sectors of the fishery are sourced from Schedule 1 of the SESS Management Plan, September 2003.
2. The maritime zone boundaries shown on this map are sourced from AMBIS 2001 (v1.1) (October 2001).
3. The area of the East Coast Deepwater Trawl Sector excludes waters within 25 nautical miles of the coastline of Lord Howe Island and Balls Pyramid at low water.

Australian Government
Australian Fisheries Management Authority

Produced by the National Mapping Division of Geoscience Australia, for the Australian Fisheries Management Authority, April 2005.
MP 03/2457.34.28


Southern and Eastern Scalefish and Shark Fishery
Commonwealth Hook Sectors and Gillnet Sector
130°E
140°E
150°E
160°E
20°S
30°S
40°S
50°S
AUSTRALIA
Brisbane
Sydney
Adelaide
Melbourne
Hobart
24°29'54" S
154°40'04" E
129°00'05" E
37°34'54" S
Lord Howe I
Balls Pyramid
See note 3
Tasman Sea
SOUTHERN OCEAN
LEGEND
Commonwealth Scalefish Hook Sector
Commonwealth Gillnet Sector or Commonwealth Shark Hook Sector
Land and coastline
Limit of Coastal Waters (3nm)
Limit of Australian Fishing Zone (200nm)
Projection: Geographic
Datum: GDA94
NOTES:
1. The sectors of the fishery are sourced from Schedule 1 of the SESS Management Plan, September 2003.
2. The maritime zone boundaries shown on this map are sourced from AMBIS 2001 (v1.1) (October 2001).
3. The area of the Scalefish Hook Sector excludes waters within 25 nautical miles of the coastline of Lord Howe Island and Balls Pyramid at low water.
Produced by the National Mapping Division of Geoscience Australia, for the Australian Fisheries Management Authority, April 2005.
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Appendix 4: Current state of knowledge – *Centrophorus* spp.

Centrophorus harrissoni

Taxonomy:

Order:	Squaliformes
Family Name:	Centrophoridae
Scientific Name:	*Centrophorus harrissoni*
CAAB Code:	37020010
Species Authority:	McCulloch, 1915
Common Name:	Harrisson's dogfish
Current Conservation Status:	IUCN (2003) – Critically Endangered (considered to be facing an extremely high risk of extinction in the wild). EPBC Act – Finalised Priority Assessment List (2008) ERA – High Risk

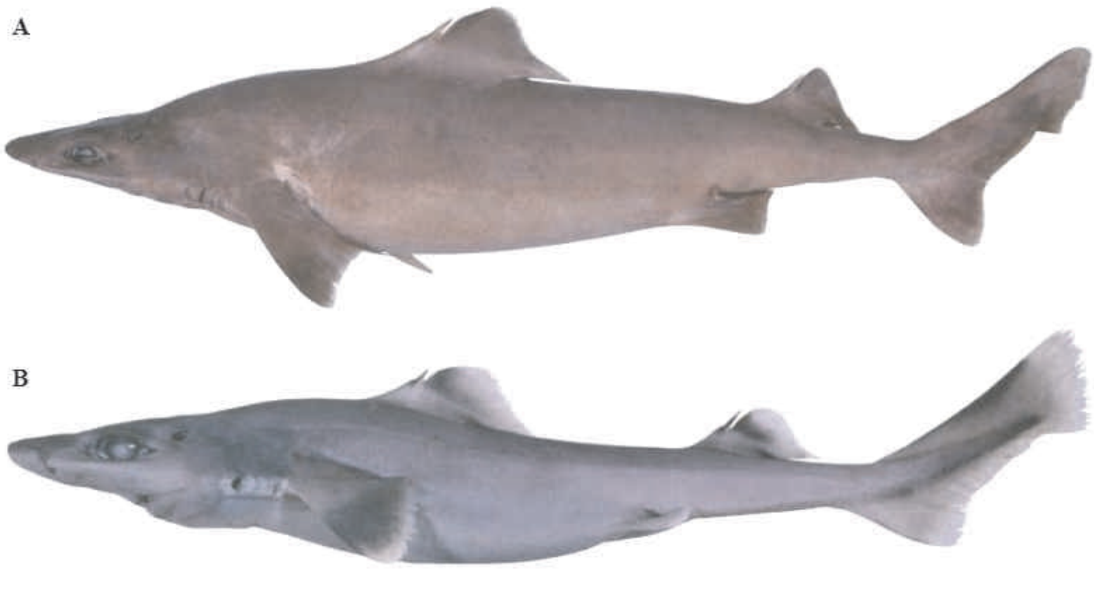


Figure 1. Lateral view of *Centrophorus harrissoni* – A. CSIRO H 2528–01 (female 1049 mm TL), B. CSIRO H 987–01 (immature female ca. 390 mm TL).

Source: White et al. (2008)

Distribution:
East Coast Australian waters and seamounts north of New Zealand (Clarke and King 1989; Duffy 2007; White et al. 2008). Mainly restricted to waters off the New South Wales coastline, from Clarence River (NSW) to South East Cape (Tasmania) (Last and Stevens 2009). Trawling on the continental slope off south-eastern Queensland has not yielded any specimens of this species (J. Stevens pers. comm.) although in 2004, three specimens were collected from the Frazer Seamount east of Bundaberg (J. Johnson pers. comm., Queensland Museum). Recently identified by Duffy (2007) as occurring on the southern Norfolk, Kings, and Kermadec Ridges off northern New Zealand. The species possibly occurs off New Caledonia (Duffy 2007; Last and Stevens 2009).

Habitat:
This species occurs on the continental and insular slopes in depths of 220–680 m (Daley et al. 2002; Last and Stevens 2009) but recorded at 1050 m (Duffy 2007).

Diet:
Details of the diet of *C. harrissoni* are poorly known, however small bony fishes (particularly myctophids), cephalopods and crustaceans have been found in stomachs of this species (K. Graham pers. comm.).

Reproduction:
C. harrissoni is viviparous (aplacental), but little is known about its biology. Females produce one, or more commonly two pups (Graham et al. 2001). *C. harrissoni* have a late age at first maturity, with females found to mature between 23–36 years, however immature females have been found up to 32 years of age (Whiteley 2004). Males mature between 15–34 years of age, with immature males found up to 27 years of age (Whiteley 2004).

Size: (Daley et al. 2002; Whiteley 2004; Last and Stevens 2009)
C. harrissoni is born at about 35 cm.
Males attain a maximum of 95–99 cm.
Females attain a maximum size of 112–114 cm.
Males mature at about 83 cm and females at about 98 cm.

Age:
Based on preliminary ageing studies of closely related species that suggest the longevity of *C. uyato* to be in excess of 46 years (Fenton 2001), *C. harrissoni* is also likely to have a high longevity.

Resilience:
Low, minimum population doubling time 4.5 - 14 years (Fecundity assumed to be 1) (Fishbase; www.fishbase.org).

Vulnerability:
High to very high (Fishbase; www.fishbase.org).

Notes:
Examination of 100 *C. harrissoni* stomachs containing food found over 80 percent with lantern fishes (Myctophidae) and about 20 percent with squid remains. Lantern fishes and deepwater squids are mostly mesopelagic species which suggests that *C. harrissoni* may feed some distance up in the water column, possibly at night (K. Graham pers. comm.).

Within Australasia, *C. harrissoni* is relatively distinctive, and can be readily distinguished from *C. moluccensis* by its long, flattened snout (pre-oral length (POR) longer than or equal to the distance from the mouth to pectoral origin) (Duffy 2007). It is, however, very similar to *C. zeehaani*. *C. zeehaani* is distinguished from *C. harrissoni* by its thicker, shorter snout (POR mostly shorter than the distance from the mouth to pectoral origin) and colour pattern (Last and Stevens 2009; Duffy 2007).

Duffy (2007) identified *C. harrissoni* from New Zealand and indicated that the possibility that these populations are specifically distinct from those in Australian waters cannot be ruled out.

Centrophorus moluccensis

Taxonomy:

Order:	Squaliformes
Family Name:	Centrophoridae
Scientific Name:	*Centrophorus moluccensis*
CAAB Code:	37020001
Species Authority:	Bleeker, 1860
Common Name:	Endeavour dogfish
Current Conservation Status:	IUCN (2003) – Data Deficient (inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status). EPBC Act – Finalised Priority Assessment List (2008) ERA – High Risk

Source: FRDC/CSIRO

Distribution:
Western Indian Ocean off southern Africa, and some areas of the Western Pacific including the Philippines, Indonesia, Taiwan, Japan and Australia (Queensland, New South Wales, eastern Victoria, and Western Australia). Reports from Tasmania and the Great Australian Bight require validation. Not recorded from southern Australia; south to about Gabo Island, but now rare south of Jervis Bay (New South Wales) (Last and Stevens 2009).

Habitat:
Demersal on the outer continental and insular shelves and upper slopes in 125 to 820 m, but in Australian waters most common in 300 to 500 m (Kyne and Simpfendorfer 2007; Last and Stevens 2009).

Diet:
Diet consists of mainly bony fish (mostly myctophids) and cephalopods, but elasmobranchs and crustaceans are also taken (Last and Stevens 2009; K. Graham, pers. comm.).

Reproduction:
Viviparous (aplacental), mostly with litters of 2 pups (Last and Stevens 2009). Born at about 31 to 37 cm (Daley et al. 2002). Males mature at 69 to 73 cm and females mature at about 85-88 cm (Compagno 1984; Daley et al. 2002; Last and Stevens 2009).

Size: (Compagno 1984; Daley et al. 2002; Last and Stevens 2009).
Males reach 86 cm.
Females reach 100 cm.

Age:
Based on preliminary ageing studies of closely related species that suggest the longevity of *Centrophorus uyato* to be in excess of 46 years (Fenton 2001), *C. harrissoni* is also likely to have a high longevity.

Resilience:
Very low, minimum population doubling time is more than 14 years (Fecundity = 2) (Fishbase; www.fishbase.org).

Vulnerability:
High to very high (Fishbase; www.fishbase.org).

Notes:
The low fecundity, high longevity and probable late age at first maturity of this species prevent it from quick recovery after sustained fishing of its populations in the last 20 to 30 years (Graham et al. 2001; Daley et al. 2002).

Centrophorus squamosus

Taxonomy:

Order:	Squaliformes
Family Name:	Centrophoridae
Scientific Name:	*Centrophorus squamosus*
CAAB Code:	37020009
Species Authority:	Bonnaterre, 1788
Common Name:	Leafscale gulper shark
Current Conservation Status:	IUCN (2003) – Vulnerable EPBC Act – N/A ERA – High Risk

Source: © CSIRO Marine & Atmospheric Research

Distribution:
Eastern Atlantic (Iceland to southern Africa), Indian Ocean (South Africa) and western Pacific (Japan, Philippines, New Zealand and Australia). In Australia they occur from Tasmania to New South Wales and Victoria (Last and Stevens 2009), extending east to New Zealand (Wetherbee 2000).

Habitat:
Demersal on the continental slope in depths of 870–950 m (Last and Stevens 2009).

Diet:
Unknown.

Reproduction:
Viviparous (aplacental) with litters of 4-8 pups (Last and Stevens 2009).
Size at maturity - Males ~ 100 cm; Females ~ 110-125 cm.
Age at maturity – Males ~30 yrs; Females ~ 35 yrs.

Size:
Probably born at about 35–40 cm. Attains a maximum size of 165 cm.

Age: Unknown.

Resilience:
Very low, minimum population doubling time more than 14 years (Fecundity = 5-8) (Fishbase: www.fishbase.org).

Vulnerability: Very high.

Notes: Nil.

Centrophorus westraliensis

Taxonomy

Order:	Squaliformes
Family Name:	Centrophoridae
Scientific Name:	*Centrophorus westraliensis*
CAAB Code:	37020050
Species Authority:	White, Ebert and Compagno, 2008
Common Name:	Western gulper shark
Current Conservation Status:	IUCN (2003) – N/A EPBC Act – N/A ERA – High Risk

Figure 5. Lateral view of *Centrophorus westraliensis* sp. nov. – A. preserved holotype (CSIRO H 2625–06, female 909 mm TL). B. fresh paratype (CSIRO H 2606–01, female 774 mm TL). C. preserved paratype (CSIRO 2358–01, immature male 371 mm TL).

Source: White et al. (2008)

Distribution:
Endemic to Western Australia. Recorded from Shark Bay to Cape Leeuwin (Last and Stevens 2009).

Habitat:
Demersal on the continental slope in depths of 616–750 m (White et al. 2008; Last and Stevens 2009).

Diet:
Probably similar to *C. harrissoni*.

Reproduction:
Viviparous (aplacental). Little is known of its biology.

Size:
Probably born at about 30 cm.
Attains a maximum size of 91 cm.

Age:
Unknown, but probably similar to *C. harrissoni*.

Resilience:
Low, minimum population doubling time 4.5–14 years (Fecundity assumed to be <100) (Fishbase; www.fishbase.org).

Vulnerability:
High to very high.

Notes:
Nil.

Centrophorus zeehaani

Taxonomy:

Order:	Squaliformes
Family Name:	Centrophoridae
Scientific Name:	*Centrophorus zeehaani*
CAAB Code:	37020011
Species Authority:	White, Ebert and Compagno, 2008
Common Name:	Southern dogfish
Current Conservation Status:	IUCN (2003) – Critically Endangered (Described as the Australian subpopulation of *C. uyato*) EPBC Act - Finalised Priority Assessment List (2008) ERA – High Risk

Figure 8. Lateral view of *Centrophorus zeehaani* sp. nov. – A. preserved holotype (CSIRO H 6628–05, adult male 893 mm TL). B. preserved paratype (CSIRO H 6628–01, immature male 506 mm TL).

Source: White et al. (2008)

Distribution:
Endemic to southern Australia from off Shark Bay (Western Australia) to Forster (New South Wales), including Tasmania. Demersal on the upper continental slope in depths of 210–700 m; mainly deeper than 400 m (White et al. 2008; Last and Stevens 2009).

Habitat:
Main depth range is 400 to 650 m (Last and Stevens 2009; White et al. 2008), but has been recorded from 208 to 740 m (Graham et al. 1997; White et al. 2008).

Diet:
The diet consists mainly of bony fishes and cephalopods (Last and Stevens 2009) but also includes crustaceans (Daley et al. 2002).

Reproduction:
Viviparous (aplacental) with litters of a single pup. Pregnant females found throughout the year (Last and Stevens 2009).
C. zeehaani also have a late age at first maturity, with females found to mature between 23-28 years, however immature females have been found up to 35 years of age (Whiteley 2004). Males mature between 9–34 years of age, with immature males found up to 24 years of age (Whiteley 2004).

Size:
Size at birth is 35-45 cm (Daley et al. 2002; Last and Stevens 2009).
Males mature at about 80 cm and females at about 96 cm.
Males attain a maximum size of 93-97 cm (Daley et al. 2002; Whiteley 2004).
Females attain a maximum size of 112-119 cm (Daley et al. 2002; Last and Stevens 2009).

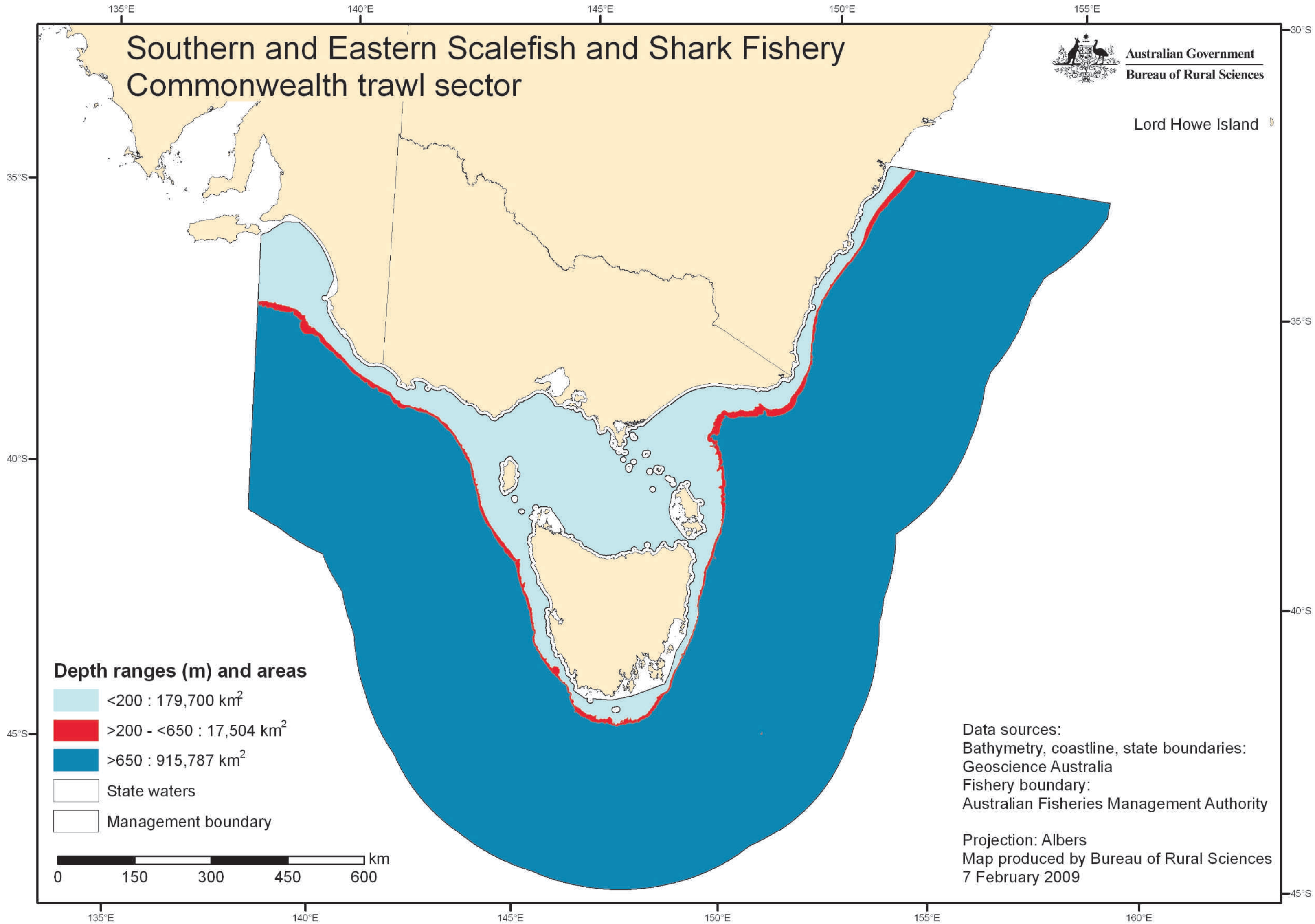
Age:
Preliminary ageing studies by Fenton (2001) suggest that *C. uyato* from Australian waters (now *C. zeehaani* in Australian waters) lives to at least 46 years of age (n = 8) (although this included only immature individuals).

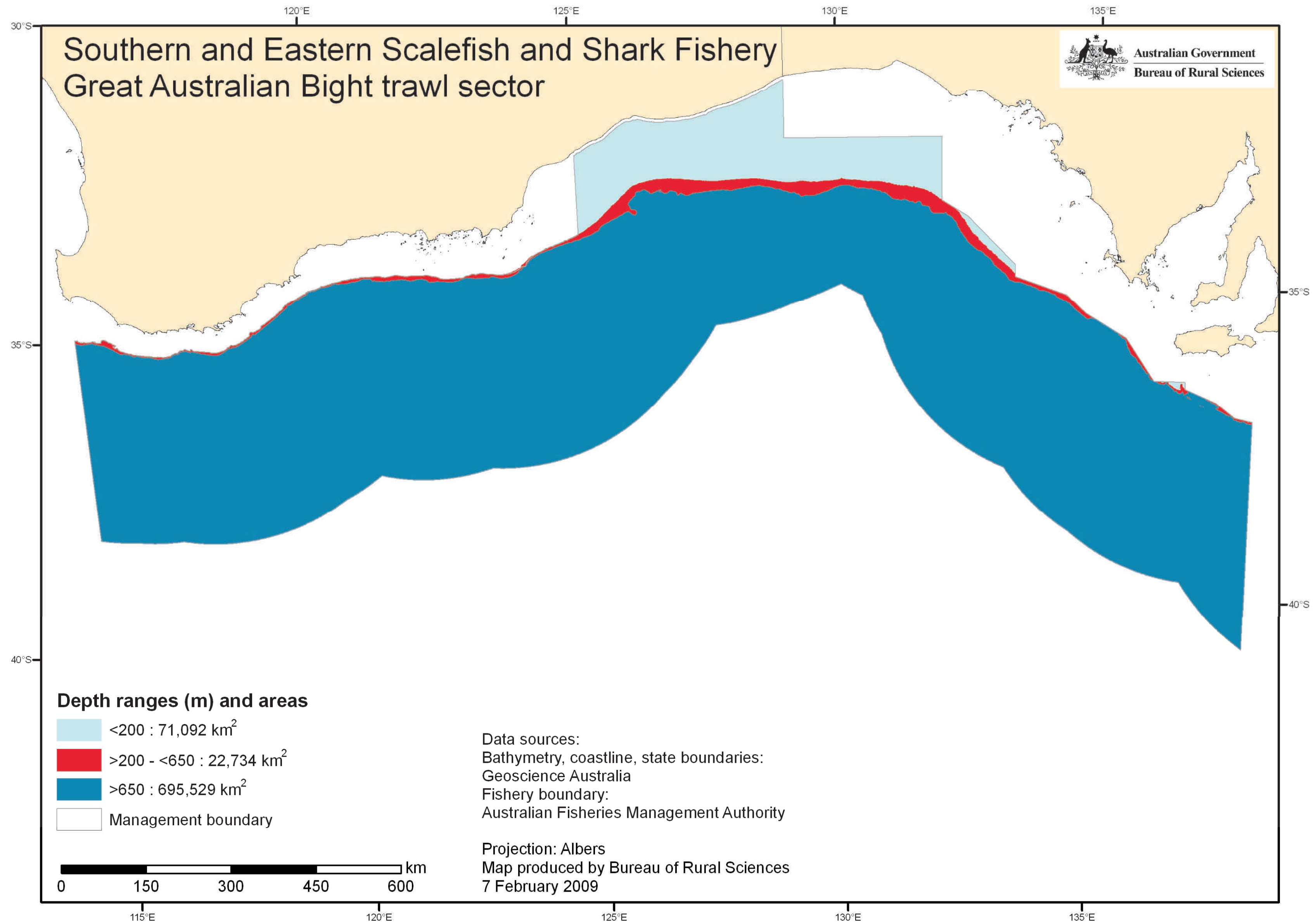
Resilience:
Very low, minimum population doubling time is more than 14 years (Fecundity = 1) (Fishbase; www.fishbase.org).

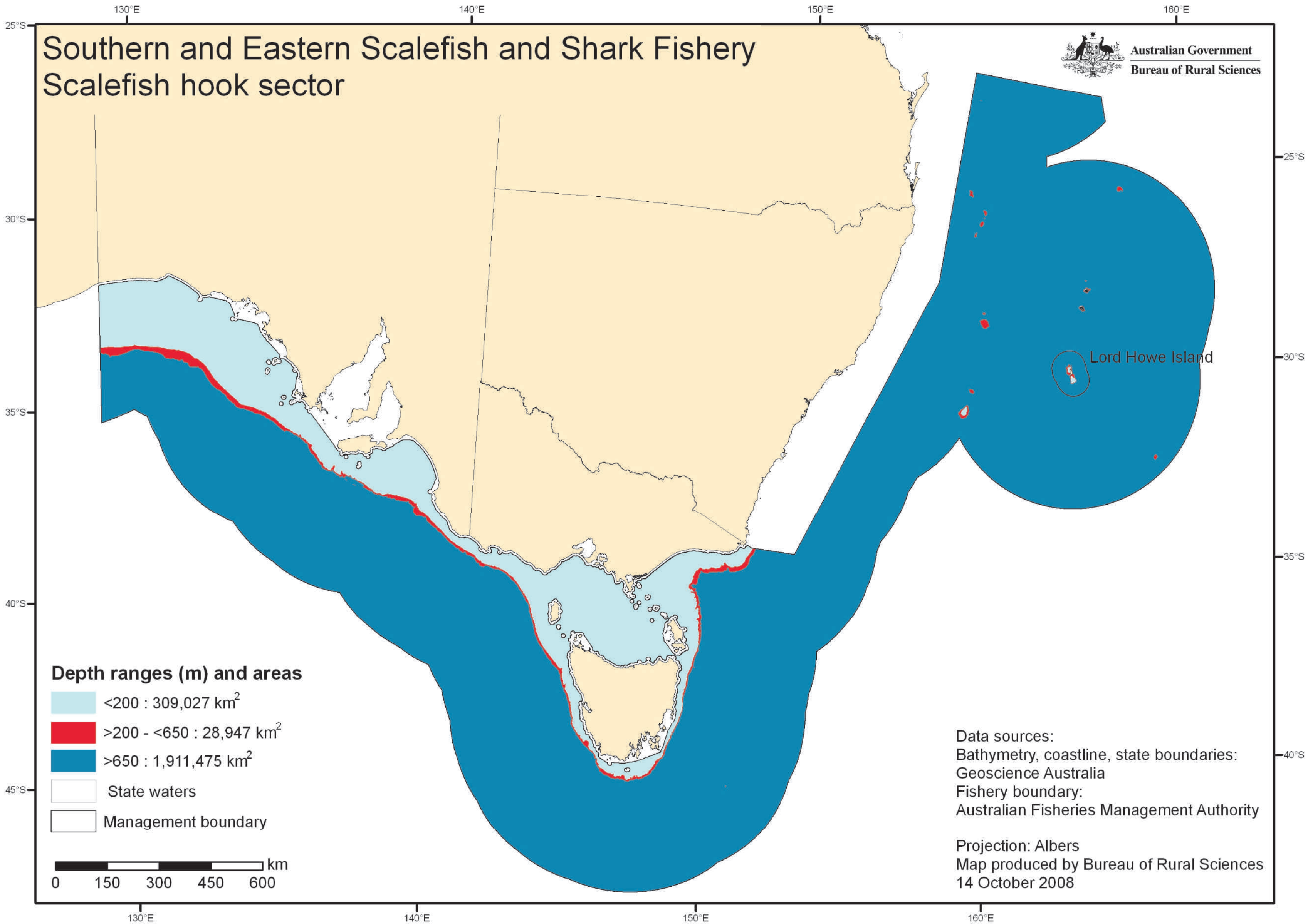
Vulnerability:
High to very high (Fishbase; www.fishbase.org).

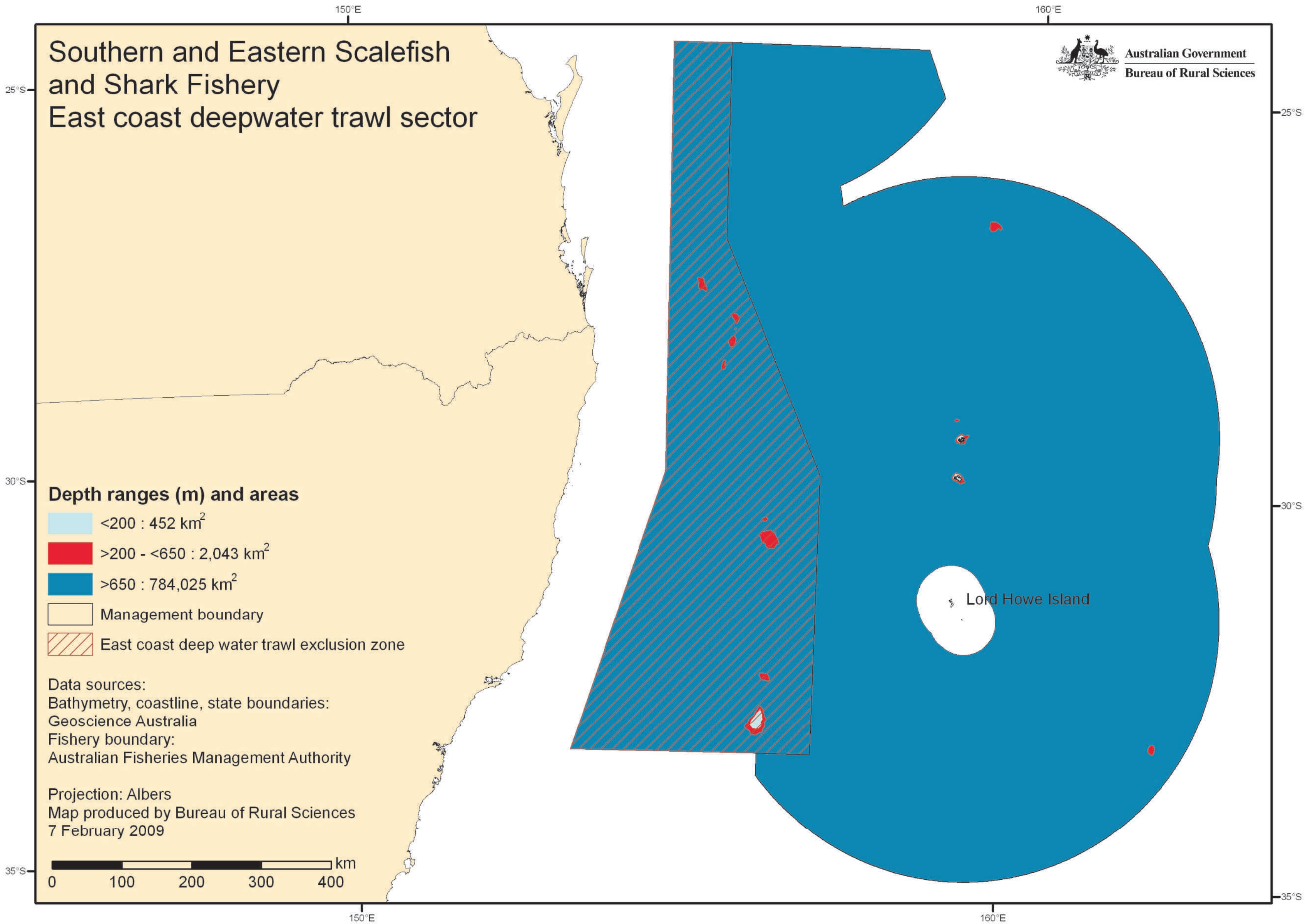
Notes:
The low fecundity, high longevity and probable late age at first maturity of this species prevent it from quick recovery after sustained fishing of its populations in the last 20 to 30 years (Graham et al. 2001; Daley et al. 2002).

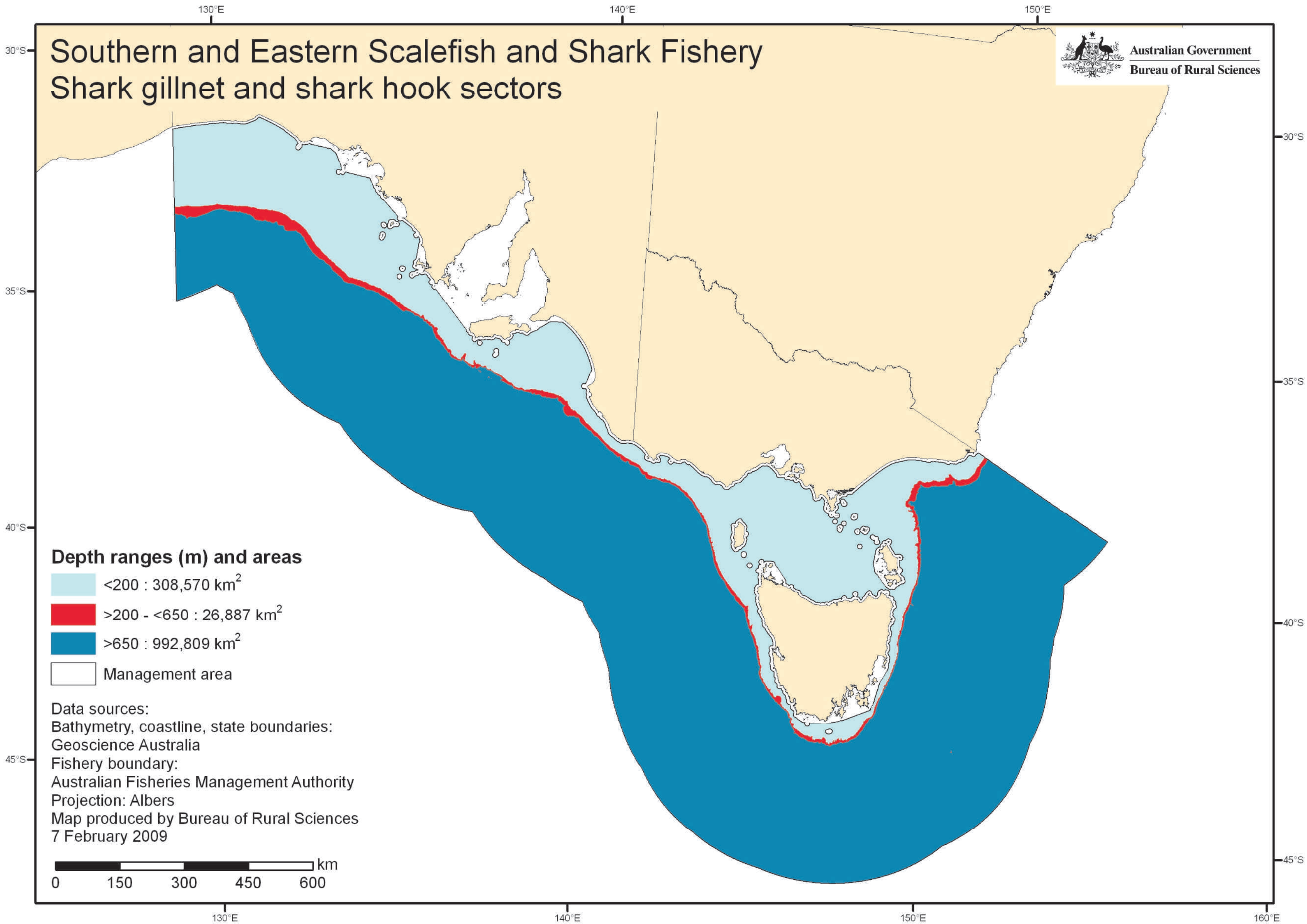
Appendix 5: Location of the upper-slope habitats in each sector of the SESSF




Southern and Eastern Scalefish and Shark Fishery
Great Australian Bight trawl sector
Australian Government
Bureau of Rural Sciences
120°E
125°E
130°E
135°E
115°E
30°S
35°S
40°S
Depth ranges (m) and areas
<200 : 71,092 km2
>200 - <650 : 22,734 km2
>650 : 695,529 km2
Management boundary
0
150
300
450
600
km
Data sources:
Bathymetry, coastline, state boundaries:
Geoscience Australia
Fishery boundary:
Australian Fisheries Management Authority
Projection: Albers
Map produced by Bureau of Rural Sciences
7 February 2009


130°E
140°E
150°E
160°E
25°S
30°S
35°S
40°S
45°S
Southern and Eastern Scalefish and Shark Fishery
Scalefish hook sector
Australian Government
Bureau of Rural Sciences
Lord Howe Island
Depth ranges (m) and areas
<200 : 309,027 km²
>200 - <650 : 28,947 km²
>650 : 1,911,475 km²
State waters
Management boundary
km
0 150 300 450 600
Data sources:
Bathymetry, coastline, state boundaries:
Geoscience Australia
Fishery boundary:
Australian Fisheries Management Authority
Projection: Albers
Map produced by Bureau of Rural Sciences
14 October 2008


Southern and Eastern Scalefish
and Shark Fishery
East coast deepwater trawl sector
Australian Government
Bureau of Rural Sciences
Depth ranges (m) and areas
<200 : 452 km2
>200 - <650 : 2,043 km2
>650 : 784,025 km2
Management boundary
East coast deep water trawl exclusion zone
Lord Howe Island
Data sources:
Bathymetry, coastline, state boundaries:
Geoscience Australia
Fishery boundary:
Australian Fisheries Management Authority
Projection: Albers
Map produced by Bureau of Rural Sciences
7 February 2009
0 100 200 300 400 km
150°E
160°E
25°S
30°S
35°S


Southern and Eastern Scalefish and Shark Fishery
Shark gillnet and shark hook sectors
Australian Government
Bureau of Rural Sciences
130°E
140°E
150°E
160°E
30°S
35°S
40°S
45°S
Depth ranges (m) and areas
<200 : 308,570 km2
>200 - <650 : 26,887 km2
>650 : 992,809 km2
Management area
Data sources:
Bathymetry, coastline, state boundaries:
Geoscience Australia
Fishery boundary:
Australian Fisheries Management Authority
Projection: Albers
Map produced by Bureau of Rural Sciences
7 February 2009
km
0 150 300 450 600

Appendix 6: Bycatch mitigation options - Chondrichthyan Technical Working Group

Table A. Options for mitigating bycatch of upper-slope (300-700m) dogfishes (i.e. gulper sharks) using auto-longline gear. Each mitigation option was ranked against a set of eight criteria. The ranking system was: ++ve (very positive impact), +ve (positive impact), --ve (very negative impact), -ve (negative impact), UK (unknown - not enough information for the working group to determine the impact), 0 (no impact). Note that the prefix of P indicates the impact given is potential. This was used in cases where the working group felt there may have been a particular type of impact but there was not enough information to say that definitively at the time. The suffix of ST indicated the impact will be short term. The suffix of SM indicates the impact would be small. The option of reducing soak time was only assessed for the first three criteria and was not discussed further due to the uncertainty of the impact.

A	Spatial / Temporal Closures	Reduce Effort	Reduce TAC (target sp.)	Stricter depth closures	No landings	Bait restrictions	Rusting hooks	Earth metal / chemical repellents	Reduction in soak time	Increase in hook size	Handling practices
1. Ability to reduce interactions	++ve	++ve	++ve	++ve	0	P +ve	0	P +ve	UK	P +ve	0
2. Ability to minimise level of discarding	++ve	++ve	++ve	++ve	--ve	P +ve	0	P +ve	UK	P +ve	P –ve
3. Ability to improve survivorship (once caught)	0	0	0	0	+ve	0	+ve	P -ve	P +ve	P -ve	+ve
4. Impact of option on other species and or habitats	+ve	++ve	++ve	++ve	0	P +ve	+ve	UK		UK	P +ve SM
5. Technical feasibility to detect a response	+ve	+ve	+ve	+ve	P +ve SM	++ve	+ve	+ve		+ve	+ve
6. Cost of monitoring (to detect response)	--ve	-ve	--ve	-ve	--ve	-ve SM	--ve	--ve		-ve	--ve
7. Level of industry support	-ve	---ve	---ve	---ve	-ve	-ve	-ve ST	+ve		-ve ST	+ve
8. Impact on currently collected catch data	-ve ST	-ve SM	-ve SM	-ve ST	-ve	-ve SM	P -ve	P –ve/ uk		-ve ST	0

Table B. Mitigation options from the Chondrichthyan Technical Working Group. Options for mitigating bycatch of upper-slope (300-700m) dogfishes using trawl gear. Each mitigation option was ranked against a set of eight criteria. The ranking system was: ++ve (very positive impact), +ve (positive impact), --ve (very negative impact), -ve (negative impact), UK (unknown - not enough information for the working group to determine the impact), 0 (no impact). Note that the prefix of P indicates the impact given is potential. This was used in cases where the working group felt there may have been a particular type of impact but there was not enough information to say that definitively at the time. The suffix of ST indicated the impact will be short term. The suffix of SM indicates the impact would be small. The option of reducing soak time was only assessed for the first three criteria and was not discussed further due to the uncertainty of the impact.

B	Spatial / Temporal Closures	Reduce Effort	Reduce TAC (target sp.)	Stricter depth closures	No landings	Earth metal / chemical repellents	Shorter shots	Gear modifications	Handling practices
1. Ability to reduce interactions	++ve	++ve	++ve	++ve	0	P +ve	P –ve	P -ve	0
2. Ability to minimise level of discarding	++ve	++ve	++ve	++ve	--ve	P +ve	P –ve	P -ve	0
3. Ability to improve survivorship (once caught)	0	0	0	0	P +ve SM	UK	P +ve	P +ve	+ve
4. Impact of option on other species and or habitats	+ve	++ve	++ve	++ve	0	UK	P -ve	P -ve	P +ve
5. Technical feasibility to detect a response	+ve	+ve	+ve	+ve	P +ve SM	+ve	+ve	+ve	+ve
6. Cost of monitoring (to detect response)	--ve	--ve	--ve	-ve	--ve	--ve	-ve	-ve	--ve
7. Level of industry support	-ve	---ve	---ve	---ve	-ve	+ve	--ve	--ve	+ve
8. Impact on currently collected catch data	-ve ST	-ve SM	-ve SM ST	-ve ST	-ve	--ve ST	-ve	--ve	0

Appendix 7: Annual catch data by sector, depth and CAAB code.

Table A. The Commonwealth Trawl Sector (CTS). Total catches (retained and discarded) of deepwater sharks (kg whole weight) from the CTS (1985-2008) from logbooks. Note: 2008 figures are incomplete. Refer to Table 2 for species codes.

CAAB Code 37 020 000	Depth zone			CAAB Code 37 020 001	Depth Zone		
Year	<200m	200-650m	>650m	Year	<200m	200-650m	>650m
1985	9 112	36 953	70	1985	0	0	0
1986	40 159	153 272	1 029	1986	0	0	0
1987	27 239	87 921	512	1987	0	0	0
1988	69 555	142 266	1 663	1988	0	0	0
1989	70 391	143 272	1 244	1989	0	0	0
1990	27 251	67 208	438	1990	0	0	0
1991	36 441	66 746	5 614	1991	0	0	0
1992	38 239	111 361	56 809	1992	0	0	0
1993	44 546	126 216	75 684	1993	0	0	0
1994	37 393	128 833	77 549	1994	0	0	0
1995	24 672	186 444	138 858	1995	0	0	0
1996	26 338	342 846	259 303	1996	0	0	0
1997	26 390	276 783	219 819	1997	0	0	0
1998	12 568	275 669	240 872	1998	0	0	0
1999	15 892	238 023	192 264	1999	90	0	0
2000	6 690	37 179	60 017	2000	265	6 779	867
2001	6 848	7 336	10 671	2001	410	11 525	818
2002	2 119	4 868	982	2002	1 214	5 743	372
2003	3 682	4 886	601	2003	38	4 489	670
2004	7 086	4 081	105	2004	437	4 784	692
2005	8 047	4 622	1 090	2005	569	4 534	69
2006	8 348	2 148	412	2006	675	2 687	40
2007	6 917	9 430	960	2007	217	2 060	312
2008	3 336	2 235	0	2008	405	332	5
Total	**559 259**	**2 460 598**	**1 346 566**	**Total**	**4 320**	**42 933**	**3 845**

Table B. The Great Australian Bight (GAB) Trawl Sector. Total catches (retained and discarded) of deepwater sharks (kg whole weight) from the GAB (1987-2008) from logbooks. Note: 2008 figures are incomplete. Refer to Table 2 for species codes.

CAAB Code 37 020 000	Depth zone			CAAB Code 37 020 001	Depth Zone		
Year	<200m	200-650m	>650m	Year	<200m	200-650m	>650m
1987	110	0	1	1987	0	0	0
1988	355	1 056	5	1988	0	0	0
1989	0	219	32	1989	0	0	0
1990	0	375	5	1990	0	380	0
1991	335	175	0	1991	0	0	0
1992	155	115	7	1992	0	0	0
1993	0	30	0	1993	0	0	0
1994	3 289	450	3	1994	0	0	0
1995	175	0	0	1995	0	0	0
1996	895	530	15	1996	0	0	0
1997	200	870	57	1997	0	0	0
1998	0	434	76	1998	0	156	0

1999	120	2 119	65	1999	0	0	0
2000	0	525	10	2000	0	90	0
2001	621	155	0	2001	0	0	0
2002	1 045	5	0	2002	0	0	0
2003	1 342	550	30	2003	0	137	0
2004	604	574	342	2004	40	0	0
2005	5 632	146	145	2005	210	0	0
2006	4 305	690	0	2006	0	30	0
2007	13 448	877	0	2007	30	10	0
2008	6 399	151	0	2008	0	0	0
Total	**39 030**	**10 046**	**793**	**Total**	**280**	**803**	**0**

Table C. Gillnet, Hook and Trap Sector (GHAT) (includes the Scalefish and Shark Hook Sectors, and the former Southeast Non-Trawl). Total catches (retained and discarded) of deepwater sharks (kg whole weight) from the GHAT (1985-2008), from logbooks. Note: 2008 figures are incomplete. Refer to Table 2 for species codes.

CAAB Code 37 020 000	**Depth zone**			**CAAB Code 37 020 001**	**Depth Zone**		
Year	**<200m**	**200-650m**	**>650m**	**Year**	**<200m**	**200-650m**	**>650m**
1985	0	0	0	1985	0	0	0
1986	0	0	0	1986	0	0	0
1987	0	0	0	1987	0	0	0
1988	0	200	0	1988	0	0	0
1989	0	0	0	1989	0	0	0
1990	0	0	0	1990	0	0	0
1991	0	0	0	1991	0	0	0
1992	0	0	0	1992	0	0	0
1993	0	0	0	1993	0	0	0
1994	0	0	0	1994	0	0	0
1995	0	0	0	1995	0	0	0
1996	0	0	0	1996	0	0	0
1997	1 787	13 710	164	1997	0	0	0
1998	1 202	3 223	40	1998	0	0	0
1999	1 037	7 646	66	1999	0	0	0
2000	26	1 419	0	2000	212	5 467	0
2001	0	1 105	0	2001	202	4 735	150
2002	58	1 194	165	2002	82	1 381	715
2003	5	237	1 055	2003	5	1 880	0
2004	60	73	144	2004	0	1 118	0
2005	1 126	185	35	2005	20	996	30
2006	592	212	20	2006	0	686	40
2007	296	1 194	57	2007	3	259	0
2008	154	23	10	2008	7	222	0
Total	**6 343**	**30 421**	**1 756**	**Total**	**531**	**16 744**	**935**

Table D. Independent Scientific Monitoring Program (ISMP). ISMP observation's of total catches (retained and discarded) of deepwater sharks (kg whole weight) in the SESSF trawl sectors combined (GAB, CTS, ECDWT) since 1992. Refer to Table 2 for species codes.

CAAB Code 37 020 000	**Depth zone**			**CAAB Code 37 020 001**	**Depth Zone**		
Year	**<200m**	**200-650m**	**>650m**	**Year**	**<200m**	**200-650m**	**>650m**
1992	0	417	28	1992	0	0	0
1993	413	149	20	1993	0	10	0
1994	2 411	10 770	2 068	1994	0	0	0
1995	1 366	8 042	2 018	1995	0	0	0
1996	11 073	532	0	1996	0	172	4
1997	2 093	203	0	1997	28	1 417	50
1998	1 308	130	85	1998	60	411	8
1999	7	37	262	1999	480	730	0
2000	3	103	132	2000	1 299	1 266	115
2001	0	0	8	2001	0	882	14
2002	0	0	73	2002	0	251	0
2003	0	0	10	2003	0	51	5
2004	0	0	118	2004	0	283	0
2005	32	10	171	2005	0	101	0
2006	0	0	1 107	2006	0	98	0
2007	275	175	17	2007	0	0	0
Total	**18 981**	**20 568**	**6 117**	**Total**	**1 867**	**5 672**	**196**
CAAB Code 37 020 009	**Depth zone**			**CAAB Code 37 020 011**	**Depth Zone**		
Year	**<200m**	**200-650m**	**>650m**	**Year**	**<200m**	**200-650m**	**>650m**
1992	0	0	0	1992	0	0	0
1993	0	10	0	1993	115	174	0
1994	0	0	26	1994	87	0	0
1995	0	0	0	1995	135	0	0
1996	0	0	0	1996	4	0	0
1997	0	0	0	1997	0	0	0
1998	0	0	0	1998	0	39	0
1999	0	0	0	1999	1	69	0
2000	0	0	0	2000	0	14	0
2001	0	0	0	2001	14	71	10
2002	0	6	0	2002	8	224	25
2003	0	0	0	2003	51	486	383
2004	0	0	0	2004	0	705	31
2005	0	0	0	2005	0	63	0
2006	0	0	0	2006	15	48	10
2007	0	0	0	2007	2	449	8
Total	**0**	**16**	**26**	**Total**	**432**	**2 342**	**467**
CAAB Code 37 020 902	**Depth zone**			**CAAB Code 37 020 010**	**Depth Zone**		
Year	**<200m**	**200-650m**	**>650m**	**Year**	**<200m**	**200-650m**	**>650m**
1992	0	0	0	1992	0	0	0
1993	0	0	0	1993	4	0	0
1994	0	0	0	1994	4	0	0
1995	0	0	0	1995	0	0	0
1996	995	0	0	1996	0	0	0
1997	1 198	0	0	1997	0	0	0

1998	0	0	0	1998	0	0	0
1999	0	0	0	1999	0	8	0
2000	0	52	11	2000	0	0	0
2001	0	46	50	2001	0	0	0
2002	0	48	53	2002	0	2	0
2003	0	33	0	2003	5	0	0
2004	0	211	50	2004	0	0	0
2005	0	27	4	2005	0	4	0
2006	0	6	0	2006	0	0	0
2007	0	0	0	2007	0	0	0
Total	**2 193**	**423**	**168**	**Total**	**13**	**14**	**0**

Table E. ISMP observation's of total catches (retained and discarded) of deepwater sharks (kg whole weight) in the SESSF Scalefish Hook Sectors since 1999 where recorded. Refer to Table 2 for species codes.

CAAB Code 37 020 000		**Depth zone**		**CAAB Code 37 020 001**		**Depth Zone**	
Year	**<200m**	**200-650m**	**>650m**	**Year**	**<200m**	**200-650m**	**>650m**
1999				1999		14	
2000				2000		37	
2001				2001			
2002				2002			
2003				2003	5	138	
2004		240		2004		273	
2005		44		2005		11	
2006		3		2006			
2007		146		2007			
Total	**0**	**433**	**0**	**Total**	**5**	**473**	**0**

CAAB Code 37 020 009		**Depth zone**		**CAAB Code 37 020 011**		**Depth Zone**	
Year	**<200m**	**200-650m**	**>650m**	**Year**	**<200m**	**200-650m**	**>650m**
2002				2002		1	
2003				2003		47	
2004		1		2004		6	
2005				2005			
2006				2006		857	
2007				2007		24	
Total	**0**	**1**	**0**	**Total**	**0**	**934**	**0**

CAAB Code 37 020 902		**Depth zone**		**CAAB Code 37 020 010**		**Depth Zone**	
Year	**<200m**	**200-650m**	**>650m**	**Year**	**<200m**	**200-650m**	**>650m**
2002				2002		1	
2003				2003		4	
2004				2004		128	
2005		2 902		2005			
2006				2006			
2007				2007		588	
Total	**0**	**2 902**	**0**	**Total**	**0**	**721**	**0**

Appendix 8: Total annual effort and scientific observations in the SESSF

Table A. Total annual reported effort in each sector of the SESSF, as recorded in logbooks (1992-2008). Number of shots, except for Fish trap (trap lifts) and DL Dropline (line sets). N/A - no information available.

Year	CTS Otter Trawl	CTS Danish Seine	GAB Otter Trawl	ECDWT Otter Trawl	GHAT Auto-longline	GHAT Demersal longline	GHAT Drop-line	GHAT Fish Trap	GHAT Gillnet
1992	24 042	9 645	2 187	N/A	N/A	N/A	N/A	N/A	N/A
1993	27 670	9 678	1 823	N/A	N/A	N/A	N/A	N/A	N/A
1994	30 624	9 487	1 527	N/A	N/A	N/A	N/A	N/A	N/A
1995	30 458	8 554	2 207	N/A	N/A	N/A	N/A	N/A	N/A
1996	32 358	10 106	2 578	N/A	N/A	N/A	N/A	N/A	N/A
1997	32 834	10 836	3 562	N/A	32	499	11 466	8 180	11 284
1998	31 097	11 289	3 211	N/A	61	521	11 269	7 761	16 070
1999	32 928	11 132	3 232	N/A	96	554	14 799	9 530	15 559
2000	35 604	9 937	2 490	68	56	656	16 680	12 290	13 488
2001	35 336	9 514	3 214	450	76	784	13 107	6 525	12 671
2002	33 502	9 823	2 586	102	278	624	9 606	11 309	12 656
2003	33 604	9 616	4 601	189	482	817	8 923	1 690	13 101
2004	32 443	8 251	5 585	269	1 391	1 052	16 057	0	12 900
2005	28 984	7 764	6 260	103	1 264	883	5 003	0	11 174
2006	23 880	6 408	5 907	0	1 313	690	4 054	0	11 212
2007	15 778	6 442	4 537	79	663	722	1 421	0	9 155
2008	15 845	6 401	3 135	0	550	605	1 041	0	7 735

Source: AFMA data section

Table B. Total number of scientific observations (number of shots/sets/lifts observed) by year for each sector of the SESSF.

Year	CTS Otter Trawl	CTS Danish Seine	GAB Otter Trawl	ECDWT Otter Trawl	GHAT Auto-longline	GHAT Demersal longline	GHAT Drop-line	GHAT Fish Trap	GHAT Gillnet
1992	69	0	0	0	0	0	0	0	0
1993	537	27	0	0	0	0	0	0	0
1994	618	261	0	0	0	0	0	0	0
1995	420	183	0	0	0	0	0	0	0
1996	607	0	0	0	0	0	0	0	0
1997	752	0	0	0	0	0	0	0	0
1998	677	23	0	0	0	0	0	0	0
1999	905	48	0	0	0	26	183	12	62
2000	750	27	122	55	0	0	210	0	29
2001	906	41	172	44	0	14	117	40	0
2002	769	35	155	71	50	4	239	17	4
2003	820	118	135	0	98	38	190	0	0
2004	758	48	173	27	197	19	19	0	0
2005	880	73	217	0	128	7	12	0	0
2006	726	131	175	0	104	4	32	0	0
2007	451	24	145	0	205	0	7	0	45
2008	571	39	158	0	281	29	0	0	56

Source: AFMA data section (2008 data preliminary)

Appendix 9: Management, data and research options

The following management, data and research options aim to meet the primary objective of the study, that is, to reduce the ecological risk to upper-slope gulper sharks in Australia's SESSF and as such, should be considered in light of the broader management context for the fishery, including the likely social, economic and wider ecological effects.

No.	Options	Priority
	Data improvements	
1	Develop a gulper shark identification key and field guide suitable for use onboard SESSF vessels	Very High
2	Train scientific observers and SESSF crew on how to use the key/guide effectively in the field	Very High
3	Develop and maintain a regular program of training/review on using the key/guide for gulper shark identification	High
4	Explore the use of genetic techniques as a means to periodically validate identifications of both logbook and scientific observer data	Low
5	Update all fishery documentation, including the SESSF Management Arrangements booklet and SFR/permit conditions, to reflect the correct use of species names	High
6	Voucher specimens to be periodically taken from industry vessels, ISMP and all future research surveys, and lodged at an appropriate facility, so that periodic validation of species identifications can be made	Med
7	Ensure that the levels of scientific observer coverage for each SESSF sector are accurately recorded, by ensuring that catch observations are paired with actual effort in the fishery, such as trawl hours or hooks set as appropriate	Med
8	Ensure that scientific observer coverage rates (by hour or hooks set as appropriate) are made publically available on a regular (at least annual) basis	Med
9	Temporarily increase scientific observer coverage rates to 20-30 percent of actual effort (hours trawled, hooks set) for all vessels fishing the upper-slope habitat, while a long-term coverage rate is determined (Option 10), as previous ISMP data was determined as being of little use in estimating species specific gulper shark catch and discard rates	Very High
10	Facilitate research aimed at statistically determining optimal scientific observer coverage levels for each sector of the SESSF, with the aim of facilitating a robust assessment and quantification of the effects of fishing on gulper shark populations	High
11	Ensure that scientific observer coverage is representative of each sector of the SESSF, by vessel-types, areas and months	High

No.	Options	Priority
	Management	
12	Implement both immediate and long-term management strategies, to recover the severely depleted (overfished) stocks of gulper sharks on the upper-slope habitat of the SESSF	Very High
	Immediate	
13	Prohibit the use of longline and auto-longline methods of fishing on the upper-slope habitat of the SESSF until research has determined the size of long-term closures necessary to ensure the viability of gulper sharks on the upper-slope	High
14	Prohibit the use of automated de-hooking machines in the SESSF	Very High
15	Place large temporary area closures on the upper-slope habitat of the SESSF, prohibiting all forms of fishing capable of taking or negatively interacting with gulper sharks, while long-term measures are developed. Noting the area west of Albany, WA, is an ideal area for closure due to the presence of unfished populations of *C. westraliensis*.	Very High
16	Replace the current gulper shark trip and voluntary annual limits with a no-take policy (zero TAC), in tandem with improved education and training on the requirement to record gulper shark discards in logbooks	Very High
	Long-term	
17	Develop a network of adequately sized area closures (determined from the research options described below, and from the range of closure options provided in this report), that prohibit all forms of fishing capable of taking or negatively interacting with gulper sharks on the upper-slope habitat of the SESSF, in tandem with a no-take/zero TAC policy in areas that remain open to fishing	Very High
18	Develop and implement a management strategy for gulper sharks on the upper-slope of the SESSF as a matter of urgency	High
19	Ensure the management strategy includes measures that will facilitate the recovery of gulper shark stocks to ecologically sustainable levels, via appropriate reference points	High
20	Ensure the management strategy considers the types of long-term management measures outlined in this report and the associated research required to improve the effectiveness of these measures	High
	Research	
21	Undertake research to determine the current distribution and abundance of gulper sharks in the SESSF and neighbouring areas, preferably using non-lethal techniques to minimise negative impacts on the remaining populations	High

No.	Options	Priority
22	Develop non-lethal sampling techniques to monitor gulper shark distribution and abundance	High
23	Determine if populations of gulper sharks are segregated by size and sex, and if so, ensure these spatially segregated sub-populations are adequately protected	Med
24	Determine spatial and temporal movement rates, particularly into and out of current and proposed closed areas, and also the movement rates between different parts of the SESSF	High
25	Undertake research to determine the degree to which gulper sharks make daily vertical migrations in the water column, to assess whether temporal depth closures are a viable option	Low
26	Replicate the current CSIRO habitat mapping surveys taking place in the Great Australian Bight, on the east coast of Australia where the majority of gulper shark interactions have been recorded	Med
27	Undertake opportunistic research aimed at improving the understanding of the biology and life history, including the validation of ageing, determining the annual fecundity, gestation period, resting period, maturity/maternity, birth size, and trophic ecology, for species of gulper shark where this information doesn't already exist	Low
28	Determine if bycatch reduction devices will reduce the take of gulper sharks from the upper-slope of the SESSF, and if so, implement such devices	Low
29	Undertake research to determine the rates of survivorship of gulper sharks that have been caught using various gear types deployed for differing times in the SESSF, and if necessary how survivorship can be improved	Med
30	If trip limits are to be retained, determine the scientific basis and validity of the current 150 kg trip limit as a conservation measure to protect gulper sharks in the SESSF	Low
31	Investigate the potential for deterrents, such as rare earth metals, to be effective in mitigating fishery interactions for gulper sharks	Low