King George whiting (*Sillaginodes punctata*) Fishery

Fishery Assessment Report to PIRSA

AJ Fowler, R McGarvey, and JE Feenstra

August 2008

SARDI Publication Number F2007/000843-2

SARDI Research Report Series Number 296

King George whiting (*Sillaginodes punctata*) Fishery

Fishery Assessment Report to PIRSA

AJ Fowler, R McGarvey, and JE Feenstra

August 2008

This publication may be cited as:
Fowler AJ, McGarvey R, Feenstra JE. (2008). King George whiting *(Sillaginodes punctata)* Fishery. Fishery Assessment Report to PIRSA Fisheries. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, 77 pp. SARDI Publication Number F2007/000843-2. SARDI Research Report Series No. 296.

South Australian Research and Development Institute
SARDI Aquatic Sciences
PO Box 120
HENLEY BEACH SA 5022

Telephone: (08) 8207 5400
Facsimile: (08) 8207 5481
http://www.sardi.sa.gov.au

Author(s):	A.J. Fowler, R. McGarvey, J.E. Feenstra
Reviewers:	M.A. Steer and T. Ward
Approved by:	T. Ward
Signed:	
Date:	8th August 2008
Distribution:	PIRSA Fisheries, SARDI Aquatic Sciences Library
Circulation:	Public Domain

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. EXECUTIVE SUMMARY

1. This is the 7th in a series of stock assessment reports on South Australia's King George whiting fishery since 1997. This assessment comes 3.5 years after important changes were made to the management in response to a significant down-turn in the fishery through the period of 1999 to 2002.

2. This report provides an assessment of three types of fishery performance indicators: State-wide and regional commercial catch, effort and CPUE data by gear type for the period of 1984 to 2007, thus adding three years of data since the last assessment; recent data population size and age structures for numerous places across the State; estimates of output parameters from the computer fishery assessment model WhitEst for the period of 1984 to 2007, including seasonal and annual estimates of recruitment, fishable biomass and exploitation rate.

3. The State-wide commercial fishery statistics were dominated by a declining trend in fishing effort due to the ongoing decline in the number of commercial fishers. As a consequence, commercial catch has also experienced a long downward trend. The trend in State-wide handline CPUE between 2005 and 2007 was upward, thus indicating a significant turn-around from the downward trend that was evident between 1999 and 2002. All regional trends in handline CPUE were also upward.

4. The size and age structures determined from market sampling done during 2006/07 did not differ from the population structure evident through the 1990s and early 2000s. As such, there is no evidence for population truncation over the past decade that is relatable to the fishery.

5. The output parameters from WhitEst showed strong increases in recruitment and fishable biomass for 2005-07, relative to the early 2000s, at the State-wide level and for each of the principal regions of West Coast, Spencer Gulf and Gulf St. Vincent. The model also indicated decreasing exploitation rates for the commercial sector.

6. The fishery performance indicators were compared against limit reference points. Breaches of limit reference points related to the on-going reduction in total catch and to the historically high levels of catch rates in each of 2005, 2006 and 2007. These results

were positive signs for the status of the fishery, indicating that there has been a significant turn-around since the negative status that was evident from 1999 to 2002.

7. The biological fishery performance indicators that were compared against limit reference points included fishable biomass, recruitment and exploitation rates. These were estimated using the WhitEst model for both the regional and State-wide spatial scales. Estimates of fishable biomass and recruitment rates in 2007 were generally above the 5-year averages and breached limit reference points. Estimates of exploitation rate were relatively low on the West Coast, but approached the maximum recommended level in the two gulfs.

8. The fourth biological performance indicator considered was population age structure. There was no evidence that any regional population age structures had changed significantly over the past decade.

9. The primary uncertainty in our understanding of the King George whiting fishery relates to the lack of time series data on catch and effort from the recreational sector. This means that trends in total catch and exploitation are unknown. A recreational fishery survey is currently underway, whose results will be comparable to data collected in 2000/01. These trends in recreational catch and effort data will be available for the next stock assessment scheduled for 2011.

10. The positive indicators provide no concern about the current status of the stocks in South Australia's King George whiting fishery.

2. GENERAL INTRODUCTION

2.1. Overview

Stock assessments have been produced regularly for King George whiting since 1997 with this being the seventh since that time. This report has two aims; to present information from the fishery and the biology of the species, and to synthesise this information into an assessment of the status of the stocks. The last stock assessment report was completed in August 2005, which reported on data available up to the end of 2004 (McGarvey et al. 2005). This report incorporates a further three years of commercial catch and effort data, presenting data collected up to the end of 2007.

This chapter provides introductory information that establishes the context for the information that follows in the subsequent empirical and modelling based chapters. It includes a description of the fishery, a statement of the management regulations, and provides historical data on catch and effort levels in the recreational sector. It also provides a summary of the population biology and life history of the species based on research that has been done over the past 30 years or so across southern Australia. Chapter 3 presents a summary of the data from the commercial fishery for the three years of 2005 to 2007, i.e. State-wide and regional estimates of fishery catch, effort and CPUE. These data are then placed in their historical context based on similar information that has been collected since 1984. This involves a detailed consideration of the regional estimates of catch and effort for the three main gear types of handlines, haul nets and gill nets for seven fishery regions.

Chapter 4 provides an analysis of the population size and age structures based on samples collected from across the State by market sampling between July 2006 and June 2007. Since the population characteristics of King George whiting are so variable from place-to-place and so dependent on life history processes it is important that such data be collected every few years to assess for possible size and age truncation and also to update the computer fishery assessment model.

Chapter 5 presents the output from the fishery stock assessment model WhitEst that integrates several types of data from the fishery to output various parameters that indicate the status of the fishery (Fowler and McGarvey 2000). The input data include: the time series of commercial catch and effort data; data on recreational catch from the NRIF survey; and regional estimates of population size and age structures that were collected at various times

between 1995 and 2008. The model output includes time-series of estimates of recruitment, fishable biomass and annual exploitation rate for the three regions of West Coast, Spencer Gulf and Gulf St. Vincent/Kangaroo Island.

Chapter 6 addresses the second aim of the report, i.e. to determine the status of the King George whiting fishery in South Australia. This is done by considering the biological performance indicators that are specified in the Marine Scalefish Fishery Management Plan (Noell et al. 2006), and by comparing the data available for King George whiting against the prescribed limit reference points. Chapter 7 also pertains to the second aim of the report. The data from various sources that were considered in Chapters 3 to 6 are considered in the context of the assessment of biological performance indicators to determine the status of the fishery at the end of December 2007.

2.2. Description of Fishery

In South Australia, the fishery for King George whiting is geographically extensive, and includes all coastal waters from Gulf St. Vincent westwards to Denial Bay, throughout which it is intensively targeted by recreational and commercial marine scalefish fishers. The commercial fishery produces, on average, about 3 times greater harvested biomass than Victoria and significantly more than the catch of Western Australia (ABARE 2007). In South Australia, King George whiting has traditionally been the most valuable marine scalefish species, but in 2000/01 its total value dropped to second behind that of sardines (Knight et al. 2004). However, King George whiting remains the highest value species by unit weight (Knight et al. 2007a).

The King George whiting fishery in South Australia is a "gauntlet" fishery. Juveniles move from shallow, protected nursery areas to adjacent deeper water where they become vulnerable to fishing. The faster growing individuals in each annual cohort reach fishable size during the period of rapid growth in late summer and autumn when water temperatures are highest. Seasonal levels of exploitation in the commercial fishery for both handlines and haul nets peak in late autumn and winter, when the new recruits are targeted. Monthly catches generally peak in July. In early summer, when fish reach about 3.5 years of age (based on a birth date of 1st May (Fowler and Short 1998)), movement of young adult King George whiting in the two gulfs is directed southwards. As fish move south they encounter a gauntlet of fishing nets and lines that are used to target these young adults, resulting in high levels of exploitation. The survivors that reach the southern, deeper, offshore spawning areas at and near the mouths of

the two gulfs replenish the populations of larger, older fish (Fowler et al. 2000a, Fowler et al. 2002).

The fisheries in Gulf St. Vincent, northern Spencer Gulf and the West Coast bays predominantly take relatively small, young, immature fish of about 3 years of age that are quite close to the minimum legal size, while fish on the spawning grounds tend to be larger and older, with some up to 18 years of age. Analysis of the reproductive activity of adult fish during the time of spawning in different regions of the two gulfs indicated that King George whiting of comparable size and age showed no evidence of spawning activity in the northern regions, but nearly all those found in the southern aggregations, regardless of size, showed evidence of active spawning (Fowler et al. 1999, Fowler et al. 2000a). Since spawning in the gulfs is confined to southern areas, the reproductive sustainability of populations is determined by successful persistence of resident populations in these spawning areas. These spawning sub-populations of larger, older fish are replenished annually by immigrants from inshore fishing grounds and the upper gulfs. These immigrants are 3-4 years of age (Fowler et al. 2000a, Fowler et al. 2002). Historically, the exploitation of spawning aggregations was relatively low, which may have accounted for the stable recruitment of King George whiting over the years for which catch data were available (Fowler and McGarvey 2000, McGarvey et al. 2000). However, anecdotal reports suggest that with a developing charter boat fishery and an expanded range offshore of the commercial and recreational sectors, it is possible that fishing pressure on the spawning aggregations has increased in recent years.

The commercial sector of the Marine Scalefish fishery uses a variety of gear types of which handlines, haul nets and gillnets are the principal ones for targeting King George whiting. Recreational fishing is by hook and line, principally from boats.

2.3. Management Regulations

New management regulations for the South Australian King George whiting fishery were implemented in October 2004. These included: (1) an increase in legal minimum length (LML) from 30 to 31 cm in all waters east of longitude 136°E; (2) the daily recreational bag limit was reduced from 20 to 12 legal-size fish per person, with the boat limit reduced from 60 to 36 fish per boat; (3) the existing licence amalgamation scheme was enhanced by reducing the number of points needed to acquire an amalgamated licence (from 26 to 24); (4) also, if a non-licensed person was detected in possession of more than 75 King George whiting, which is considered a commercial quantity, then that person may be guilty of an offence. At that time

consideration of appropriate management options were informed by management simulations that were undertaken using the simulation model WhitSim that tested a range of different strategies. The results of these had previously been summarised in an earlier stock assessment report (McGarvey et al. 2003).

The principal means of effort control in the commercial sector is limited entry. Furthermore, since 1994 a license amalgamation scheme has been operating to reduce effort in this sector and to remove latent effort from the fishery. As a consequence, the number of commercial Marine Scalefish licenses ('M' and ''B' class) has fallen from 701 in 1984 to 350 in 2005/06. Furthermore, the use of haul nets in the commercial sector is strongly regulated by a complex suite of input and output controls. The nets must have a mesh size of less than 15 cm, a maximum length of 600 m, a maximum drop of 5 m in the wings and 10 m in the bunt or pocket. Their use is restricted to waters of less than 5 m depth, and is banned within half a nautical mile of any officially recognised artificial reef and within a radius of 100 m of any jetty, wharf or pier. Furthermore, there are many permanent and seasonal netting closures that have been introduced over the years for such reasons as protection of nursery areas and spawning grounds (Noell et al. 2006). A significant rationalisation of the net sector was undertaken in 2005 when a net license buy-back scheme resulted in the reduction in net endorsements from 104 to 49 and the removal of approximately 45% of net fishing effort. At that time further permanent spatial closures to the net fishery were also implemented in large parts of the State's inshore waters.

Previous significant changes to the management of the King George whiting fishery include a reduction in the recreational bag limit from 30 to 20 fish.day^{-1} or from 90 to 60 fish.boatday^{-1} in September 1994. This was followed by an increase in the LML from 28 to 30 cm TL for both commercial and recreational sectors in September 1995 (Fowler and McGarvey 1997).

2.4 Recreational Fishery

Since the production of the Marine Scalefish Green Paper (Jones et al. 1990) our understanding of the recreational catch and effort for King George whiting in South Australia has been based on results from two surveys; a creel survey through 1994-96 (McGlennon and Kinloch 1997), and the National Recreational and Indigenous Fishing Survey (NRIFS) for the period of May 2000 – April 2001 (Henry and Lyle 2003). The sampling methodologies and estimates of recreational catch and effort for King George whiting from these two large-scale surveys are described below. Furthermore, since September 2005 the charter boat sector has been

providing monthly catch and effort data that were recently summarised in a status report (Knight et al. 2007b).

Creel Survey (1994-'96)

This was an extensive two-year SARDI/FRDC project that estimated the recreational catch of marine boat-fishers in several regions across South Australia, between Victor Harbor and Ceduna (McGlennon and Kinloch 1997). The study used the 'bus-route' survey method where interviewers travelled around pre-determined circuits of boat ramps, where at each ramp the number of boat trailers was counted to estimate fishing effort and any fishers that returned to the boat ramp during the waiting period were interviewed to provide estimates of catch. The results were used to derive estimates of total catch and effort, using the techniques summarised in McGlennon and Kinloch (1997). Since the creel survey was restricted to some public boat ramps during daylight hours it provided estimates of only a subset of the total recreational catch. Also, Kangaroo Island and east of Victor Harbor were excluded due to the time and costs of travel.

Spatial comparison

Over the 2 years of the recreational boat survey, 631 sample-days were surveyed during which 3,513 interviews were conducted. Total annual fishing effort was estimated at 988,980 boat hours, distributed over 200,000 boat trips. Of this total fishing effort, 41% was targeted at King George whiting. The total harvest of all major species was estimated to be 3,770,256 fish, which included 1,154,662 (31% of total) King George whiting.

Of the catch of King George whiting, 98.8% was taken in six of the fishery regions for which commercial fishery data are considered, i.e. Far West Coast (FWC), Mid-West Coast (MWC), Coffin Bay (CB), Southern Spencer Gulf (SSG), Northern Spencer Gulf (NSG) and Gulf St. Vincent (GSV) (Table 2.1). Targeted recreational effort increased from west to east, probably reflecting the trend in human population density, with Gulf St. Vincent having the highest recreational effort due to the influence of metropolitan Adelaide. Total catches also decreased from east to west, presumably reflecting geographic variation in fishing effort. However, CPUE was variable among the regions, i.e. the two Spencer Gulf regions and the Far West Coast had the highest catch rates, while Gulf St. Vincent and the Mid West Coast produced the lowest.

Table 2.1 Summary of results of catch and targeted effort on King George whiting, based on the creel survey of the recreational boat fishery through 1994 –'96 (McGlennon and Kinloch 1997).

Region	Total catch (t)	Total catch (numbers)	Targeted effort (boat-days)	CPUE (kg.boat-day^{-1})	CPUE (no.boat-day^{-1})	% of total by rec fishery
FWC	21.1	94,039	4,537.1	4.65	20.7	15.8
MWC	5.8	35,466	3,871.3	1.50	9.2	14.9
CB	21.3	110,184	7,039.4	3.03	15.7	28.1
SSG	80.5	274,220	15,605.8	5.16	17.6	39.3
NSG	51.9	227,269	12,267.7	4.23	18.5	34.9
GSV	85.1	399,536	33,230.9	2.56	12.0	48.4
Total	265.7	1,140,714	76,552.2			34.2

In Gulf St. Vincent, the total recreational catch was almost comparable with that of the commercial fishery. Westwards from there, there was a trend of decreasing significance of recreational catch. In Spencer Gulf, the recreational component was greater than a third of the total, but on the west coast the recreational catch was less than one sixth of the total.

National Recreational and Indigenous Fishing Survey (2000/01)

Recreational Catch

A national FRDC-NHT funded project for estimating non-commercial catches of marine fish species was undertaken from May 2000 to April 2001 (Henry and Lyle 2003). The sampling method was by telephone and diary survey, providing a more comprehensive census of the total recreational and indigenous catch than the creel survey described above. This telephone and diary survey also included catches from charter boats, which accounted for 1.7% of the recorded recreational fishing effort.

The estimate of State-wide recreational harvest of King George whiting was 2,238,071 fish, with an estimated total weight of 584.7 tonnes (Table 2.2). Both these estimates were approximately twice those from the creel survey (c.f. Table 2.1). In 2000/01 the highest catches were made in (GSV + KI) and SSG. The catches decreased from east to west. In every region the estimated recreational catch in 2000/01 was substantially higher than that of 1994/96. For the survey period, the total State-wide catch of King George whiting, combining recreational and commercial catches, was 1,023.4 tonnes. The estimated recreational catch of 584.7 tonnes exceeded that of the commercial catch. Also, in most regions the recreational component of the total catch exceeded the commercial component (Table 2.2).

Table 2.2. Summary of results from the National Recreational and Indigenous Fishing Survey (Henry and Lyle 2003) for King George whiting in South Australia for the period of May 2000 – April 2001, compared with estimates of the commercial catch over the same time period.

Region	Estimate of numbers caught	Average weight per fish (g)	Estimated recreational catch (tonnes)	Estimated commercial catch (tonnes)	Total regional catch (tonnes)	Recreational % of total
(FWC + MWC)	227,867	233.01	53.1	138.6	191.7	27.7
CB	425,941	199.40	84.9	24.3	109.2	77.7
SSG	548,354	322.09	176.6	107.7	284.3	62.1
NSG	407,218	209.51	85.3	69.0	154.3	55.3
(GSV + KI)	588,940	289.26	170.4	98.8	269.2	63.3
Other Regions	39,751	362.20	14.4	0.3	14.7	98.0
Total	2,238,071		584.7	438.7	1,023.4	57.1

Recreational Effort

The NRIF survey estimated that there were 328,277 recreational fishers in the State, representing approximately 176,000 households that used a total of 38,713 boats for their recreational fishing activities (Jones and Doonan 2005). Recreational fishers from across all South Australian waters, including inland waters and the Lakes and Coorong, engaged in an estimated 2,216,041 fishing events that occupied a total of 9,767,947 fishing hours. Of these totals, it is estimated that there were 1,544,295 fishing events and 5,783,000 fishing hours undertaken in marine waters for Marine Scalefish fish species.

Table 2.3 Summary of regional estimates of recreational fishing effort for King George whiting, based on the results of the National Recreational and Indigenous Fishing Survey by region (Jones and Doonan 2005).

Fishing Region	Effort (hrs) - targeted on KGW	Effort (hrs) – KGW not targeted, but landed	Total effort (hrs) on KGW	Targeted effort (% of total effort)
West Coast	317,632	80,404	398,036	79.8
Spencer Gulf	570,716	127,402	698,118	81.8
Gulf St. Vincent	359,487	120,476	479,963	74.9
Kangaroo Island	45,251	10,436	55,687	81.3
South East	46,574	28,194	74,768	62.3
Total	1,339,659	366,912	1,706,571	78.5

For King George whiting the estimates of total estimated targeted and non-targeted effort were 1,339,659 hours and 366,912 hours, respectively (Table 2.3). Thus, targeted effort constituted about 78.5% of the total on King George whiting. The highest levels of effort were in the two gulfs, whilst Spencer Gulf supported the highest targeted effort. The West Coast also received

a high level of targeted recreational effort. The waters around Kangaroo Island and the South East experienced relatively low levels of effort on King George whiting, compared with the other regions.

2.4. Population Biology and Life History

Although the general life cycle of King George whiting has been known for a number of years (Jones et al. 1990), our understanding of it was further enhanced through FRDC project 95/008 (Fowler and McGarvey 2000). That study synthesised information on population age structures, adult movement patterns, reproductive biology, characteristics of recruitment and genetic structure to develop a comprehensive picture of the life history and stock structure of this species in South Australia.

The nursery areas for recruitment of King George whiting are shallow, protected bays where the post-larvae arrive during the winter and spring in each year. Important nursery areas include Barker Inlet, Franklin Harbor, and the West Coast bays. Juveniles reside in these nursery habitats for a year or two before they move out into gulf waters or deeper areas of the West Coast bays, which are characterised by broken, low-profile reef and stands of seagrass (e.g. *Posidonia* spp.) (Jones et al. 1990).

When the fish reach 3-4 years of age they are capable of moving distances of up to several hundred kilometres within a few months (Fowler and McGarvey 1997, Fowler and March 2000, Fowler and McGarvey 2000, McGarvey and Feenstra 2002, Fowler et al. 2002). They migrate from nursery areas to spawning grounds, whilst there are also less directed movements among coastal areas, mostly along the coast. Fish from Gulf St. Vincent and northern Spencer Gulf move the greatest distances, generally in a net southerly direction. Some tagged fish from Gulf St. Vincent were recaptured along the north coast of Kangaroo Island; some from northern Spencer Gulf were recaptured principally in Hardwicke Bay in the south-east of the gulf, whilst some were found around the islands of the south-western part of the gulf; those from West Coast bays were rarely recaptured, but are thought to end up around shoals and islands offshore of the bays. In contrast, fish tagged near Kangaroo Island and southern Spencer Gulf did not move far and showed no systematic directional displacement (Fowler and McGarvey 1997, 1999; Fowler and March 2000; Fowler et al. 2002). These different movement patterns influence population structure. In those source areas from where fish move and where fishing is concentrated, population structure is generally truncated, consisting of small fish from a few young age classes. By contrast, at destination locations, many older age

classes are well represented with some fish up to 18 years of age (Fowler et al. 1999, Fowler et al. 2000a).

Spawning occurs at the offshore grounds to which fish migrate, including: in Investigator Strait along the north coast of Kangaroo Island; the south-eastern tip of Yorke Peninsula in Gulf St. Vincent (Tapley Shoal); and south-eastern Spencer Gulf around Corny Point and Wardang Island. Spawning typically occurs between March and May (Fowler et al. 1999, Fowler et al. 2000a). Patterns of distribution and abundance of larvae, determined by plankton sampling during the 1980s (Bruce 1989), provided further evidence that spawning occurs in the southern locations and that larvae are advected northwards into the gulfs (B. Bruce unpublished data). To date, the spawning areas responsible for replenishing the West Coast bays have not been determined. Commercially harvested fish from these bays display minimal gonad maturation, suggesting that spawning may occur further offshore from these fishing grounds.

The long pre-settlement duration of 80 to >120 days for larval King George whiting (Fowler and Short 1996) would be expected to provide ample opportunity for advection over long distances by hydrodynamic processes, as is the case for Victorian populations (Jenkins et al. 2000). In Port Phillip Bay, Victoria, the inter-annual variation in post-larval abundance is strongly correlated with the strength of the zonal westerly winds that presumably influence the rate of transport of the larvae. This influences recruitment success and productivity to the fishery several years later (Jenkins 2005). Because of this, it is possible that spawning by the South Australian stock ultimately replenishes the populations of King George whiting in Port Phillip Bay, Western Port and Corner Inlet, i.e. the places where this species is commercially fished in Victoria. In contrast, however, hydrodynamic modelling for the coastal areas around South Australia suggests that King George whiting larvae are advected over only relatively short distances of 50-100 km (Fowler et al. 2000b). This suggests that the South Australian populations are sustained by local spawning. The hydrodynamic modelling suggested the existence of relationships between particular spawning locations and nursery areas separated only by 100-200 km. Furthermore, the combination of hydrodynamic modelling, sampled larval distributions, and adult movement patterns suggest that the two gulfs are largely distinct self-sustaining populations. Nevertheless, analysis of stock structure based on mitochondrial DNA and microsatellite primers found no significant phylogeographic structure across the distribution of King George whiting (Haigh and Donnellan 2000). This is consistent with its long pre-settlement duration, and does not counter the above-mentioned subpopulation model since only a minimal but consistent exchange of individuals (two or three fish per year) between sub-populations is sufficient to maintain them as genetically homogeneous (Taylor and Dizon 1996).

Several studies have focussed on the diets of King George whiting. The stomachs from post-larvae that were collected from shallow seagrass beds contained mobile crustacea, primarily calanoid copepods and to a less extent benthic harpacticoid copepods with benthic amphipods, cyclopoid copepods and cladocerans in low numbers (Moran et al. 2004). That study also revealed benthic prey items in the stomach contents of post-larvae collected by plankton tows that were done adjacent to seagrass beds, which suggests the likelihood of secondary planktonic dispersal of post-larvae after settlement. In an earlier study, Robertson (1977) considered the diets of King George whiting in the shallow, mud, tidal flats of Western Port, Victoria. The diet of the very young 0+ fish was predominantly made up of harpacticoid copepods, gammarid amphipods and Mysidacea, which are abundant in the seagrasses associated with the mudflats. Later, the stomach contents of the 0+ fish were dominated by larvae of the ghost prawn *Callianasa australiensis*, whilst polychaete worms and juvenile sentinel crabs were also included in the range of prey. A total of 26 food types were taken by the 1+ and 2+ age groups, but the diets were dominated by six prey categories: several types of polychaete worms; the ghost prawn; amphipods and the juvenile sentinel crab *Macrophthalmus latifrons*. Another dietary study was done in Wilson Inlet, Western Australia (Platell et al. 2006). It determined that the major components of the diet were polychaete worms that were found in 65% of the guts, and contributed up to 56.5% of the diet volume. Polychaetes were ingested by individuals of all length classes but their volumetric contribution was greatest in the smallest fish, i.e. 25-124 mm. The contribution to the diet of large crustaceans declined from the 175-224 mm size class to the larger fish, whilst bivalve siphons and neogastropods were found only in the guts of fish >225 and 275 mm, respectively.

3. TRENDS IN COMMERCIAL CATCH, EFFORT AND CPUE

3.1 Introduction

Commercial fishers in the Marine Scalefish fishery are required to submit a monthly catch return that relates their catch and effort for that particular month. Such data have now been collected since 1984, thus providing a data time-series that exceeds 20 years. For this stock assessment on King George whiting the catch and effort data were accumulated across fishers to provide regional, annual totals of catch and effort by gear type, which were then used to calculate annual estimates of catch per unit effort (CPUE) for each region. The data for the three main gear types, i.e. handlines, haul nets and gill nets are reported for the seven regions shown in Fig. 3.1. The Marine Fishing Areas that comprise these are identified in Table 3.1.

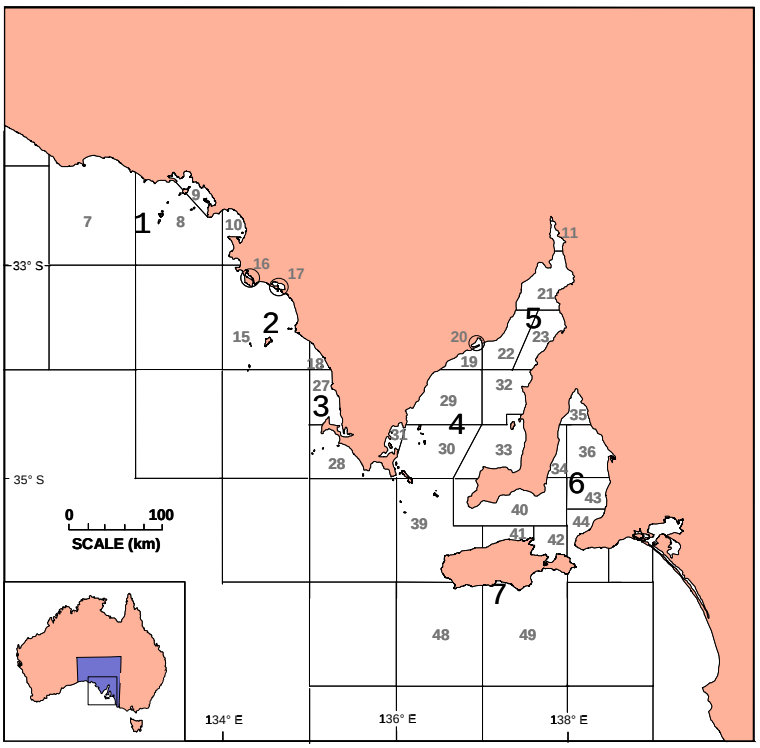

Fig. 3.1 Map of South Australia showing the seven fishery regions for which data are presented in this report. (1 = Far West Coast, 2 = Mid West Coast, 3 = Coffin Bay, 4 = Southern Spencer Gulf, 5 = Northern Spencer Gulf, 6 = Gulf St. Vincent, 7 = Kangaroo Island.)

With respect to fishing effort, data are reported as fisherdays, which relate to the number of days fished and number of personnel involved. If there were two fishers on board a vessel for a day of fishing then this counted as two fisherdays. There are two components of fishing effort for each gear type, i.e. targeted and untargeted effort. For handlines and gillnets, total effort was estimated from targeted effort, which was scaled upwards by the proportional additional catch that was taken by untargeted effort. Thus, for handlines and gill nets it was possible to provide annual estimates of total catch and effort and associated estimates of CPUE. However, for haul nets the situation is more complex because fishers may catch substantial numbers of King George whiting whilst targeting other species, or when targeting no species in particular. Under such circumstances it is not possible to determine the targeted effort that was directed specifically at King George whiting, making it impossible to provide a direct estimate of targeted CPUE. Consequently, for haul nets, estimates of catch, effort and CPUE are provided for three different fishing effort categories: targeted effort; effort targeted at other species; and effort not directed at any particular species.

Table 3.1 Fishery regions considered for the King George whiting fishery and the Marine Fishing Areas that comprise them (refer Fig. 3.1).

Region name	Marine Fishing Areas
Far West Coast (FWC)	07, 08, 09, 10
Mid West Coast (MWC)	15, 16, 17, 18
Coffin Bay (CB)	27, 28
Southern Spencer Gulf (SSG)	29, 30, 31, 32, 33
Northern Spencer Gulf (NSG)	11, 19, 20, 21, 22, 23
Gulf St. Vincent (GSV)	34, 35, 36, 40, 43
Kangaroo Island (KI)	39, 41, 42, 44, 48, 49

3.2 Results

Trends in commercial catch and effort

The specific data on commercial catches and levels of effort by region and gear type for each year of 2005, 2006 and 2007 are presented in Tables A.1, A.2 and A.3 in Appendix 1. These add three years of data to the longterm trends. The estimates of State-wide commercial catch of King George whiting decreased substantially between 1984 and 2007 (Fig. 3.2). From 1984 to 1992 catch was variable, showed no long term trend, and culminated in the highest ever annual catch of 776 t in 1992 (Fig. 3.2). Subsequently, catch decreased and stabilised at 550-600 $t.yr^{-1}$ until 1999, before dropping substantially below 450 $t.yr^{-1}$ in 2000. It dropped again to 370-380 $t.yr^{-1}$ in 2002 and 2003, and has been consistent at 340-350 $t.yr^{-1}$ between 2004 and 2007. As

such, in 2007 the commercial catch of King George whiting was 42% lower than that taken in 1999 and 55% lower than that of 1992.

The estimates of annual value of the commercial fishery for King George whiting increased between 1984 and 1995 from $2.8 million to $5.4 million. The value then dropped substantially in 1997 to less than $4 million, before increasing again in 1999 to greater than $5 million. The total value of the King George whiting commercial fishery decreased in both 2004 and 2005, before increasing again to above $4.5 million in 2006 (Fig. 3.2).

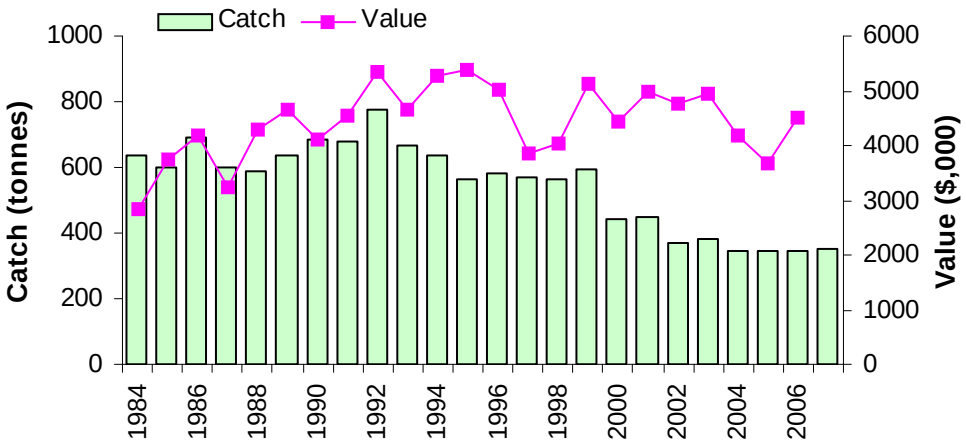

Fig. 3.2 Total annual catch and value of the South Australian King George whiting fishery since 1984.

Since 1984, handlines have been the dominant gear type in the commercial fishery (Fig. 3.3). Between 1984 and 1999 handline catch varied around 400 $t.yr^{-1}$, with no obvious long-term trend. However, since then handline catch has dropped consistently from 426 t in 1999 to 281 t in 2007, i.e. a drop of 34%, with a decline since 1992 of 39%. Haul nets remain the second most significant gear type for taking King George whiting despite that catches have decreased systematically since the record catch taken with this gear in 1992. The haul net catch of 40 t recorded in 2006 was the lowest yet recorded after which there was a marginal increase to 51 t in 2007. The gillnet catch has always been below 50 $t.year^{-1}$. In 2000, it dropped by 49% to 24 t and has gradually been decreasing since then, falling to only 13 t in 2007.

Handline effort has decreased from 31,235 fisherdays in 1992 to 14,410 fisherdays in 2007, i.e. a reduction of 54% over this 15 year period (Fig. 3.3). Gill net effort has declined by 88% from 2,523 to only 305 fisherdays over the same period. Such decreases in effort reflect the declining trend in the number of licence holders in the commercial fishery, which accelerated

after 1994 when the licence amalgamation scheme was introduced (Fig. 3.4). Consequently, over the years there has been a considerable decrease in numbers of commercial fishers who targeted and/or caught King George whiting (Fig. 3.4).

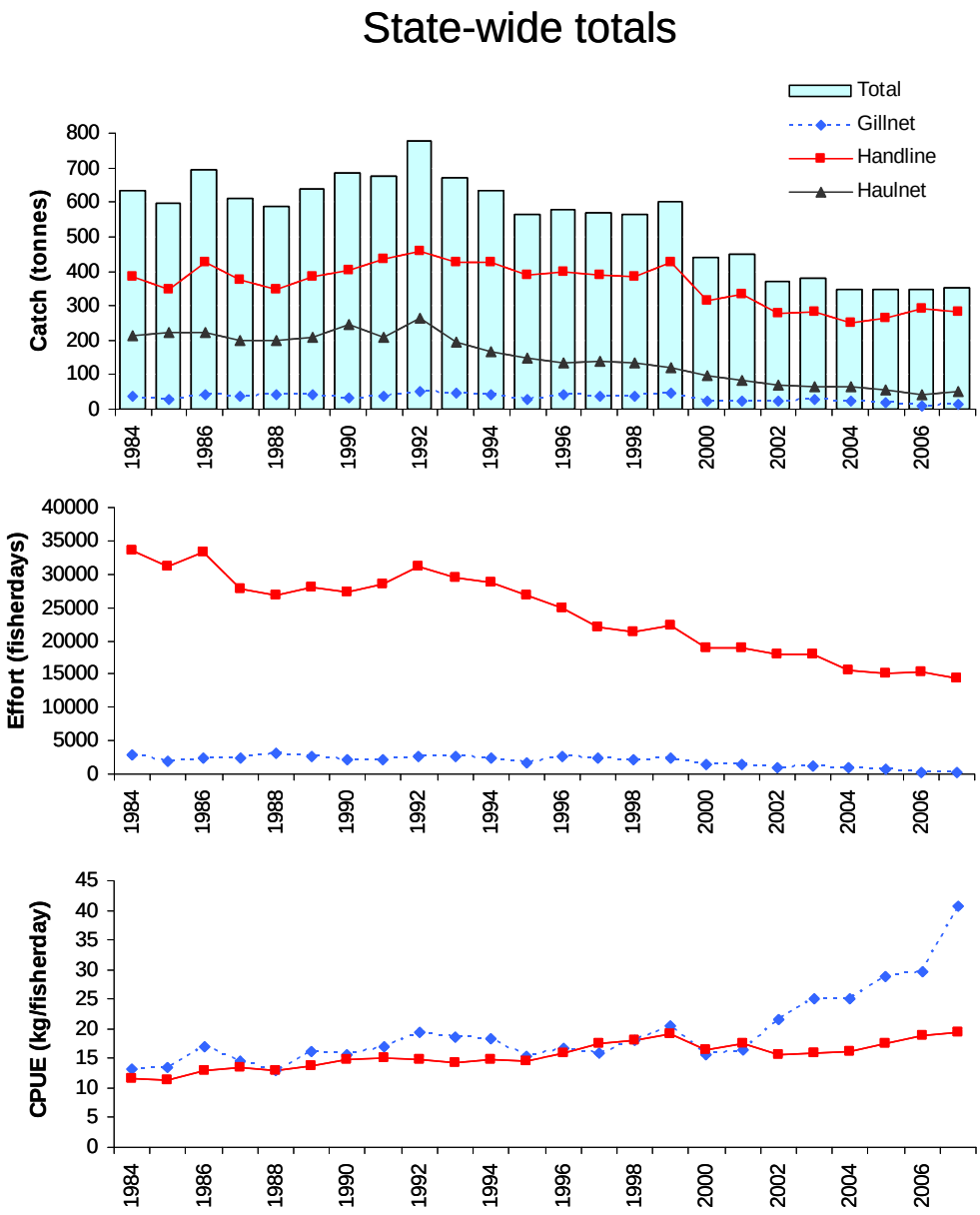

Fig. 3.3 Historical trends in State-wide totals for catch, effort and CPUE for the main gear types used by the commercial fishing sector. Note that it was not possible to provide State-wide estimates of targeted effort for haul nets, which thereby prevented estimating targeted CPUE.

The estimates of State-wide CPUE for handlines and gillnets have been variable, but generally trended upward between 1984 and 1999 (Fig. 3.3). Both dropped noticeably in 2000. Since then CPUE has increased dramatically in the gillnet fishery, but these estimates are based on low levels of catch and effort. Targeted CPUE from the handline fishery decreased substantially in both 2000 and 2002, but has trended upwards since 2002. In 2007, State-wide handline CPUE was 19.5 kg.fisherday^{-1}, i.e. the highest ever recorded, being marginally above the previous maximum of 19.1 kg.fisherday^{-1} recorded in 1999.

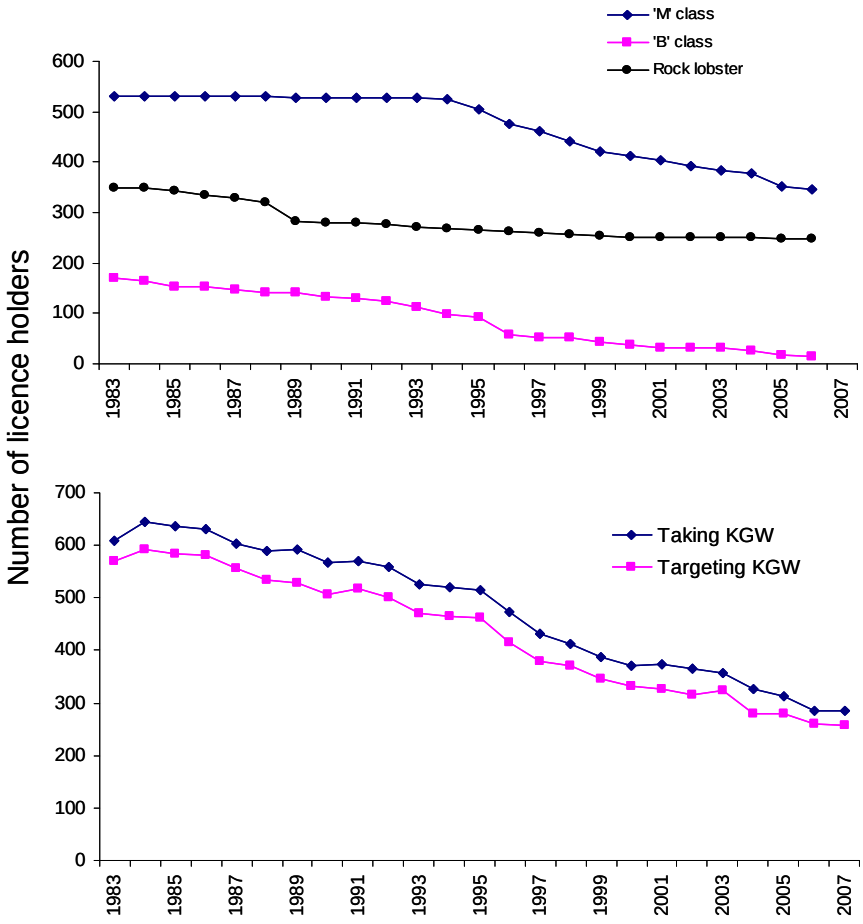

Fig. 3.4 Top graph shows the number of licence holders who could legally take King George whiting in each year. Bottom graph shows the actual number of licence holders who reported taking some King George whiting and those who targeted this species in each year.

Seasonality of catch

The seasonality of the State-wide commercial catch of King George whiting is apparent from monthly catch totals (Fig. 3.5). For the period of July 2003 to December 2007 monthly catches were highest during winter, and dropped to annual minima in summer. The monthly estimates for effort on King George whiting tended to be highest from March through to September, but were particularly low in each year between November and January.

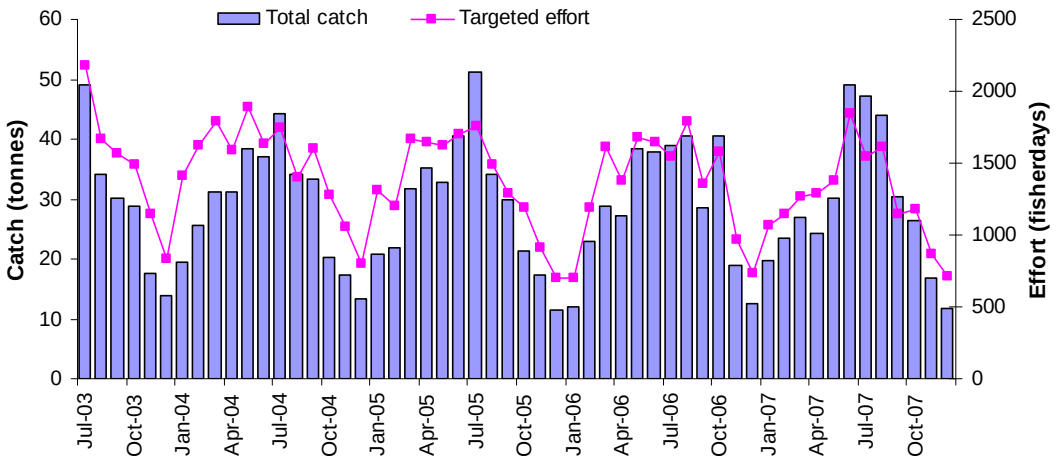

Fig. 3.5 Monthly estimates of total State-wide catch and fishing effort (all gears combined) for the King George whiting commercial fishery between July 2003 and December 2007.

Regional Catch and Effort Statistics

The remainder of this chapter provides a summary of the catch, effort and CPUE data from 1984 to 2007 for each of the seven fishery regions that were identified in Table 3.1 and Fig. 3.1. For each region, estimates of total catch are presented for the three gear types of handlines, haul nets and gillnets. Estimates of total effort and CPUE are provided for handlines and gill nets. For the regions where haul nets remain a significant gear type (NSG, GSV and KI), or have diminished recently as a consequence of the netting closures in 2005 (SSG) a separate figure is provided that relates the region-specific estimates of catch, effort and CPUE for where effort was reported as 'targeted', 'no specific species targeted' and 'other species targeted'.

Far West Coast (Denial and Streaky Bays)

The annual catch from the bays of the Far West Coast is usually the highest of any region across the State (Appendix 1 - Tables A.1-A.3). Historically, the catch in this region has been dominated by the handline sector since the implementation of a netting ban in 1958. The handline catch from the Far West Coast reached a peak of 150,455 kg in 1989 after which it declined consistently until 1998 (Fig. 3.6). It was then highly variable through the period of 1999 to 2002, but has been gradually declining since then. Between 1984 and 1997 handline effort declined by 40% to approximately 6,000 fisherdays.year^{-1} (Fig. 3.6). It then increased again in 1999, was relatively stable until 2004 but has gradually declined since then. Targeted handline effort declined by 24.6% from 6,384 fisherdays in 2004 to 4,815 fisherdays in 2007.

CPUE showed a long-term increasing trend through the period of 1984 and 1999 (Fig. 3.6). Through this period there were two notable peaks, one from 1989 to 1992 and the second from 1996 to 1999. It was in this latter year that the highest CPUE ever of 22.3 kg.fisherday^{-1} was recorded. Between 1999 and 2004, CPUE declined substantially, dropping to a minimum of 15.9 kg.fisherday^{-1}. It has subsequently risen again to 18.7 kg. fisherday^{-1}.

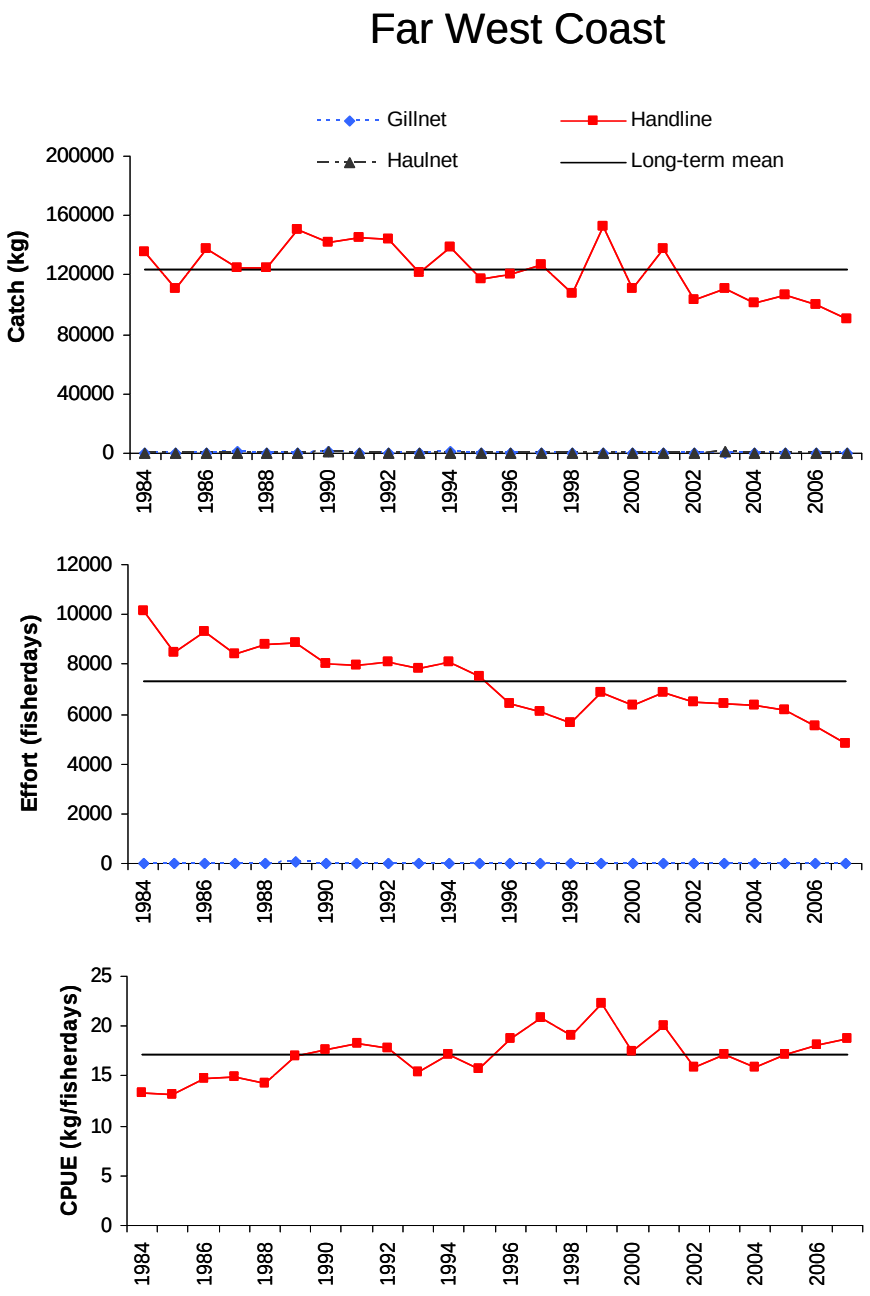

Fig. 3.6 Far West Coast. Top graph – historical trends in total catch by gear type. Middle graph – historical trends in total effort by gear type. Bottom graph – historical trends in CPUE. The long-term mean for the handline fishery is indicated on each graph.

Mid West Coast (Baird and Venus Bays)

The catch from the bays of the Mid West Coast is generally considerably less than that from the Far West Coast (Tables 3.2 - 3.4). Handlines, gillnets and hauling nets have each historically contributed to the catches in this region in order of decreasing significance (Fig. 3.7). Prior to 2005, Baird Bay and half of Venus Bay were closed to net fishing. In August 2005, the remaining part of Venus Bay was also closed to net fishing, thus restricting the fishing activity in these bays to line fishing.

The handline catch in these West Coast bays has generally been highly variable from year-to-year but in 2000 dropped to the lowest recorded level, and then remained low in both 2001 and 2002. Handline catch has subsequently increased considerably to at least an average catch level in 2005. The catches from gillnets and haul nets have also been historically quite variable, but they also dropped to their lowest levels in the period of 2000 to 2002. From then they remained low until no net catch was taken subsequent to the netting closures in August 2005.

Handline effort has been highly variable from year-to-year but nevertheless has demonstrated a significant and accelerating long-term decline, particularly through the period of 1999 to 2002, culminating in the lowest recorded effort in 2001 and 2002 (Fig. 3.7). There was a substantial increase in effort in 2003, followed by another fall in 2004. Effort stabilised at a relatively low level through the years of 2005 to 2007. Effort in the gillnet sector declined significantly after 1992, falling to its lowest level in 2002 before dropping to zero in 2006 due to the net closure.

Between 1984 and 2000 handline CPUE was quite variable by virtue of the highly variable annual catch and effort data. There was no long-term trend through this period. Nevertheless, since 2000 handline CPUE has risen consistently from a low level of 7.8 kg.fisherday^{-1} to a maximum of 23.8 kg.fisherday^{-1} in 2006. Gillnet CPUE was also highly variable between 1984 and 2000 before increasing considerably through the years of 2002 to 2005 (Fig. 3.7).

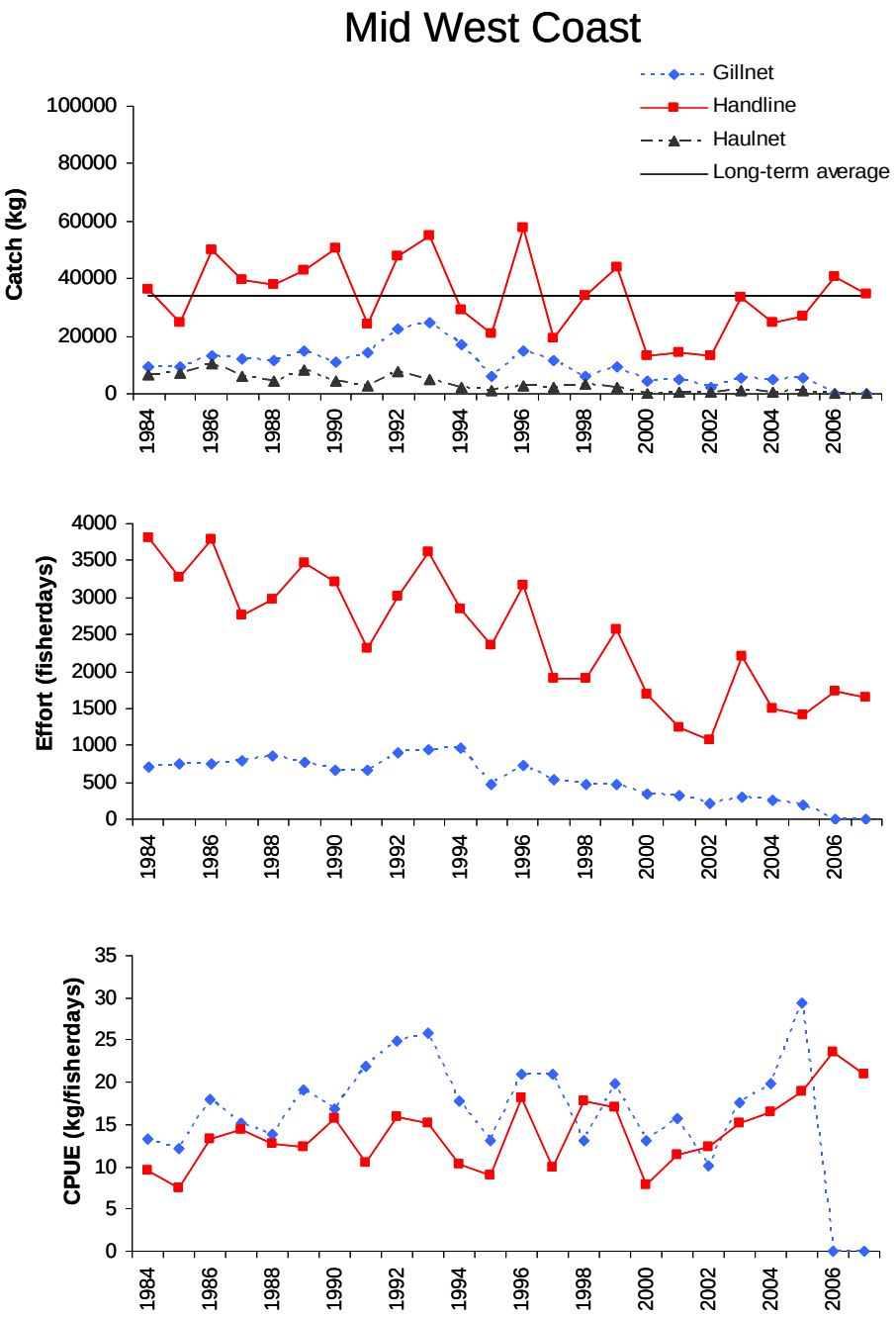

Fig. 3.7 Mid West Coast. Top graph - historical trends in total catch by gear type. Middle graph - historical trends in total effort by gear type. Bottom graph - historical trends in CPUE by gear type.

Coffin Bay

As consequence of a review of the net fishery that was undertaken in 1995 and 1996, Coffin Bay was closed to net fishing in 1996. As such, this region has effectively been a line fishery since then.

Between 1984 and 1988 handlines and haul nets contributed similarly to the King George whiting catch in Coffin Bay (Fig. 3.8). After this, the two trend lines diverged as the catch from haul nets increased, whilst that from handlines decreased. The haul net catch decreased between 1990 and 1995, before dropping to zero due to the net closure. Handline catch increased significantly at that time, but subsequently declined to a minimum in 2005. Total handline catch increased considerably from 6,121 kg in 2005 to 18,704 kg in 2006.

The temporal variation in fishery catches is also reflected in the trends in effort (Fig. 3.8). There have been several peaks and troughs in handline effort since the mid 1980's with the two peak years being 1995 and 2000. Since then handline effort declined to a minimum of 316 fisherdays in 2005 before increasing to 713 fisherdays in 2007. Although gillnet effort has always been low in Coffin Bay, it decreased considerably in 1994, before dropping to zero in 1997.

CPUE for handlines increased substantially and reached a maximum of 24 kg.fisherday^{-1} in 1995 (Fig. 3.8). There was another peak in 1998 of 23.0 kg.fisherday^{-1} before declining systematically over a six-year period, dropping to a minimum of 17.8 kg.fisherday^{-1} in 2002. Since 2004, handline CPUE has gradually increased to 26.2 kg.fisherday^{-1} that was attained in 2007.

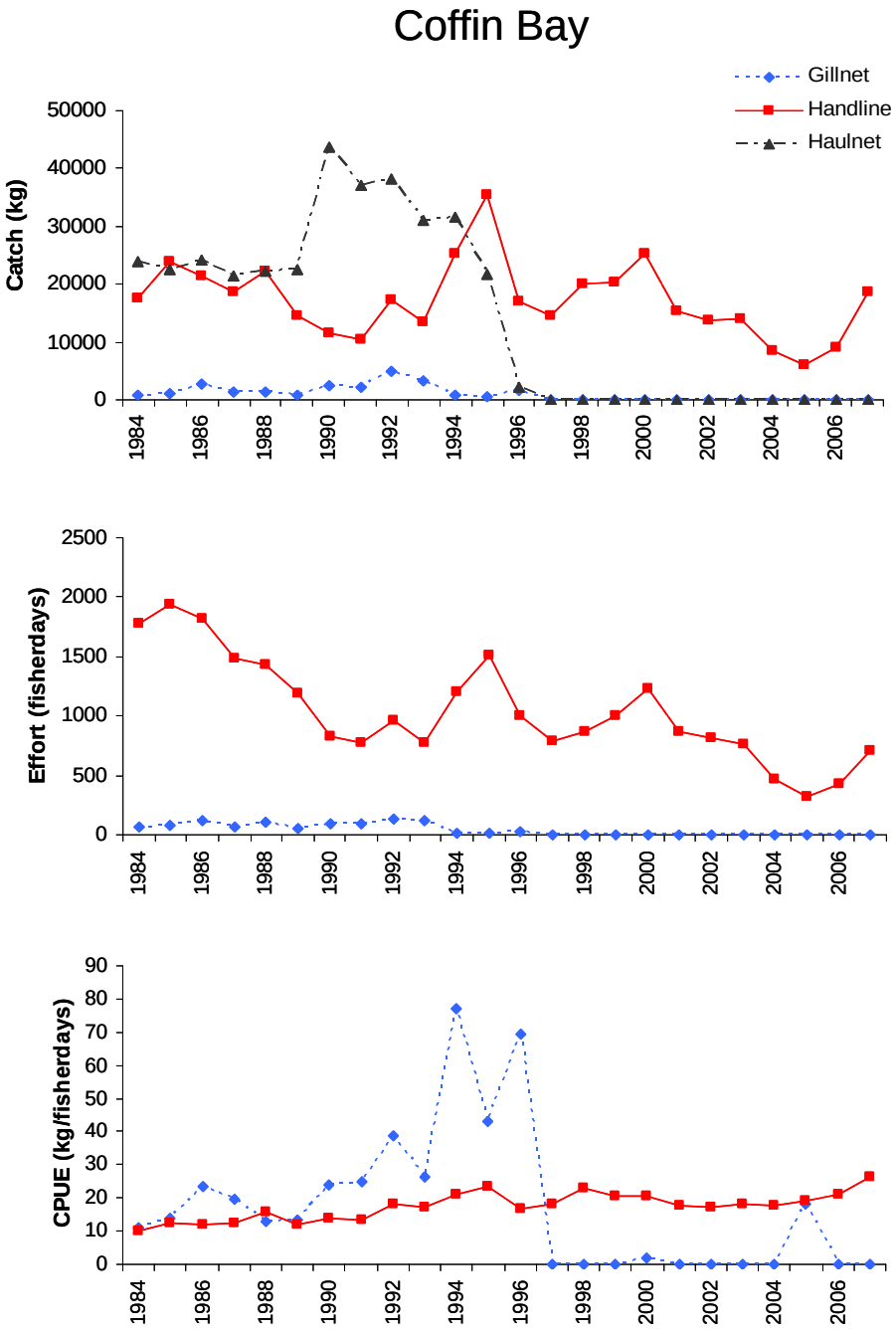

Fig. 3.8 Coffin Bay. Top graph - historical trends in total catch by gear type. Middle graph – historical trends in total effort by gear type. Bottom graph – historical trends in CPUE by gear type.

Southern Spencer Gulf

Handlines are the most significant gear type in this region followed by haul nets and gillnets (Fig. 3.9). Catch in the handline sector has been highly variable over the years with three obvious peaks, one in 1986, the next in 1991 and the third in 1997. Since then, catches have decreased systematically from 131,074 kg to only 57,395 kg in 2004 before recovering to 74,140 kg in 2007. Haul net catch declined considerably between 1984 and 2004, particularly through two periods, i.e. 1992 to 1995 and 1999 to 2002. There was a marginal increase in haul net catch between 2003 and 2005 before dropping to minimal levels as a consequence of the netting closures that were implemented in 2005. Gillnet catches also fell considerably in 2000, and have remained low since. Nevertheless, they remain considerably higher than the haul net catches.

Handline effort has been variable since 1984, with peaks in 1986, 1991-92, and a minor one in 1997 (Fig. 3.9). Nevertheless, there has been a consistent declining trend since the peak in 1992, when handline effort was 8,997 fisherdays. This declined by 61.4% to 3,471 fisherdays in 2007. Gillnet effort declined from a maximum of 1,018 fisherdays in 1999 to only 59 fisherdays in 2006, before increasing marginally to 81 fisherdays in 2007.

The estimates of CPUE for handlines increased between 1984 and 1998, declined consistently to 2003, but then increased in each year to 2007 (Fig. 3.9). CPUE was variable for the gillnet sector between 1984 and 1997, before increasing dramatically in 1998. Since then it has been highly variable, due to the very low levels of catch and effort.

The annual catches with haul nets through the period of 2000 to 2004 were the lowest ever recorded, due to low fishing effort (Fig. 3.10). The catches then dropped to negligible amounts in 2006 and 2007 due to the large areas that were closed to netting in 2005. The estimates of CPUE were highly variable in recent years, which may reflect that the catches and effort were low and variable. The time series for the different categories of CPUE do not show any consistent trend and are difficult to interpret because of the low catch and effort levels.

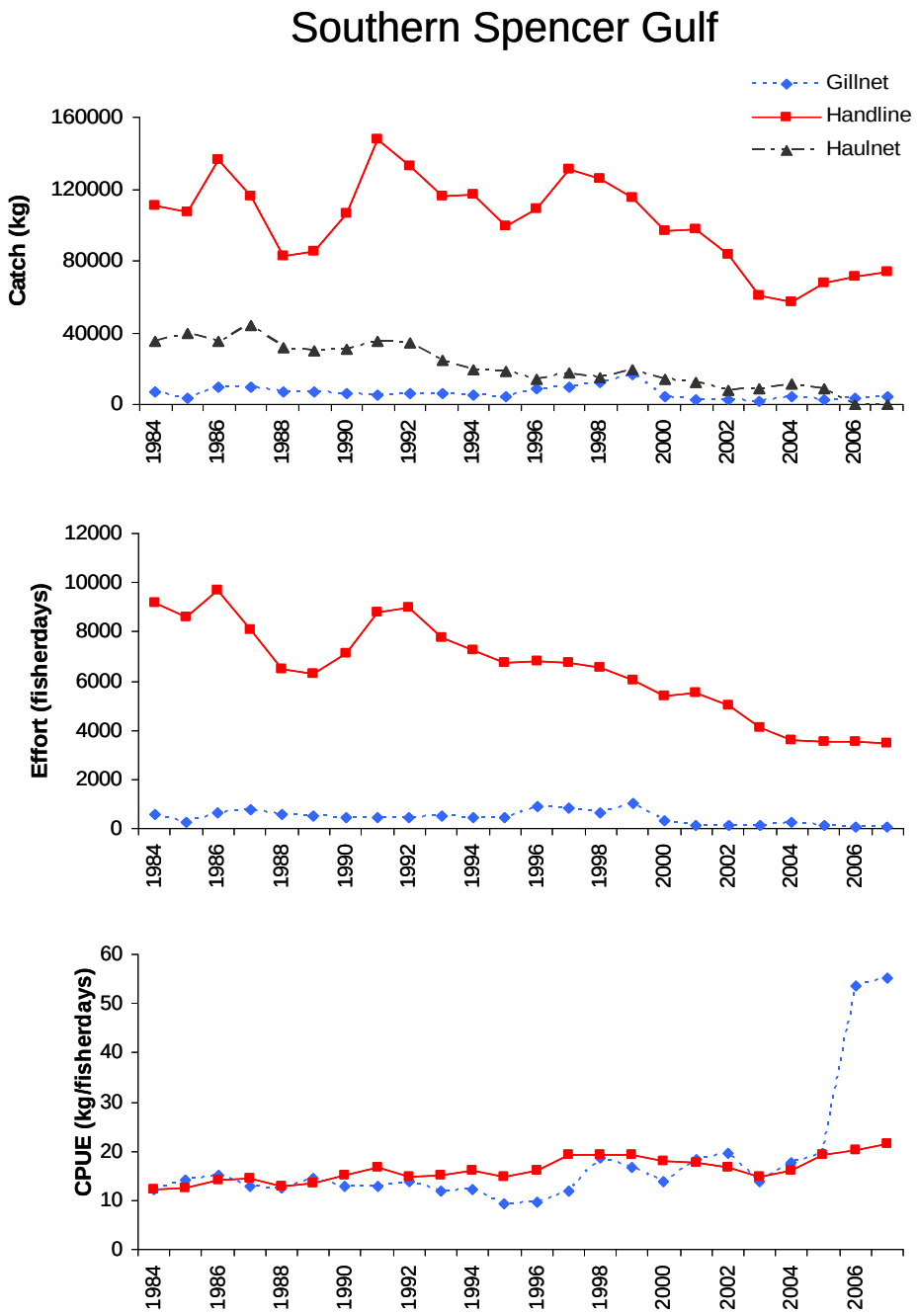

Fig. 3.9 Southern Spencer Gulf. Top graph - historical trends in total catch by gear type. Middle graph - historical trends in total effort by gear type. Bottom graph - historical trends in CPUE by gear type.

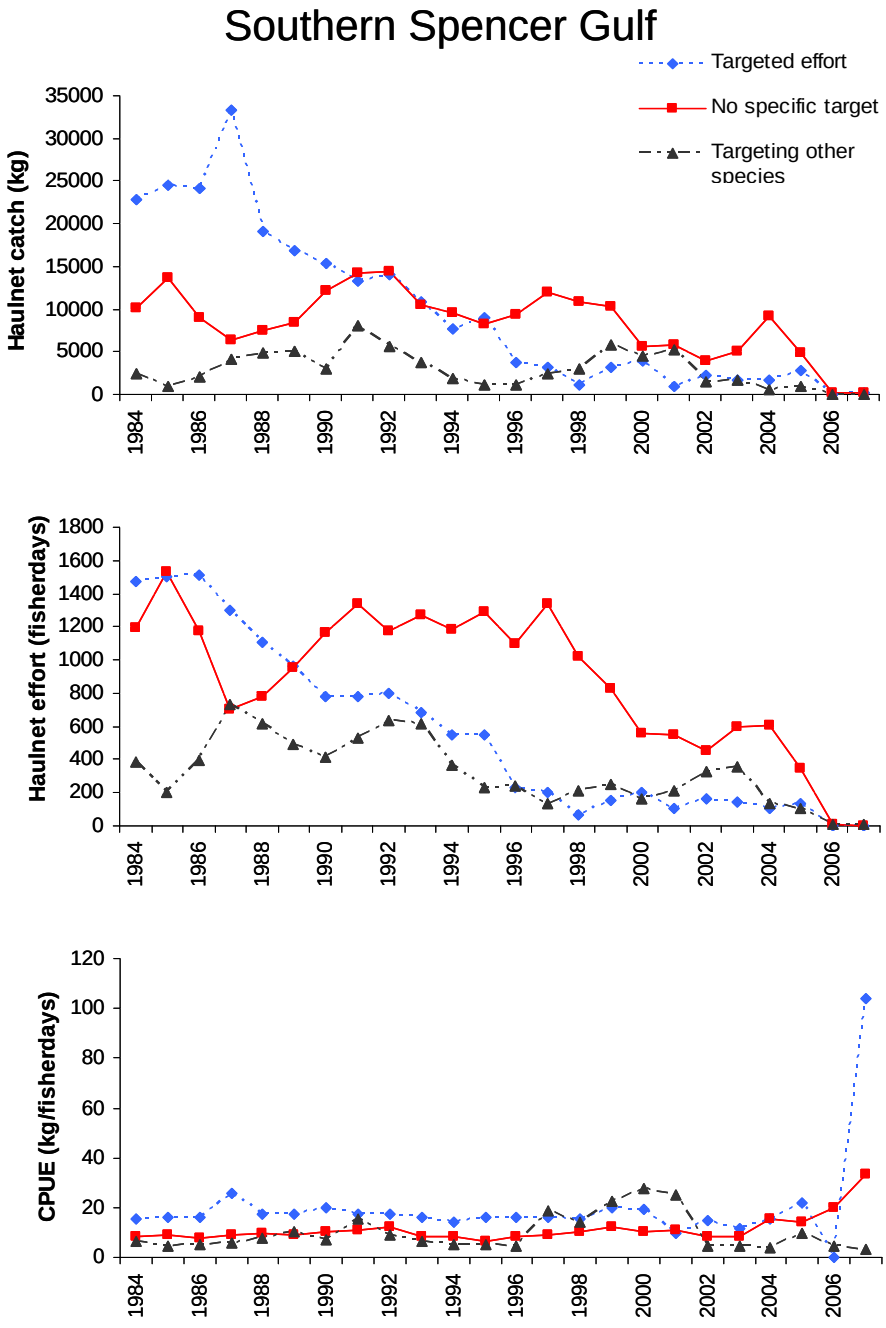

Fig. 3.10 Southern Spencer Gulf. Top graph - historical trends in haul net catch for each of the three effort categories. Middle graph - historical trends in haul net effort for each of the three effort categories. Bottom graph - historical trends in CPUE for each of the three effort categories.

Northern Spencer Gulf

Haul nets have consistently been the dominant gear type in this region (Fig. 3.11). Haul net catch was highly variable until 1997 after which there has been a consistent downward trend. The lowest haul net catch of 22,171 kg was taken in 2006 that was followed by a marginal increase in 2007 (Fig. 3.11). Handline catch has also declined considerably since the high catches of the early 1990s, resulting in the lowest catches on record during 2000, 2001 and 2002, and a marginal recovery from 2002 to 2007. This decline in handline catch from 1997 was consistent with a decrease in fishing effort, particularly through the period of 1994 to 2001. There has been a marginal increase in handline fishing effort since 2001. The low catch of the gillnet sector reflects the reduction in effort that occurred in 1988, when effort was virtually reduced to zero.

CPUE in the handline sector has varied in several phases between 1984 and 2007, but has nevertheless demonstrated a long-term increasing trend (Fig. 3.11). CPUE in 1984 was 10.4 kg.fisherday^{-1} and has gradually increased to 18.7 kg.fisherday^{-1} in 2007. CPUE for the gillnet sector has been highly variable due to the low catch and effort with this gear type.

Both targeted and non-targeted haul net catch have declined since 1992 (Fig. 3.12), reflecting a continual decline in both targeted and non-targeted effort since 1988. CPUE of both targeted and non-targeted effort have declined since 1990, with the decrease most evident through the period of 1998 to 2001. Since then, there have been marginal increases in CPUE for the different effort types (Fig. 3.12).

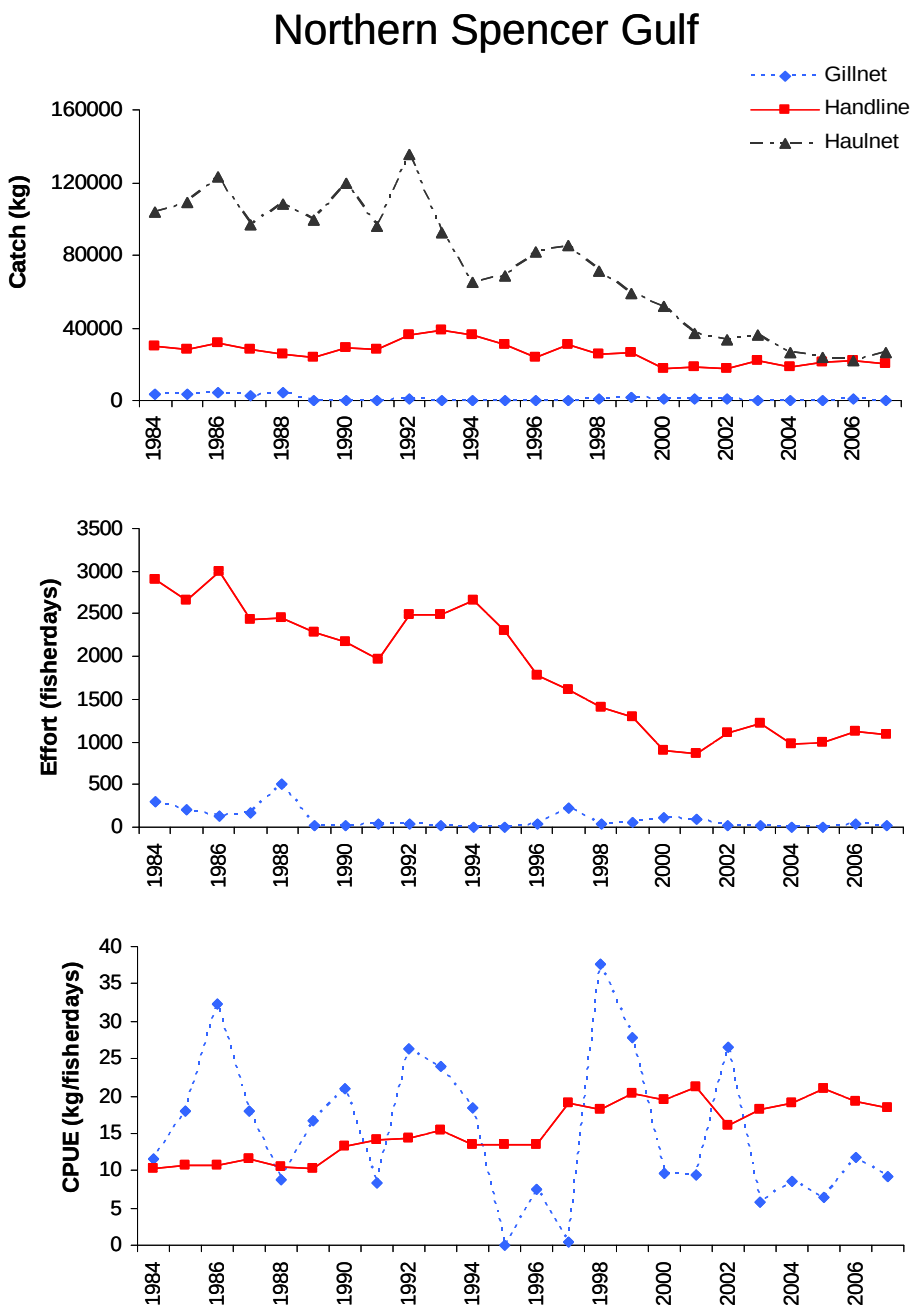

Fig. 3.11 Northern Spencer Gulf. Top graph - historical trends in total catch by gear type. Middle graph - historical trends in total effort by gear type. Bottom graph - historical trends in CPUE by gear type.

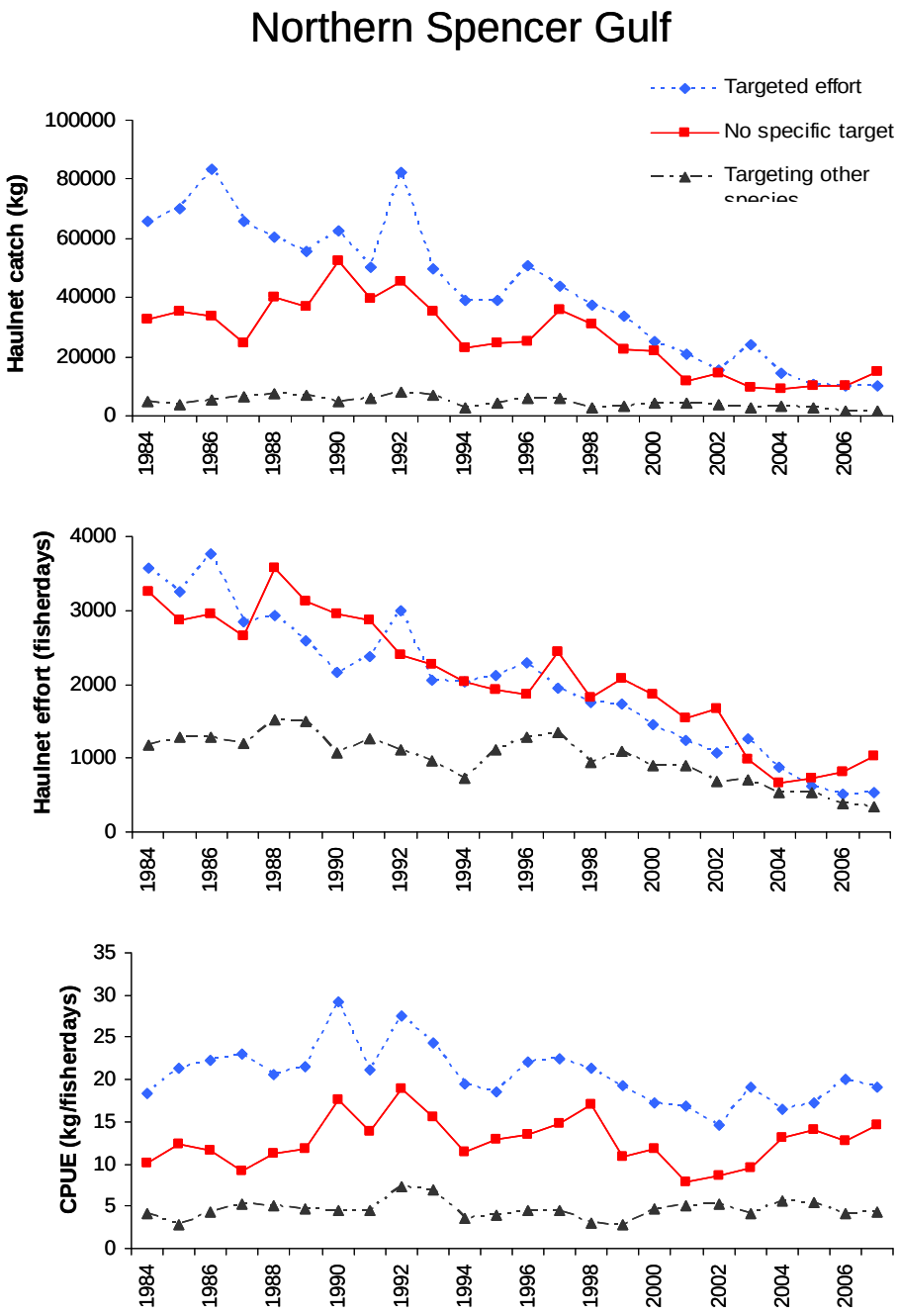

Fig. 3.12 Northern Spencer Gulf. Top graph - historical trends in haul net catch for each of the three effort categories. Middle graph - historical trends in haul net effort for each of the three effort categories. Bottom graph - historical trends in CPUE for each of the three effort categories.

Gulf St. Vincent

Haul nets, handlines and gillnets have each contributed substantially to the fishery for King George whiting in Gulf St. Vincent (Fig. 3.13). Haul net catch was quite variable from 1984 but reached a peak in 1998 after which it declined systematically. It fell from 37,762 kg in 1998 to only 10,089 kg in 2006, before increasing in 2007 to 15,935 kg. Handline catches were highest through the early and mid 1990's but have shown a long-term systematic decline from 38,916 kg to 9,347 kg that was attained in 2005. The gillnet catches were also relatively low through 2000-2002, increased in 2003, but then decreased to a minimum level of 2,017 kg in 2006.

Handline effort was quite variable from 1984 until it reached a peak in 1992, after which it decreased systematically (Fig. 3.13). The peak in effort in 1992 was 3,787 fisherdays, which fell to 789 fisherdays in 2005. Gillnet effort has also declined over the same period, particularly between 2001 and 2006.

CPUE in the handline fishery increased consistently from 1984, attaining a maximum of 14.7 kg.fisherday^{-1} in 2001 before decreasing annually between 2001 and 2005 (Fig. 3.13). It has subsequently increased to 13.9 kg.fisherday^{-1}. CPUE for gillnets increased to 1999, but then became highly variable due to the low levels of catch and effort.

Haul net catch has decreased considerably since 1998 (Fig. 3.14), primarily reflecting a significant decline in effort directed at 'no specific targeted species'. The different categories of CPUE in the haul net sector have either remained steady or increased in recent years. Although targeted catch and effort have been relatively low in Gulf St. Vincent, the CPUE has increased through the years particularly from 1998 to 2002. CPUE for the untargeted effort types have been relatively stable.

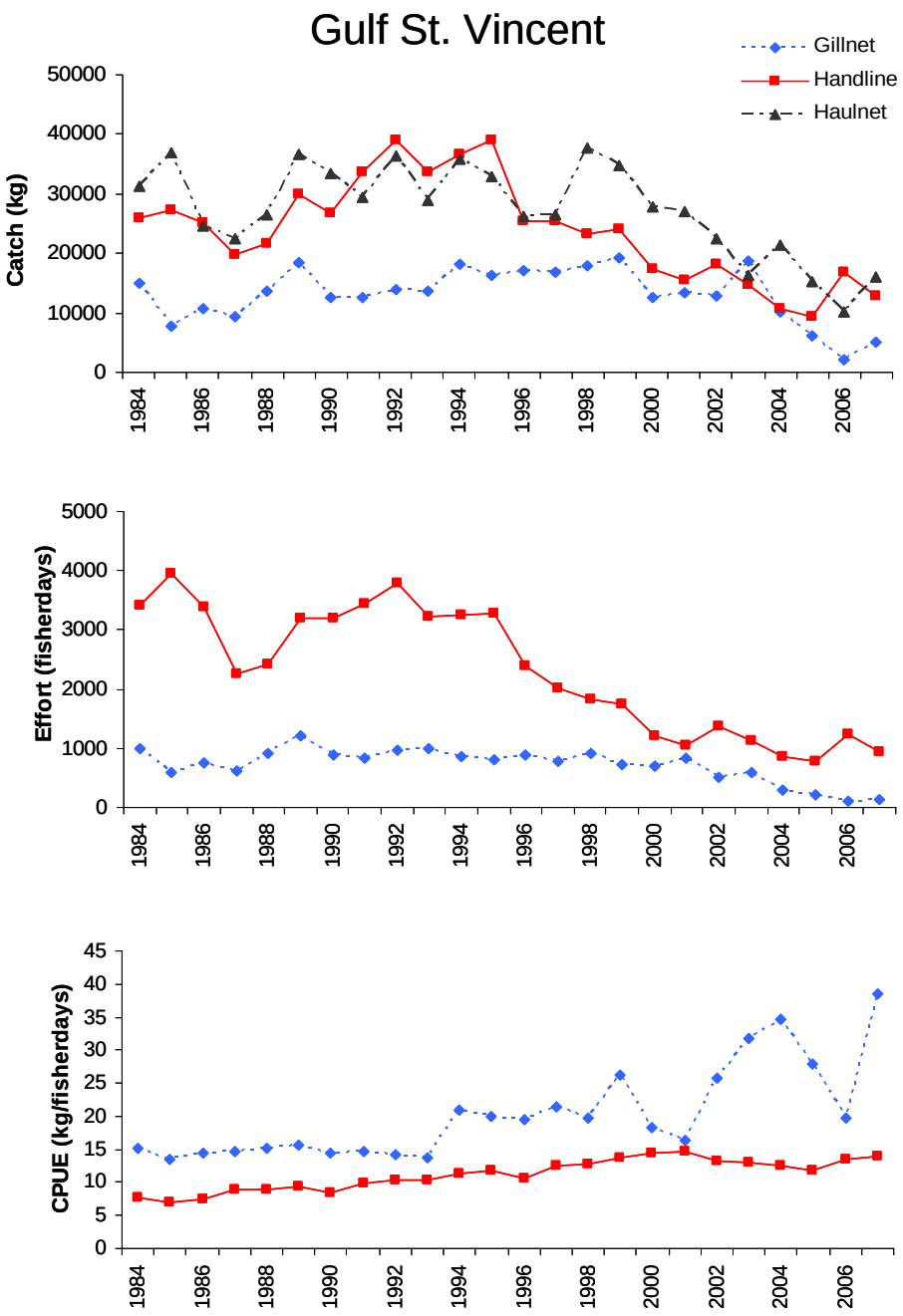

Fig. 3.13 Gulf St. Vincent. Top graph – historical trends in total catch by gear type. Middle graph – historical trends in total effort by gear type. Bottom graph – historical trends in CPUE by gear type.

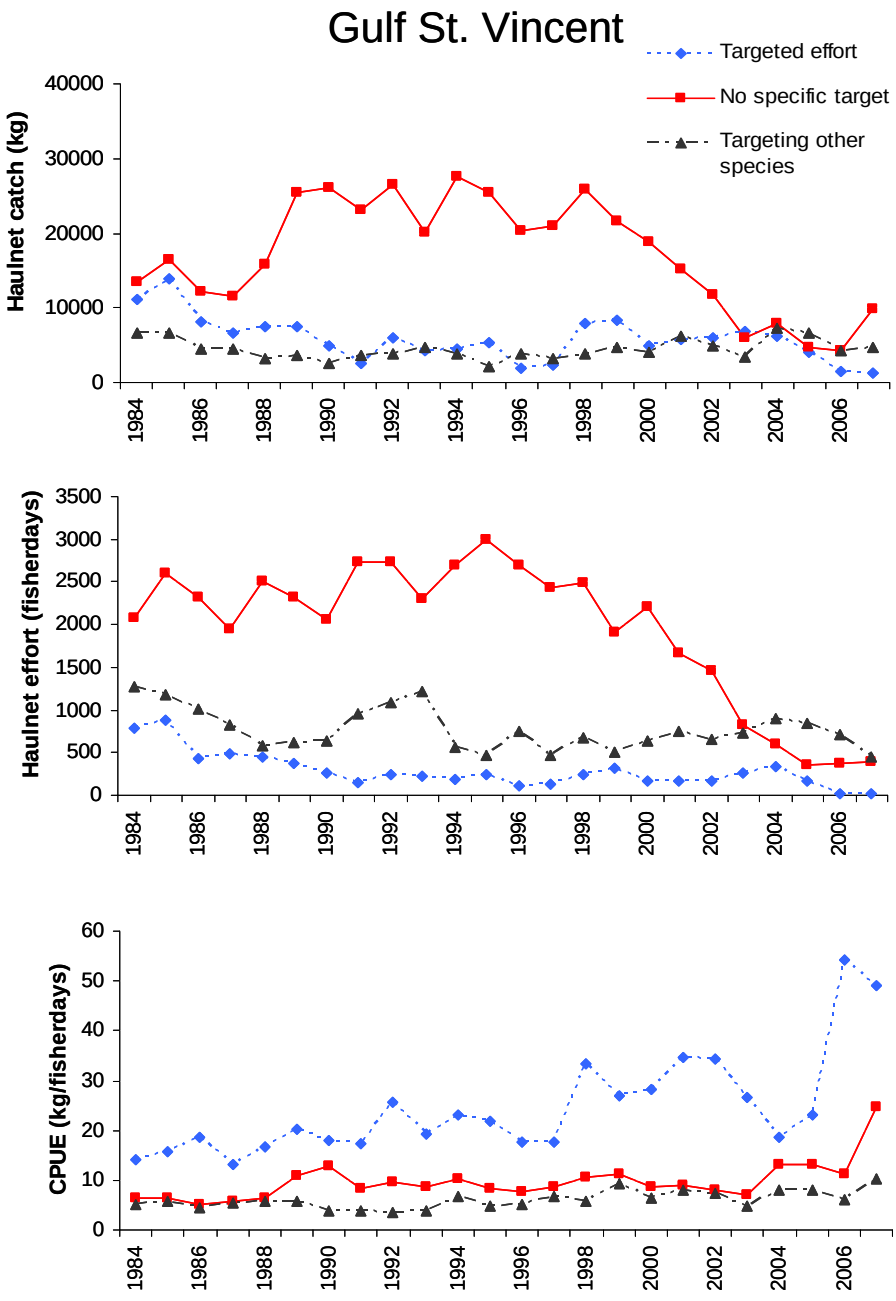

Fig. 3.14 Gulf St. Vincent. Top graph – historical trends in haul net catch for each of the three effort categories. Middle graph – historical trends in haul net effort for each of the three effort categories. Bottom graph – historical trends in CPUE for each of the three effort categories.

Kangaroo Island

Handlines have been the main gear type in this region since 1984. Handline catches increased from 1986 to a maximum of 47,880 kg in 1998, after which they declined substantially to 27,337 kg in 2002 (Fig. 3.15). Since then there has been a gradual increase in annual catch to 30,330 kg that was taken in 2007. Haul nets have also been an important gear type in this region. Catches gradually declined from the peak of 13,594 kg in 1992 to 3,533 kg in 2003. Since then, haul net catch has increased considerably to 7,826 kg in 2007. Gillnets have only ever provided a marginal catch but nevertheless the catches have increased since the late 1990s.

Handline effort increased substantially between 1988 and 1992, before declining systematically over the following years (Fig. 3.15). Handline effort in 1992 was 3,887 fisherdays and in 2007 was 1,742 fisherdays, representing a 55.2% reduction. Effort in the gillnet sector decreased to virtually zero through the early 1990's but has increased moderately since then, and in the early 2000s has generally been less than 100 fisherdays.yr^{-1}.

CPUE in the handline sector increased moderately through the years to a maximum of 15.5 kg.$fisherday^{-1}$ in 1998 (Fig. 3.15). After that, CPUE slowly declined to 13.7 kg.$fisherday^{-1}$ in 2002, but has subsequently been on an upward trend. The CPUE of 17.4 kg.$fisherday^{-1}$ in 2007 was the highest ever recorded.

The haul net catch increased through the 1980's and early 1990's but decreased from 1994 to 2004 (Figs. 3.15, 3.16). The catch and effort data, reflect a significant change from targeted to untargeted catch and effort between 1991 and 1992, which more likely reflects the way that such data have been reported by fishers rather than a change in fishing methodology. Catch and effort have decreased significantly in the main reporting category, i.e. "no specific target", since 1992. Estimates of CPUE were higher in the 1990s and 2000s compared to the 1980s. Nevertheless, the estimates were variable through the 2000s due the low estimates of catch and effort through this period.

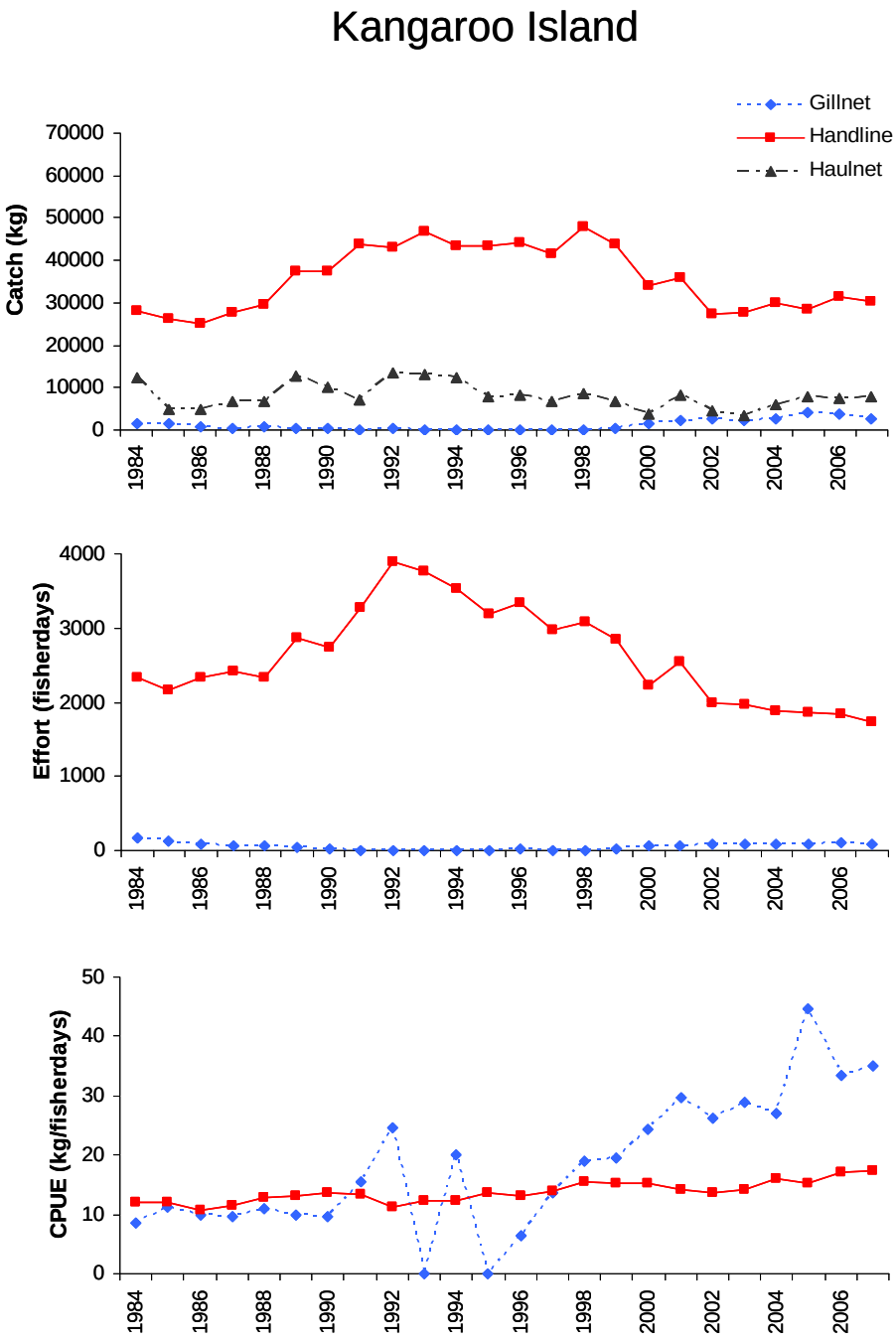

Fig. 3.15 Kangaroo Island. Top graph - historical trends in total catch by gear type. Middle graph - historical trends in total effort by gear type. Bottom graph - historical trends in CPUE by gear type.

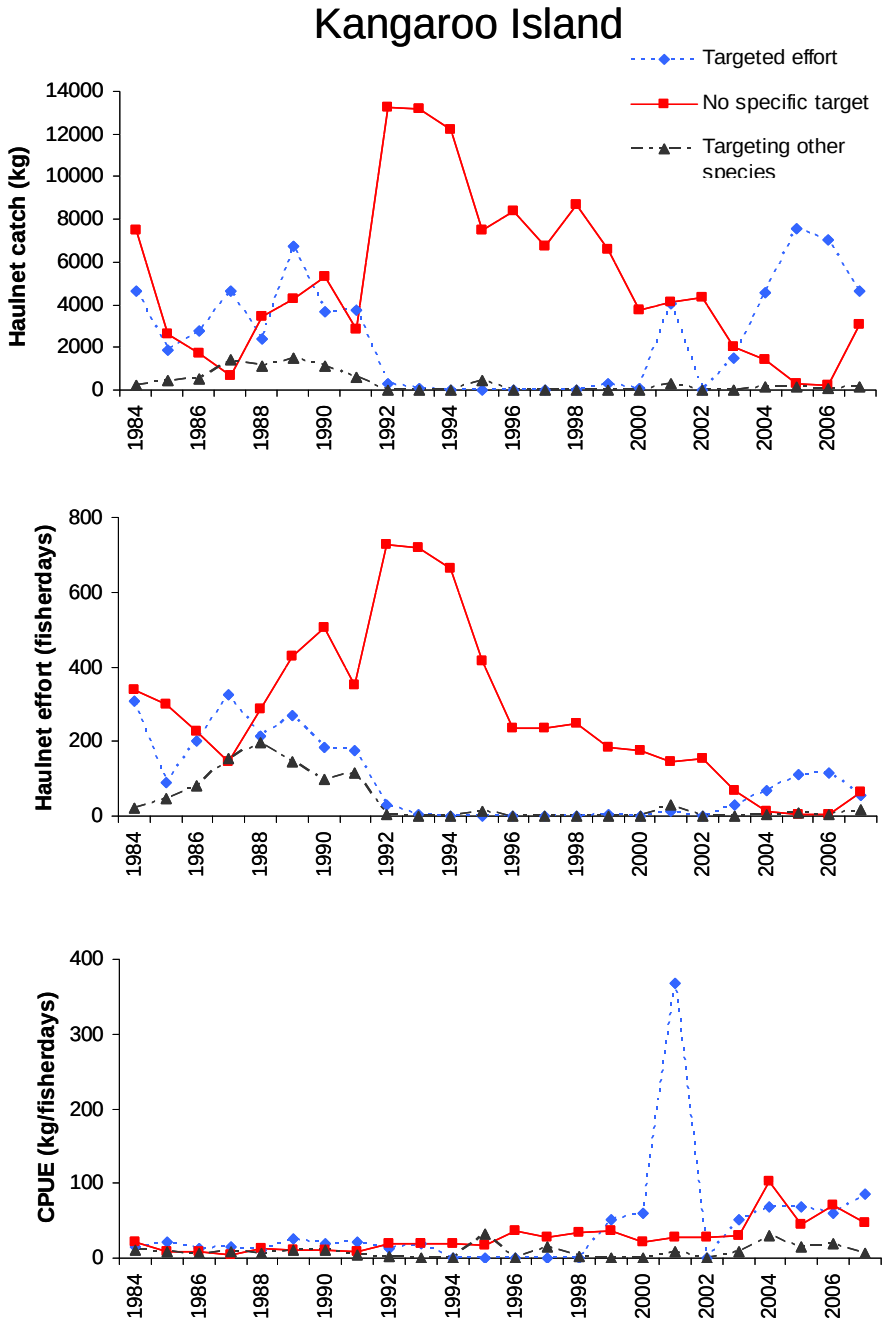

Fig. 3.16 Kangaroo Island Top graph - historical trends in haul net catch for each of the three effort categories. Middle graph - historical trends in haul net effort for each of the three effort categories. Bottom graph - historical trends in CPUE for each of the three effort categories (note the exceptionally high estimate of CPUE for targeted effort in 2001).

3.3 Discussion

The State-wide commercial fishery statistics demonstrate some strong trends that largely reflect significant changes in the structure of the fishery. Between 1984 and 2007 the State-wide commercial catch dropped in several significant steps. These decreases reflect substantial reductions in handline and gillnet catches since 1999 and a gradual decline in haul net catch since 1992. Such reductions are the consequence of substantial falls in commercial fishing effort. Both targeted handline and gillnet fishing effort have fallen considerably since 1992. It is more problematic to determine levels of targeted haul net effort, nevertheless since 1984 there has been a substantial reduction in the number of net endorsements that has culminated in a decrease in the total number of haul net fishing days (Fowler 2005), suggesting the likelihood that targeted haul net effort on King George whiting has declined.

Despite the changes in commercial catch and effort described above, which are attributable to structural changes in the fishery, the important indicator of stock status is CPUE. The State-wide estimates of CPUE for both handlines and gillnets have generally increased since 1984 but demonstrated considerable declines in the early 2000s, which caused the concern for stock status that was expressed in an earlier stock assessment report (McGarvey et al. 2003). Nevertheless, the State-wide estimates of handline and gillnet CPUE have now recovered, and reached new maxima in 2006 and 2007.

The most significant gear types differ between the different regions and are partly a consequence of historical management decisions. As such, line fishing has become the dominant gear used in most regions, with the use of haul nets largely now restricted to the northern gulfs. In each region, handline CPUE increased between 2005 and 2007, relative to the preceding few years. Furthermore, in the northern gulfs haul net CPUE also increased in the past few years. These are consistent positive indicators for the status of the regional stocks of King George whiting.

4. POPULATION STRUCTURE

4.1 Introduction

Populations of fish that are subjected to fishing pressure normally experience some degree of truncation of their age and size distributions as a consequence of the removal of the larger, older individuals. This can have further population-level effects by influencing egg production, and ultimately recruitment success (Longhurst 2002; Francis 2003, Berkeley et al. 2004). As such, population structure can be an important indicator of the status of a fishery. Nevertheless, its assessment as an indicator depends on having a good understanding of the life history of the species and its influence on spatial variation in population structure.

The characteristics of the populations of King George whiting throughout South Australia's coastal waters have been determined on several occasions, revealing a complex interaction between population structure and life history. King George whiting are not distributed evenly with respect to size and age (Fowler 1998, Fowler et al. 2000a, Fowler and McGarvey 2000). Catches from throughout Gulf St. Vincent, northern Spencer Gulf and from the bays of the West Coast of Eyre Peninsula tend to be almost exclusively small fish from the 3+ age class. Alternatively, fish sampled from Investigator Strait along the northern coast of Kangaroo Island and from south eastern Spencer Gulf show a much broader size and age range. The latter populations are found in deeper waters in more exposed places, and consist of multiple year classes of fish of up to 20 years of age.

Tag/recapture studies have revealed that the populations of larger, older fish on the spawning grounds are replenished by migration from the northern gulfs (Fowler et al. 2002). Thus, fish movement constitutes an important obligative process that closes the life history cycle between nursery areas and spawning grounds. These older, larger fish that occur in the deeper offshore places constitute the spawning populations (Fowler et al. 1999). Spawning does not occur generally throughout all South Australia's coastal waters but rather only at particular locations or spawning grounds. Given this geographic separation between the spawning grounds and nursery areas, the eggs and larvae must be advected to the nursery areas. As such, it is likely that the larger, older fish in the spawning populations make substantial contributions to egg production and so the age structures of these populations may be important indicators of egg production.

The age structures show evidence of strong and weak year classes. This suggests that year class strength is a consequence of recruitment processes, with the rates showing considerable inter-annual variability. Furthermore, similar strong year classes have been evident in both Southern Spencer Gulf and Investigator Strait, showing that environmental influences over recruitment operate at the geographic spatial scale.

The studies on population structure that were done between 1995 and 1998, identified both the spatial dispersion patterns, with respect to size and age, as well as the locations of the spawning grounds (Fowler et al. 1999, Fowler et al. 2000a). The sampling that was done between 2001 and 2004 purposely focussed on the populations on the spawning grounds since their age structures may be important indicators of egg production. In each case these historic sampling programs depended on samples that were accessed from both the commercial and recreational fishing sectors. In 2006, a new sampling protocol for King George whiting was initiated, i.e. a fish market-based sampling protocol for the commercial catch. The aim of this chapter is to present the results from the recent sampling that was done between July 2006 and June 2007, and to provide a qualitative comparison with data collected from the same regions in the past. This will determine whether there is evidence for recent truncation of the population structure that is relatable to fishing pressure.

4.2 Materials and Methods

The market sampling was concentrated at the SAFCOL fish market. Generally once per week, a team of three researchers processed samples of King George whiting prior to the morning auction. These data were augmented with that collected on field trips to the West Coast. Catches were selected from those available to ensure as broad a geographic coverage as possible. A two-stage sampling protocol was used in processing catches. First, a relatively large number of fish were measured to obtain size information for the catch, from which a sub-sample of fish was taken for further biological analysis. Back in the laboratory, these fish were measured for total length (TL) and weighed individually, sexed and the stage of reproductive development determined. They were then dissected for the removal of the sagittae, i.e. the largest pair of otoliths, for ageing. One otolith from each fish was embedded in resin and sectioned using a diamond saw to produce a thin transverse section. The section was mounted on a glass microscope slide and then interpreted using low power microscopy by counting the opaque zones. Each count was then interpreted to provide an estimate of fish age (Fowler and Short 1998). For each region an age/length key was developed to convert the sample

proportions by length into proportions by age. Thus, a population size and age structure was produced for each region.

4.3 Results

West Coast of Eyre Peninsula

The size structures of fish sampled from the West Coast of Eyre Peninsula showed considerable spatial variation (Fig. 4.1). The length frequency distribution for the Far West Coast ranged from 30 to 52 cm TL, but most fish were <38 cm, with the modal size at 34 cm. Alternatively, the size distribution for the Mid West Coast was dominated by smaller fish that rarely exceeded 34 cm TL. Both populations consisted of only a few age classes and were each dominated by the 3-year age class (Fig. 4.1). The remaining fish from the Far West Coast included representatives from the 2+, 4+ and 5+ age classes whereas for the Mid West Coast the remaining 10% of the population involved only 4+ fish.

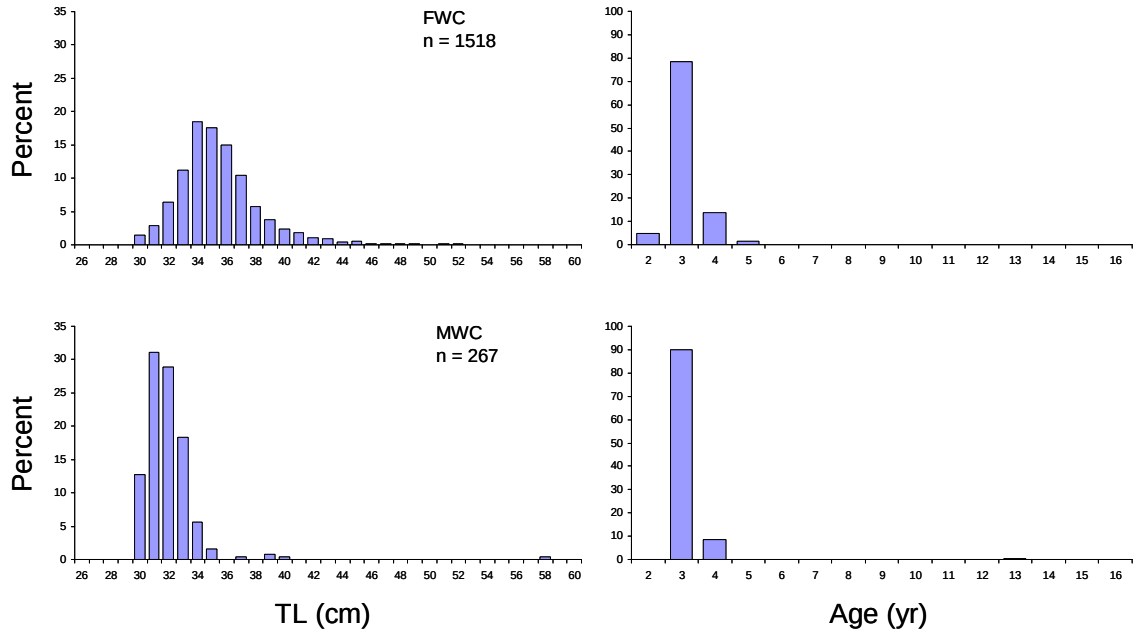

Fig. 4.1 Age and size structures of samples of King George whiting collected between July 2006 and June 2007 from the West Coast of Eyre Peninsula (FWC = Far West Coast, MWC = Mid West Coast).

Spencer Gulf

Samples were collected from Northern Spencer Gulf that had been taken using both handlines and haul nets. The size distributions were similar between gear types with catches dominated by fish from 31 – 36 cm TL, with a modal size of either 33 or 34 cm (Fig. 4.2). The age distributions ranged from 2+ to 5+ fish, but were dominated by the 3+ age class that contributed up to 80% of the catch (Fig. 4.2). Southern Spencer Gulf provided a much broader size distribution with the majority of fish from 34 to 41 cm TL. The age distribution was also broader with some fish up to 11 years of age. Fish from the 4+ and 5+ age classes constituted considerably higher proportions of the catch than was the case for Northern Spencer Gulf.

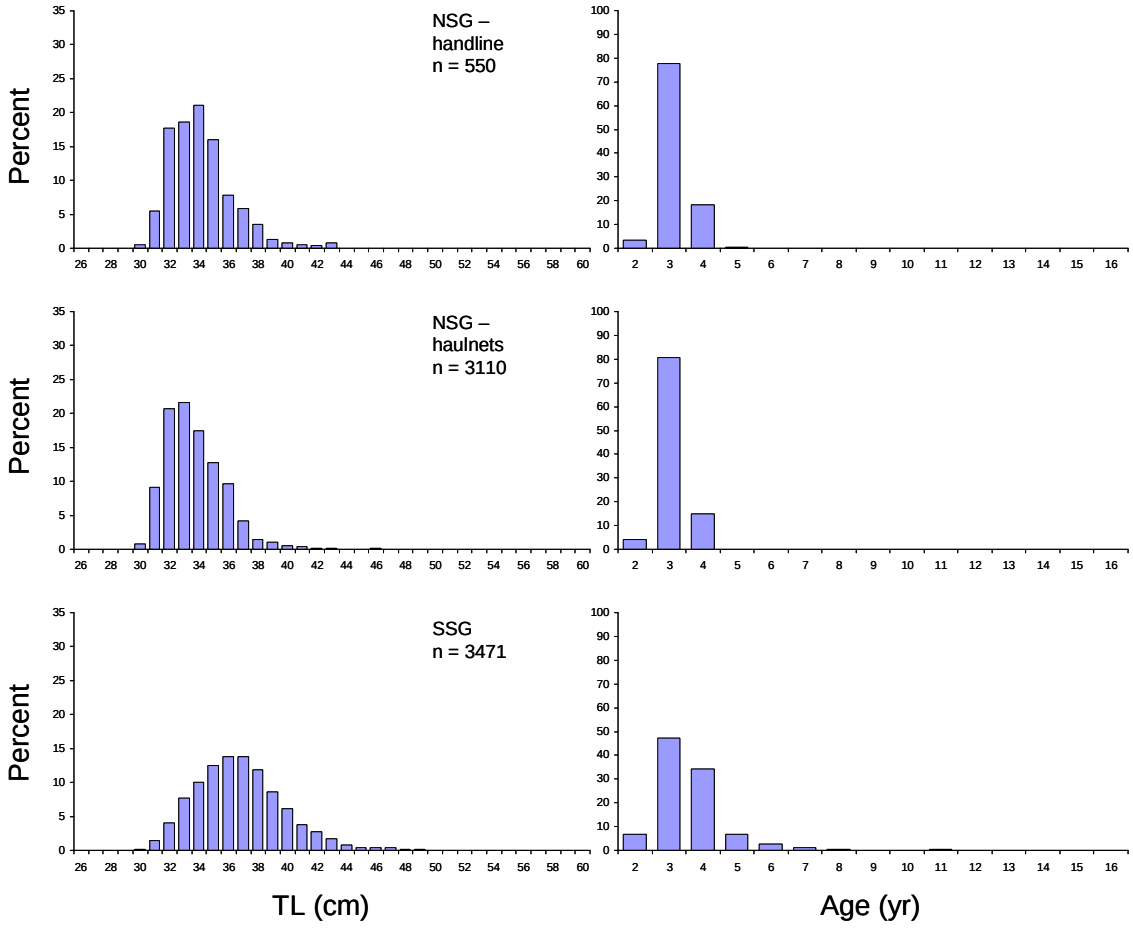

Fig. 4.2 Age and size structures of samples of King George whiting collected between July 2006 and June 2007 from Spencer Gulf (NSG = Northern Spencer Gulf, SSG = Southern Spencer Gulf).

Gulf St. Vincent and Investigator Strait

The fish sampled from MFAs 34 and 35 in northern Gulf St. Vincent were predominantly from 31 to 36 cm TL with the mode at 32 cm TL (Fig. 4.3). Although fish of up to 5 years of age were recorded, approximately 90% of those sampled were from the 3+ age class. In comparison, the fish from Block 40, which incorporates the south western corner of Gulf St. Vincent as well the majority of Investigator Strait, had a very broad size distribution, being dominated by fish from the 33 to 43 cm TL size classes. The age distribution included fish that were up to 10 years old but was dominated by those from 3 to 7 years. The fish sampled from along the northern coast of Kangaroo Island also had a broader size distribution than those from the gulf. Although there was a distinct mode at 34 cm, the distribution included relatively large numbers of fish that were up to 42 cm TL. As such, the age distribution was also broad, involving fish of up to 12 years of age, but was still dominated by relatively young fish from the 3+ and 4+ age classes.

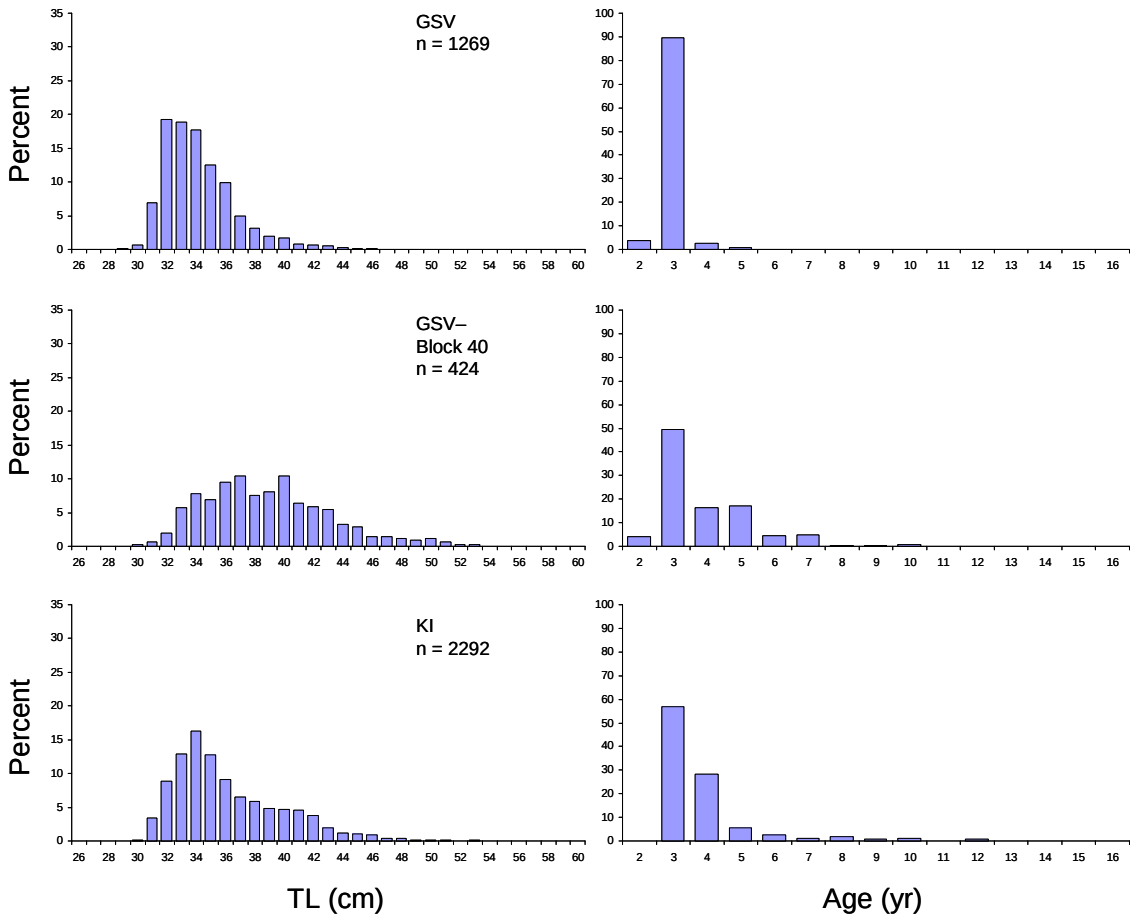

Fig. 4.3 Age and size structures of samples of King George whiting collected between July 2006 and June 2007 from Gulf St. Vincent and Investigator Strait (GSV = Gulf St. Vincent, KI = Kangaroo Island).

4.4 Discussion

The market sampling program undertaken between July 2006 and June 2007 produced estimates of population structure for each of the different fishery regions considered for South Australia's King George whiting fishery (Fig. 3.1). The data were consistent with those collected previously and with the current understanding of the life history of the species. Comparison of these size and age structures with those collected during the 1990s and early 2000s indicates that there has been no significant change over the past decade. As such, there is no evidence that population truncation has occurred over this time.

5. MODEL ASSESSMENT OF BIOLOGICAL PERFORMANCE INDICATORS

5.1. Introduction

WhitEst model: description and input data

For King George whiting in South Australia the primary management objective remains to ensure sustainability of the fishery. To facilitate this, a computer fishery model was developed in an FRDC-funded project (Fowler and McGarvey 2000). This is a dynamic, spatial, age-structured model that is used to integrate up-to-date data from several data sources to provide estimates of biological performance indicators on the status of the fishery. The model involves six spatial cells, five of which contribute most of the catch, i.e. the West Coast, and the upper and southern regions of the two gulfs, whilst the last cell is located offshore from the West Coast (Fig. 5.1). The model takes into account yearly summer migration from inshore areas in the northern gulfs to the spawning regions in the southern gulfs. Furthermore, a spatial model breakdown in combination with a monthly time step allows the model to keep account of the exploitation that varies seasonally in space and time. Exploitation is high in the upper gulfs and inshore, but lower in the southern-gulf offshore areas where spawning occurs. The data and inputs to the model are (1) monthly catch and effort totals, (2) samples of commercial-catch proportions by fish age and sex in different spatial cells for some months through the two sampling periods of September 1994-June 1997 and July 2004-June 2007, (3) a growth curve of estimated length-at-age (McGarvey and Fowler 2002), (4) estimated migration rates among the 5 spatial cells based on tag/recapture studies done in the 1960's, 1970's, and 1980's (McGarvey and Feenstra 2002), (5) a partition of each yearly cohort length distribution into monthly slices. A new model slice (i.e. length bin) is created in each monthly model time step, a 'slice' being defined as the proportion of each King George whiting cohort that reaches legal size each month. This slice partition model framework (McGarvey et al. 2007) permits a description of the seasonal growth of each cohort into the legally harvestable size range, as the yearly recruitment pulse reaching legal size in late summer and autumn of each year, and the subsequent large shift of MSF fishing effort to King George whiting that occurs each winter, often peaking in July. The slice partition modelling method (1) separates legal from sublegal fish, (2) explicitly models the arrival of new recruits that grow into legal size each month, and (3) keeps account of model-predicted, legal fish numbers by both age and length. Recent improvements to the model are summarised in Appendix 2.

The model is fitted to monthly catches, conditional upon the associated effort in fisher days. Catch and effort data are analysed and modelled separately for the four gear types (handline, haul net, gillnet, and all other gears combined) and three target types (targeting King George whiting, targeting any other specific marine scalefish species, and not targeting any species in particular) reported in monthly commercial catch and effort logbooks. Recreational catch and effort by month and spatial cell are from the National Recreational and Indigenous Fishing Survey (Henry and Lyle 2003) and cover one year only. Further details of this model are included in the FRDC final report (Fowler and McGarvey 2000), with the additional details added since 2000 summarised in Appendix 2. The King George whiting model was externally reviewed in detail by Dr André Punt (University of Washington, Seattle, USA).

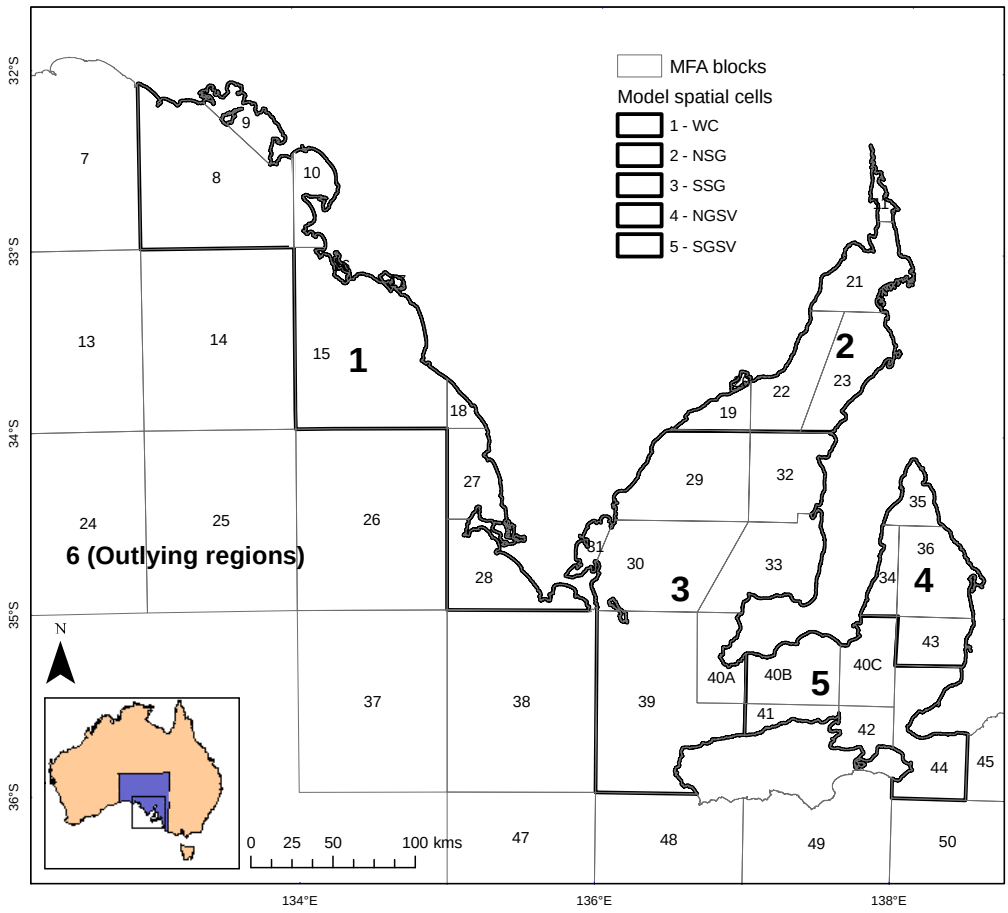

Fig. 5.1 Map of South Australia showing the Marine Fishing Areas in which commercial catch and effort are reported, and the 6 spatial cells used in WhitEst, the King George whiting stock assessment model.

WhitEst model indicators: recruitment, biomass and exploitation rate

The model outputs three principal biological performance indicators: recruitment; legal-size population biomass; and exploitation rate. Biomass and exploitation rate are presented as monthly model estimates, and also as their yearly averages. Yearly biomass is calculated for each calendar year as the mean of the monthly model-estimated biomass levels. Exploitation rate is defined as the fraction of biomass harvested over any specified time period. The yearly exploitation rate performance indicator is defined as the sum of yearly catches across all gear and target types,divided by the (yearly average) legal biomass in each calendar year. Recruitment is estimated as yearly numbers of 1 year olds. In the recruitment time series graphs, the year shown on the x-axis is the year that these fish entered the fishable stock as 3-year olds.

5.2 Results

Yearly recruitment is shown in all model output figures (Figs. 5.2-5.4). Monthly biomass and harvest fraction estimates are first presented broken down among the three main fishery regions (Gulf St. Vincent, Spencer Gulf and West Coast; Fig. 5.2). To examine long-term trends, biomass and exploitation rate are also shown as yearly quantities in Figs. 5.3-5.4, specifically yearly State-wide totals (Fig. 5.3) and yearly regional totals (Fig. 5.4). Confidence intervals were calculated from the maximised model likelihood only for the yearly regional indicators. Estimated model population indicators for South Australian King George whiting show the following features:

1. Seasonal variation: As observed directly in monthly catch and effort time series (Fig. 3.5), model estimates of fishing mortality and biomass show high seasonal variation (Fig. 5.2). The yearly cycle of model-estimated biomass occurs months ahead of the cycling trend in commercial catch and effort. King George whiting are most abundant in late summer and autumn subsequent to the late summer season of fastest growth when the highest numbers recruit to legal size. The seasonal peaks in commercial catch occur in mid-winter (Fig. 3.5), when the effort of fishers is principally targeted on the newly recruited year class of 3-year-old King George whiting.

2. Long-term trends, biomass and recruitment: Since model catch and effort data were first collected in July 1983, yearly model population abundance indicators for South Australian King George whiting have been generally stable. Over decadal time scales, the trends of

State-wide model estimates of recruitment and biomass (Fig. 5.3) have shown relatively flat time trends with modest yearly variation.

3. Long-term trends, exploitation rate: Model estimated exploitation rate has shown a steady decline over two decades. This presumably reflects the declining trend in the number of M- and B-class marine scalefish license holders who catch and target King George whiting (Fig. 3.4).

4. Recent years 2005-2007, biomass and recruitment: The model estimates show a striking improvement in the status of the King George whiting resource over the last three years. State-wide estimates of biomass and recruitment (Fig. 5.3) showed strong yearly increases over these years, reversing the downward trend that was evident in 1999 to 2002, which led to the management actions of 2004. All three regions showed rising trends in both recruitment and biomass, with historically unprecedented increases evident on the West Coast, and with Spencer Gulf showing greater increases than Gulf St. Vincent (Fig. 5.4). West Coast biomass and recruitment estimates reached new highs in 2007.

5. Trends for long-term exploitation rates remain somewhat uncertain because of insufficient effort data for the recreational sector. The model data inputs come principally from the commercial sector while recreational catch was estimated to comprise more than half the total State-wide catch in 2001. In the absence of any time series data for the recreational sector, the WhitEst model assumes that recreational catch and effort vary proportionally with the South Australian human population. Thus, the model does not take account of either possible change in recreational effort or of possible increase in effective effort that might result from the increased use of fish-finders, GPS and of published increased information sharing in relation to fishing 'hot spots' through various media including television, newspaper, magazines and internet forums.

6. In earlier runs the model underestimated the observed catches from the West Coast, and from the upper Gulf St. Vincent, for the last model year, 2007. Sensitivity testing showed that this effect on the West Coast was specifically due to an absence of newly recruited fish in the age samples from January to June 2007. Because the sample sizes in these last few months from the West Coast were small, this model effect is presumed to be an artefact of sampling. This was corrected for the West Coast only, by removing the age samples from the fitted dataset for July 2006-June 2007, after which the underestimation of catches for West Coast in the last year was alleviated (Appendix 3 - Fig. 10.1).

7. The model is now generating estimates of exploitation rate that are, on average, about 20-25% lower than previous WhitEst model versions. The reasons for this change are two-fold: namely an important change to the way yearly measures of biomass and exploitation rate (the latter being catch divided by biomass) are defined and reported; and second, due to the effect on model estimates of reducing the number of model spatial cells. The definition for the statistic reported as the indicator for yearly biomass has been changed from reporting the value of monthly estimated model biomass from the start of each year (1 January) to now being calculated as the mean of monthly biomass estimates over the full 12 months of each calendar year. Examination of seasonal variation in monthly biomass (Fig. 5.2) shows that, particularly for the West Coast, and to a lesser extend for GSV, the value at 1 January is lower than the yearly average. Thus, for these two regions in particular, part of the reduced level of estimated exploitation rate is due to the implementation of the new definition for the yearly biomass indicator. Second, a further reduction in the mortality rate estimates was found to be linked to changes in the movement rates in the two gulfs (by sensitivity testing and comparison of model runs) after model cells were re-aggregated. In particular, the exploitation rate estimates declined in the upper subregions of both gulfs, which was linked to changes in the estimated rates of movement. Estimated movement rates southward were about 10-12% higher after the lower gulf cells (and in GSV only, the two upper gulf cells) were amalgamated.

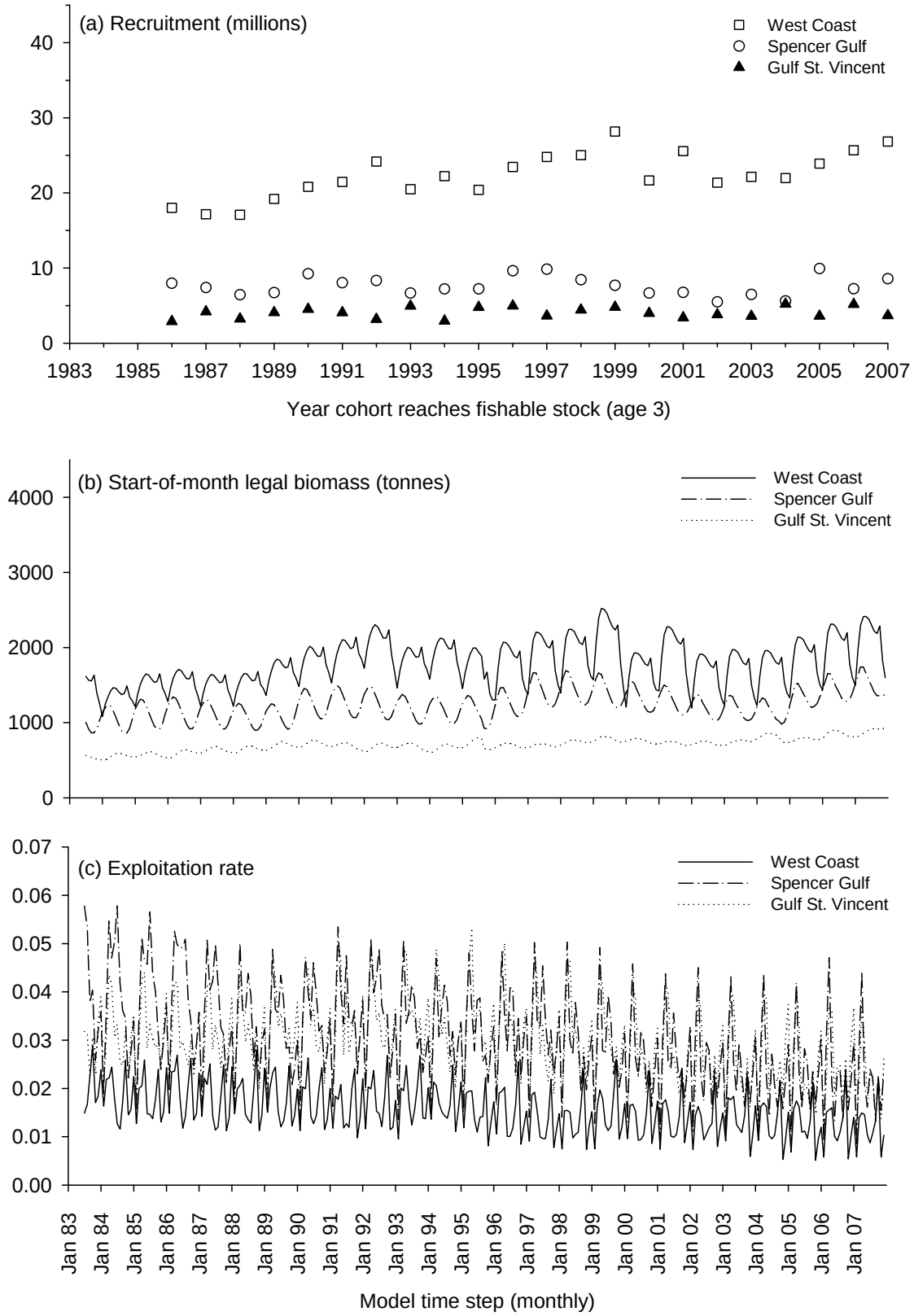

Fig. 5.2 Monthly regional biological indicators 1984-2007 for the South Australian King George whiting population. These performance indicators of (a) yearly recruit numbers, (b) legal biomass averaged over the 12 months of each calendar year, and (c) harvest fraction as the monthly model-estimated catch divided by the start-of-month legal biomass, are estimated by the FRDC-sponsored spatial dynamic stock assessment model (WhitEst).

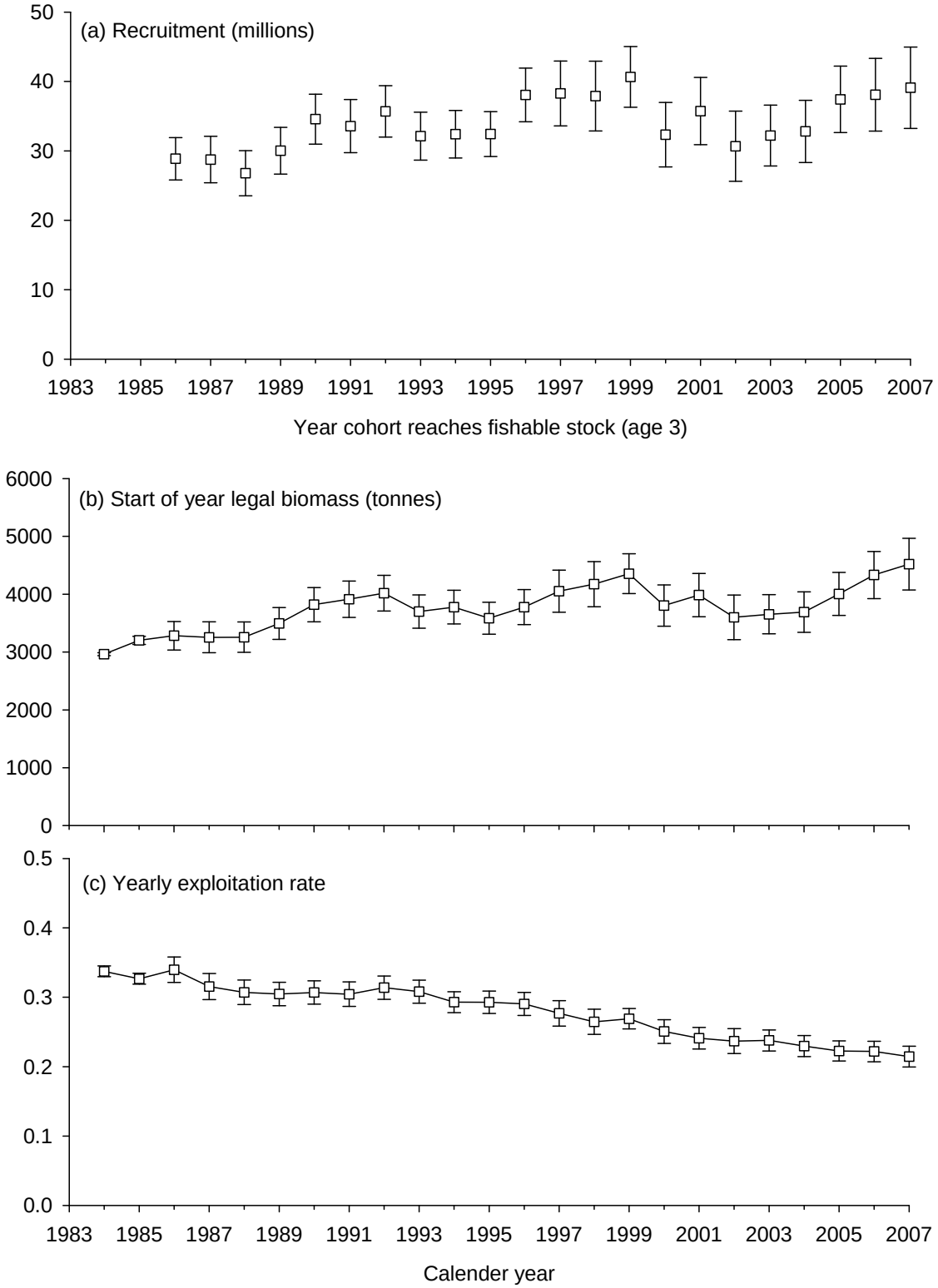

Fig. 5.3 Yearly State-wide (excluding spatial cell 6) model biological indicators 1984-2007 for South Australian King George whiting. These performance indicators of (a) yearly recruit numbers, (b) legal biomass averaged over the 12 months of each calendar year, and (c) harvest fraction as the yearly model-estimated catch divided by the yearly average legal biomass, are estimated by the FRDC-sponsored spatial dynamic stock assessment model (WhitEst). Error bars show 95% confidence intervals.

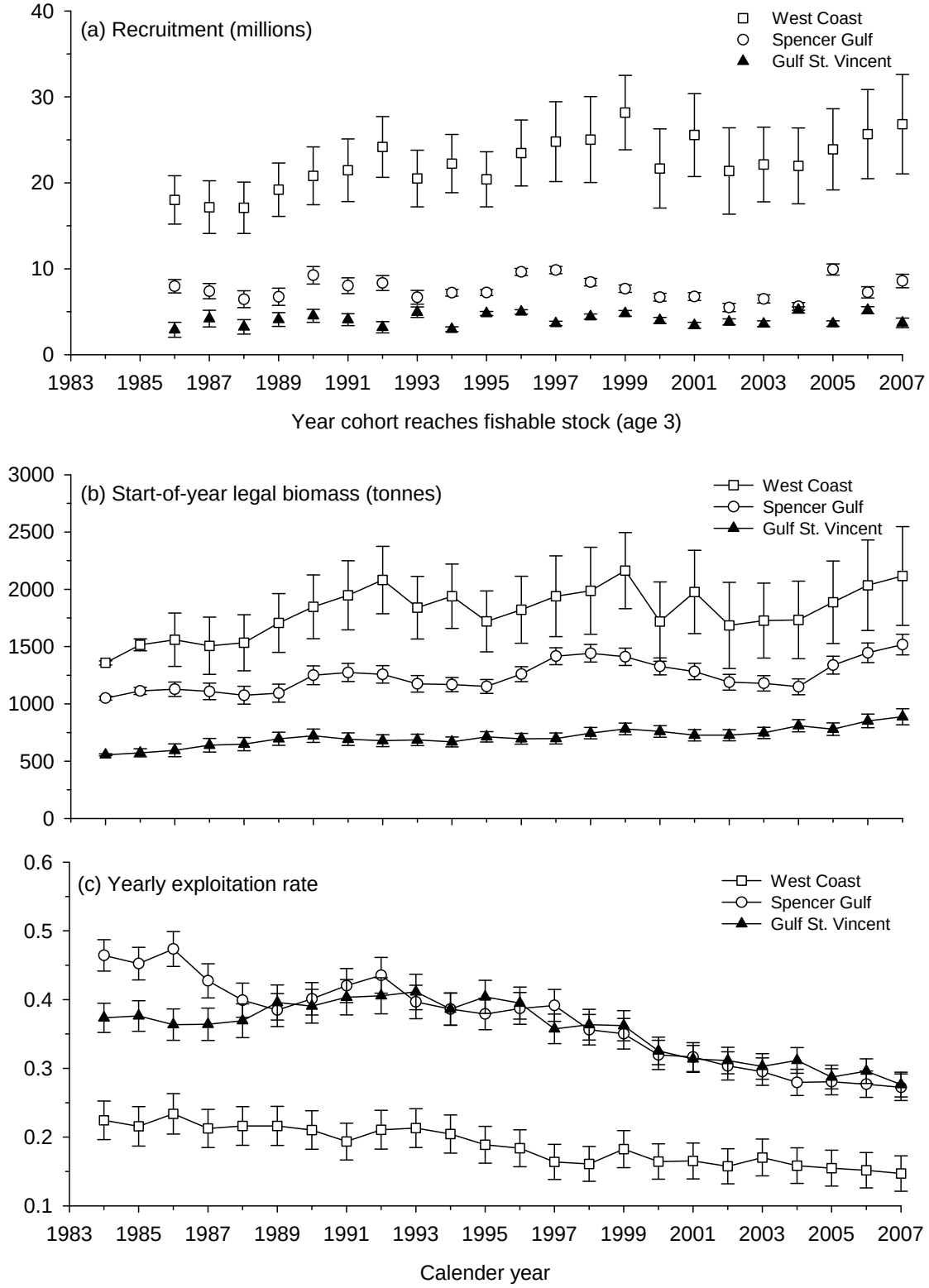

Fig. 5.4 Yearly regional model biological indicators 1984-2007 for South Australian King George whiting. Regions are the West Coast (including Far and Mid West Coast, and Coffin Bay, spatial cell 1 shown in Fig. 5.1), Spencer Gulf (Fig. 5.1, spatial cells 2 and 3), and Gulf St. Vincent and Kangaroo Island (Fig. 5.1, model cells 4 and 5). Error bars show 95% confidence intervals.

6. ASSESSMENT OF BIOLOGICAL PERFORMANCE INDICATORS

6.1 Introduction

The recently completed Management Plan for the Marine Scalefish Fishery of South Australia provides a strategic framework to guide fishery management decisions (Noell et al. 2006). This framework links the management goals with the stock assessment process and also identifies the appropriate responses to the potential outcomes of the assessment. Essential to this process are fishery performance indicators that relate to the status of the fishery, with respect to the management objectives. For this fishery there are two sets of fishery performance indicators that are assessed against particular limit reference points, i.e. the 'general performance indicators' that relate to the commercial catch and effort data and 'biological performance indicators' that relate to estimates of biological parameters. For the former, the indicators and reference points that are specified in the Management Plan (Noell et al. 2006) were not used in this assessment. At a meeting of the Marine Scalefish Fishery Management Committee that was held on the 17th February 2006,it was agreed that new sets of general performance indicators and limit reference points should be adopted (Minutes of meeting No. 98 of MSFMC), which are outlined below. The biological performance indicators remain as specified in the Management Plan (Noell et al. 2006).

6.2 Materials and Methods

General Performance Indicators

There are three general fishery performance indicators that were calculated from the commercial fishery statistics: total commercial catch; targeted effort; and targeted CPUE. These were assessed against the following limit reference points:

1. the 3rd highest and 3rd lowest values over the reference period;
2. the greatest (%) inter-annual variation (+ and -) over the reference period;
3. the greatest rate of change (trend) over periods of three years (+ and -) through the reference period.

Since three new years of commercial catch and effort data were presented in this report, i.e. for 2005, 2006 and 2007 (Chapter 3), the status of the fishery at the end of each year was considered. The annual State-wide totals of commercial catch, targeted effort and targeted

CPUE for the handline sector were calculated for each calendar year from 1984 until each prescribed year. In each case, the limit reference points were then derived based on the time series of data. The estimates of data in each of 2005, 2006 or 2007 were then compared with the limit reference points determined for the whole time series.

Biological Performance Indicators

For King George whiting, the four biological performance indicators that were assessed were fishable biomass, exploitation rate of the fishable biomass, abundance of pre-recruits, and age structure (Noell et al. 2006). The first three of these were outputs from the WhitEst model (Chapter 5), and the fourth relates to the analysis of population structure that was presented in Chapter 4.

The definitions of the time series indicators for biomass and exploitation rate, as determined by WhitEst, were modified in this assessment compared to earlier ones. Here, biomass was calculated as the average monthly model estimate across the 12 months, rather than the start-of-year (1 January) model biomass estimate, as was the case previously. This definition is appropriate because it avoids the arbitrary choice of any particular month as the yearly indicator value. Yearly exploitation rate was calculated as the ratio of the model-estimated catch, summed over the whole year, divided by the yearly average biomass, as defined above. Using model rather than data catch is appropriate because it is most consistent with the data measures of mortality rate from age samples that underlie the best estimates of exploitation rate.

For fishable biomass and the abundance of pre-recruits (as model estimates of 1-year olds for each cohort), the limit reference points were triggered if the indicator in the most recent (reference) year was either 10% lower or greater than its average value from the previous five years (Noell et al. 2006). Here, the estimates of fishable biomass and recruitment, as outputs from the WhitEst fishery model for 2007, were compared with the model-estimated yearly averages from 2002 to 2006. The estimates of all three biological performance indicators were evaluated for each of the three main regions that were considered in the WhitEst model, i.e. West Coast, Spencer Gulf and Gulf St. Vincent (yearly regional indicators shown in Fig. 5.4). The State-wide indicators of biomass and recruitment (Fig. 5.3) were summed across the three regions while for exploitation rate, an overall ratio of the model catch for all regions divided by the biomass sum, was evaluated.

6.3 Results

General Performance Indicators

For the assessment of the general performance indicators up to the end of each of 2005, 2006 and 2007, similar limit reference points were breached in each year (Table 6.1). In both 2005 and 2006, the 2nd lowest commercial catches were recorded, whilst in each of the three years, the handline catch rate was close to the highest ever recorded.

Table 6.1 Summary of the results of the comparisons between the general fishery performance indicators and the limit reference points for the King George whiting fishery, based on State-wide data.

Biological Performance Indicator	Limit Reference Point	Year	Limit exceeded?	Comments
Total commercial catch	3rd lowest/ 3rd highest	2005	Yes	2nd lowest
		2006	Yes	2nd lowest
		2007	No	
	Greatest inter-annual change	2005	No	
		2006	No	
		2007	No	
	Greatest 3-year trend	2005	No	
		2006	No	
		2007	No	
Total commercial effort	3rd highest	2005	No	
		2006	No	
		2007	No	
	Greatest inter-annual change	2005	No	
		2006	No	
		2007	No	
	Greatest 3-year trend	2005	No	
		2006	No	
		2007	No	
Target handline CPUE	3rd lowest/ 3rd highest	2005	Yes	3rd highest
		2006	Yes	2nd highest
		2007	Yes	Highest
	Greatest inter-annual change	2005	No	
		2006	No	
		2007	No	
	Greatest 3-year trend	2005	No	
		2006	No	
		2007	No	

Biological Performance Indicators

In 2007, estimates of fishable biomass for each of the West Coast, Spencer Gulf and Gulf St. Vincent, and at the State-wide level were considerably higher than the five-year averages, and in all cases breached the limit reference point of 10% above average (Table 6.2). Similarly, the estimates of numbers of pre-recruits in 2007 for all three regions and at the State-wide level, were also more than 10% greater in 2007 than the average of the previous 5 years. As such, the evaluation of biomass and recruitment as biological performance indicators for King George whiting showed a favourable outcome for the status of the fishery.

The third output parameter from the WhitEst model considered as a biological performance indicator was exploitation rate. The assigned limit reference point for this is that the exploitation rate should not exceed the international standard of 28% (Caddy 1998). The estimate of exploitation rate for the West Coast for 2007 fell well below this upper limit (Table 6.2). However, in both gulfs the estimates of exploitation rate were only marginally lower than this limit, suggesting that in each case the proportion of the legal biomass that was harvested was approximately equal to the maximum recommended level. At the State-wide level, the limit reference point was not breached.

The final biological fishery indicator was age structure. The limit reference point for this indicator is that there has been no significant change over the previous 5 years. The age structures at numerous places across the fishery were considered in Chapter 4. Comparison of these age structures against data collected during the 1990s and early 2000s indicated that there had been no significant change over the past decade or so (Table 6.2).

6.4 Discussion

Several general performance indicators and biological performance indicators breached the limit reference points. These breaches were all consistent with each other, and point to a consistent indication of stock status. The results are best interpreted with respect to data presented in Fig. 3.3, which indicate that between 2005 and 2007, commercial catch and effort were at their lowest ever recorded levels, whilst CPUE had attained record high levels. The model outputs indicate that these are the result of above-average levels of fishable biomass. Also, in several regions, recruitment rates have also been above average. Overall, the data suggest that the declining catch is the consequence of declining fishing effort, and that the high

catch rates currently reflect high levels of biomass available to the fishers, a consequence of above-average recruitment.

Table 6.2 Yearly biological performance indicators for the three regions considered in the WhitEst model, as well as combined at the State-wide level. Limit reference points that were breached are highlighted in yellow. The current performance year covers the period January 2007 – December 2007.

Biological performance indicator	Biological limit reference point	West Coast	Spencer Gulf	Gulf St. Vincent	State-wide
Fishable biomass	+/- 10% of previous 5-yr average	16.7% above average of previous 5 years	20.4% above average of previous 5 years	13.4% above average of previous 5 years	17.2% above average of previous 5 years
Pre-recruit Abundance	+/- 10% of previous 5-yr average	2004 cohort is 17% above average of previous 5 years	2004 cohort is 23% above average of previous 5 years	2004 cohort is 14% below average of previous 5 years	2004 cohort is 14% above average of previous 5 years
Exploitation rate	Exceeds international standard (28% yearly)	14.7%	27.2%	27.6%	21.5%
Age structure	Significant change over previous 5 years	No change over time	No change over time	No change over time	No change over time

7. DISCUSSION

7.1 Context of this assessment

In the early 2000s there was considerable concern about the long-term sustainability of the South Australian King George whiting fishery (McGarvey et al. 2003). It was apparent from several sets of data that the abundances of this species across South Australia had decreased considerably through the period of 1999 to 2002. This concerning status prompted a review of the management of the fishery through 2004 that culminated in significant changes that came into force on the 1st October 2004. The next stock assessment that was done after this implementation was completed in August 2005 (McGarvey et al. 2005). That report summarised data that were collected only up to the end of 2004 and so was unlikely to have revealed any benefits from the management changes. However, it did provide an opportunity to assess whether the downward trends in biological performance indicators that were evident through the period of 1999 to 2002 had continued or not. In this regard that assessment provided the initial indications that there had been a turn-around across a broad geographic area in the declining trends in the catch and effort data, whilst the associated output from the WhitEst model indicated marginal increases in recruitment and biomass in the three main fishery regions. Nevertheless, that stock assessment also identified that there still remained some concerning breaches of fishery performance indicators.

The current stock assessment report is significant as it provides the first opportunity to assess the status of the King George whiting fishery from data collected up to approximately 3 years after the new management changes were implemented. There were several sets of data considered here that relate to the status of the fishery. Firstly, the commercial catch, effort and CPUE data were considered at both the State-wide and regional scales. Secondly, the size and age structures of populations at various places across the fishery were considered. Finally, these two independent datasets were then integrated in the WhitEst fishery assessment model, to generate a number of output parameters that are indicative of fishery status. The various fishery performance indicators were assessed against prescribed limit reference points.

7.2 Determination of stock status

Commercial fishery statistics

The most complete and informative data on the status of the King George whiting stocks are the estimates of catch, effort and CPUE from the commercial fishing sector. In this report we presented data for the calendar years of 1984 to 2007, thus providing an additional three years of data subsequent to those reported by McGarvey et al. (2005). The dominant long-term trend in this 24-year dataset was a steady decline in commercial fishing effort that was particularly evident after 1992. This has been driven by an on-going reduction in the number of marine scalefish commercial fishers, particularly as a consequence of the licence amalgamation scheme. This continual decline in licence holders has resulted in less fishing days, culminating in a general reduction in commercial catch. Prior to 1999 these reductions in commercial catch and effort were generally associated with estimates of rising CPUE. However, between 1999 and 2002 there were declines in the regional estimates of CPUE that were the primary cause for concern with respect to stock status through that period. Then in 2005 it became apparent that the downward trends in regional estimates of CPUE had been arrested in most regions, based on the catch and effort data of 2003 and 2004 (McGarvey et al. 2005). Fortunately, it now appears that those regional trends of increasing CPUE have continued to 2007. Even in Gulf St. Vincent the handline CPUE has increased in both 2006 and 2007, halting a four year declining trend. As such, in all regions, handline CPUE was higher through the period of 2005 to 2007 than during the earlier years of the 2000s, providing a positive indication of stock status.

Population structure

The second set of data considered as indicators of stock status were population size and age structures. Through broad-scale population sampling during the 1990s it became evident that King George whiting in South Australia are not distributed evenly with respect to size and age (Fowler and McGarvey 2000, Fowler et al. 2000). Whilst some populations consist of relatively small, young fish, others support broader age and size ranges of individuals. These latter populations form the spawning aggregations during the reproductive season (Fowler et al. 1999), and are supplemented by movement of small, young adults from the inshore areas (Fowler et al. 2002). The different size and age distributions of fish in different regions are the culmination of a complicated sequence of life history and demographic processes. As such, we consider that the regional estimates of population structure provide significant indicators of

stock status. In this study market sampling for King George whiting was undertaken across the geographic range of the fishery between July 2006 and June 2007 and the size and age distributions were considered against historical data. These comparisons did not provide any evidence of significant change in population structure across the range of the species in South Australia that was attributable to the fishery.

Computer fishery assessment model

The computer fishery assessment model 'WhitEst' integrates fishery and biological data to provide annual estimates of recruitment, fishable biomass and annual exploitation rate. As reported by McGarvey et al. (2003), there were some concerning trends in these output parameters estimated up to 2002. In comparison, the estimates of output parameters calculated up to the end of 2007, as reported here, showed much more positive trends. Estimates of recruitment for the West Coast and Spencer Gulf increased between 2002 and 2007. The estimates of fishable biomass increased appreciably for each of the three regions, particularly between 2004 and 2007, and were associated with continual declines in the annual exploitation rates for each region. These model outputs are favourable outcomes for the status of the fishery.

Comparisons with limit reference points

The different fishery performance indicators that were discussed above were assessed against specific limit reference points. Most of the general performance indicators that relate to catch and effort data from the commercial sector did not exceed the limit reference points. Nevertheless, there were some breaches that were consistent for the period of 2005-2007. The first related to the historically low total commercial catches. This highlights the extent to which commercial catch has declined in recent years, a reflection of the decreasing commercial fishing effort. The other breaches related to high estimates of State-wide handline CPUE, which have increased in the recent three years to the highest on record. This is strongly indicative of the significant turn-around in stock status that has taken place since the early 2000's.

Three of the biological performance indicators were output parameters from WhitEst. There were breaches for fishable biomass and recruitment indices that were consistent across the three regions and at the State-wide level. For fishable biomass all breaches were indicative of the current positive status of the stocks. Similarly, for recruitment, the breaches for the West Coast and Spencer Gulf reflected higher than average recruitment. It was only for Gulf St.

Vincent that the breach related to lower recruitment than for the 5-year average. In this latter region recruitment was particularly variable between 2003 and 2006, with relatively high rates recorded in both 2004 and 2006. Nevertheless, the overall State-wide recruitment estimate in 2007 was 17% above the previous 5-year average. The fourth biological performance indicator was population age structure. There were no significant changes in any regional age structures over the past five years.

7.3 Uncertainty in the fishery

The range of fishery indicators considered in this stock assessment provided consistent results with respect to the status of the stocks of King George whiting. Nevertheless, the assessment is fundamentally dependent on the commercial catch and effort statistics. These data constitute the general performance indicators, and are also the primary data input into the fishery assessment model WhitEst, which outputs the biological performance indicators. As such, the commercial catch and effort data are implicit to both sets of indicators. At present, there are no alternative indicators that are independent of the commercial fishery. This dependence on a particular data source provides the greatest uncertainty about the assessment of stock status.

There also remains some uncertainty about the fishery with respect to the lack of understanding about the recreational sector and the influence that recreational catch and effort have on total catch and fishing mortality. This lack of data was accommodated in the 'WhitEst' fishery model by assuming that the annual catch and effort of the recreational sector varied proportionally with change in human population size in South Australia, extrapolating forward and backward from the single set of regional estimates from the NRIF survey (Henry and Lyle 2003). However, it is unlikely that this really provides a satisfactory time-series of recreational catch and effort, as it does not accommodate a potentially increasing rate of participation in recreational fishing or changes to effective effort due to the increased availability of better boats and electronic equipment, such as echo sounders and GPS. In the absence of time-series data for this sector it is not possible to determine what accounted for the downturn in the stocks and fishery catches that occurred between 1999 and 2002. Fortunately, however, in 2007/08 a new telephone diary survey of the South Australian recreational sector has been underway, which will provide new estimates of regional recreational catch and effort for comparison with those recreational data collected in 2000/01 (Henry and Lyle 2003).

7.4 Management implications

The new management regulations that were implemented in October 2004 raised the minimum legal size, reduced recreational bag and boat limits and sought to accelerate the rate of commercial licence amalgamation. It is now more than three and a half years since those management changes were implemented. The various fishery performance indicators monitored in this study are all currently positive with respect to the status of the stocks, indicating no immediate requirement to reconsider the current management regulations for the species. The recreational fishing survey that has been underway since August 2007 will be completed in late 2008 and the results should become available some time in 2009 or 2010. As such, the next stock assessment for King George whiting that is scheduled for 2011 will provide opportunity to undertake a comprehensive analysis of the new results for the recreational sector. Since the same sampling methods are being used as those used in 2000/01 (Henry and Lyle 2003), it will be possible to determine whether recreational catch and effort have increased through the intervening six and half years or so, and the consequences of the results for the status of the King George whiting stocks.

7.5 Future work

The current plans for future work on King George whiting are outlined in a 5-year plan that was agreed to in 2005. The monitoring of the commercial catch and effort, and that of the Charter Boat sector, by SARDI's Fisheries Statistics Unit will continue into the future. The collection of new catch and effort data from the recreational sector is currently being done and the results will be available in 2009 or 2010. The plan for future surveys of the recreational sector remains unresolved.

A significant catch sampling program for King George whiting, which was aimed at describing the spatial variation in population structure, was undertaken through the 1990s. Since then catch sampling has been undertaken in 2004/05 and 2006/07. In both cases, the sampling was concentrated at the SAFCOL fish market in Adelaide, which provided good samples from Gulf St. Vincent and northern Spencer Gulf. The sampling also involved trips to the West Coast so as to access fish that were captured near and landed at various ports between Port Lincoln and Denial Bay. The next market-based catch sampling planned for this species is for the period of July 2008 to June 2010. These data will be used to inform the WhitEst fishery assessment model for future stock assessments, and to monitor for contractions in size and age structures that may relate to fishing activity. The next stock assessment is planned for the financial year of 2010-2011 to be delivered in July 2011.

The work outlined above is designed to ensure that the King George whiting fishery, being the premier and icon species of South Australia's Marine Scalefish fishery, is not overfished. Nevertheless, this is only one aspect of ensuring that the fishery conforms to the principles of ecologically sustainable development. Recently, SARDI has undertaken a project that was aimed at determining the bycatch issues in the Marine Scalefish fishery. This study has determined that some undersized King George whiting are taken as bycatch when targeted using both handlines and haul nets. Although these undersized fish are released it is currently unknown what level of mortality they experience as a consequence of their capture and release. A research focus for the future is to determine the release mortality for these undersized fish when they are captured using haul nets of different mesh sizes and handlines with different hook sizes.

8. REFERENCE LIST

Australian Bureau of Agricultural and Resource Economics (ABARE (2007). Australian Fisheries Statistics, 2006. Canberra.

Berkeley SA, Hixon MA, Larson RJ and Love MS (2004) Fisheries sustainability via protection of age structure and spatial distribution of fish populations. Fisheries 29: 23-32.

Bruce BD (1989) Studying larval fish ecology: benefits to King George whiting research. SAFISH 13: 4-9.

Caddy JF (1998) A short review of precautionary reference points and some proposals for their use in data-poor situations. FAO Fishery Technical Paper 379. 30 pp.

Francis RC (2003) A web of small tensions. Fisheries 28: 20-23.

Fowler AJ (1998) King George whiting (*Sillaginodes punctata*). South Australian Fisheries Assessment Series 98/6. 58 pp.

Fowler AJ (2002) Snapper (*Pagrus auratus*). South Australian Fisheries Assessment Series 01/013. 64 pp.

Fowler AJ, March WA (2000) Characteristics of movement of King George whiting (Percoidei: Sillaginidae) in South Australian waters. Fish Movement and Migration. Australian Society of Fish Biology Workshop, Bendigo 28-29th Sept. 1999. pp. 136-143.

Fowler AJ, McGarvey R (1997) King George whiting (*Sillaginodes punctata*). South Australian Fisheries Assessment Series 97/6. 93 pp.

Fowler AJ, McGarvey R (1999) King George whiting (*Sillaginodes punctata*). South Australian Fisheries Assessment Series 99/03. 41 pp.

Fowler AJ, McGarvey R (2000) Development of an integrated fisheries management model for King George whiting (*Sillaginodes punctata*) in South Australia. Final report to FRDC for project 95/008. 232 pp.

Fowler AJ, Short DA (1996) Temporal variation in the early life-history characteristics of the King George whiting (*Sillaginodes punctata*) from analysis of otolith microstructure. Marine and Freshwater Research 47: 809-818.

Fowler AJ, Short DA (1998) Validation of age determination from otoliths of the King George whiting *Sillaginodes punctata* (Perciformes). Marine Biology 130: 577-587.

Fowler AJ, Jones GK, and McGarvey R (2002). Characteristics and consequences of movement patterns of King George whiting (Perciformes: *Sillaginodes punctata*) in South Australia. Marine and Freshwater Research 53: 1055-1069.

Fowler AJ, McLeay L, Short DA (1999) Reproductive mode and spawning information based on gonad analysis for the King George whiting (Percoidei: Sillaginidae) from South Australia. Marine Freshwater Research 50: 1-14.

Fowler AJ, McLeay L, Short DA (2000a) Spatial variation in size and age structures and reproductive characteristics of the King George whiting (Percoidei: Sillaginidae) in South Australian waters. Marine and Freshwater Research 51: 11-22.

Fowler AJ, Black KP, Jenkins GP (2000b) Determination of spawning areas and larval advection pathways for King George whiting in south-eastern Australia using otolith microstructure and hydrodynamic modelling. II. South Australia. Marine Ecology Progress Series 199: 243-254.

Fowler AJ, McGarvey R, Feenstra JE, Jackson WB (2007) Snapper (*Pagrus auratus*) Fishery. Fishery Assessment Report to PIRSA. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, F2007/000523-1, SARDI Research Report Series No. 224. Pp 90.

Haigh LJ, Donnellan S (2000) Stock structure based on analysis of mitochondrial DNA and microsatellites. In: (Fowler AJ, McGarvey R, eds) Development of an integrated fisheries management model for King George whiting (*Sillaginodes punctata*) in South Australia. Final Report to FRDC for project 95/008. pp 105-124.

Henry GW, Lyle JM (2003) The National Recreational and Indigenous Fishing Survey. Final Report to FRDC for project 99/158. 200 pp.

Jenkins GP (2005) Influence of climate on the fishery recruitment of a temperate, seagrass-associated fish, the King George whiting *Sillaginodes punctata*. Marine Ecology Progress Series 288: 263-271.

Jenkins GP, Black KP, Hamer PA (2000) Determination of spawning areas and larval advection pathways for King George whiting in southeastern Australia using otolith microstructure and hydrodynamic modelling. I. Victoria. Marine Ecology Progress Series Vol 199: 231-242.

Jones GK, Hall DA, Hill KM, Staniford A (1990) The South Australian marine scalefish fishery: stock assessment, economics, management. South Australian Department of Fisheries green Paper. 186 pp.

Jones GK, Doonan A (2002) 2000-01 National Recreational and Indigenous Fishing Survey. South Australian Regional Information. South Australian Fisheries Management Series. Paper No. 46.

Knight MA, Tsolos A, Doonan AM (2004) South Australian fisheries and aquaculture information and statistics report. SARDI Research Report Series No. 60. 82 pp.

Knight MA, Doonan AM, Tsolos A (2007a) South Australian wild fisheries information and statistics report. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, F2007/000571-1. SARDI Research Report Series No. 200.

Knight MA, Doonan AM, Tsolos A (2007b) South Australian Recreational Charter Boat Fishery. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, F2007/000847-1. SARDI Research Report Series No. 239.

Kumar MS, Hill R, Partington D (1995) The impact of commercial hauling nets and recreational line fishing on the survival of undersize King George whiting (*Sillaginodes punctata*). SARDI Research Report Series No. 6. 60 pp.

Longhurst A (2002) Murphy's law revisited: longevity as a factor in recruitment to fish populations. Fisheries Research 56: 125-131.

Moran, SM, Jenkins GP, Keough MJ, Hindell JS (2004) Evidence for secondary planktonic transport of post-larvae of seagrass-associated King George whiting. Journal of Fish Biology 64: 1226-1241.

McGarvey R, Feenstra JE (2002) Estimating rates of fish movement from tag-recoveries: conditioning by recapture. Canadian Journal of Fisheries and Aquatic Sciences 59: 1054-1064.

McGarvey R, Fowler AJ (2002) Seasonal growth of King George whiting (*Sillaginodes punctata*) from length-at-age samples truncated by legal minimum size. Fishery Bulletin 100: 545-558.

McGarvey R, Feenstra JE, Fowler AJ (2000) King George whiting (*Sillaginodes punctata*). South Australian Fisheries Assessment Series 00/03. 47 pp.

McGarvey R, Fowler AJ, Feenstra JE, Fleer DA, Jones GK (2003) King George whiting (*Sillaginodes punctata*). SARDI Aquatic Sciences Publication No. RD03/0152. 76 pp.

McGarvey R, Fowler AJ, Feenstra JE, Jackson WB and Jennings PR (2005). King George whiting (*Sillaginodes punctata*) fishery. Fishery Assessment Report to PIRSA for the Marine Scalefish Fishery Management Committee. South Australian Research and Development Institute (Aquatic Sciences), Adelaide RD03/0152-2.

McGarvey R, Fowler AJ, Feenstra JE, Jackson WB (2006). Garfish (*Hyporhamphus melanochir*) Fishery. Fishery Assessment Report to PIRSA for the Marine Scalefish Fishery Management Committee. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, RD04/0152-2. SARDI Research Report Series No. 163. pp 55.

McGarvey R, Feenstra JE, Ye Q (2007) Modeling fish numbers dynamically by age and length: partitioning cohorts into 'slices'. Canadian Journal of Fisheries and Aquatic Sciences 64: 1157-1173.

McGlennon D, Kinloch MA (1997) Resource allocation in the South Australian marine scalefish fishery. FRDC project 93/249, Final Report. 105 pp.

Moran SM, Jenkins GP, Keough MJ, Hindell JS (2004) Evidence for secondary planktonic transport of post-larvae of seagrass-associated King George whiting. Journal of Fish Biology 64: 1226-1241.

Noell C, Presser J, Jones K (2006) Management Plan for the South Australian Marine Scalefish fishery. The South Australian Fisheries Management Series Paper No. 45. 68 pp.

Platell ME, Orr PA, Potter IC (2006) Inter- and intraspecific partitioning of food resources by six large and abundant fish species in a seasonally open estuary. Journal of Fish Biology 69: 243-262.

Robertson, AI (1977) Ecology of juvenile King George whiting Sillaginodes punctata (Cuvier + Valenciennes) (Pisces: Perciformes) in Western Port, Victoria. Australian Journal of Marine and Freshwater Research 28: 35-43.

Taylor BL, Dizon AE (1996) The need to estimate power to link genetics and demography for conservation. Conservation Biology 10: 661-664.

9. ACKNOWLEDGEMENTS

We wish to extend our gratitude to the numerous fish processors and fishers who gave us access to samples of King George whiting for the collection of data and biological material. In particular we thank Don Dew and his co-workers of Adelaide's SAFCOL fish market for their on-going support of the catch sampling program. In all cases the data on population structure make a significant contribution to our stock assessment work.

The data on catch and effort from the commercial sector of the Marine Scalefish fishery were provided to us by Angelo Tsolos of the Fisheries Statistics Unit of SARDI (Aquatic Sciences). The market sampling was undertaken by Bruce Jackson and Matt Lloyd. The figures presented in Chapter 6 were prepared by Janet Matthews. The report was reviewed by Michael Steer and Tim Ward from SARDI Aquatic Sciences and Andrew Sullivan from PIRSA Fisheries, whose comments helped to improve an earlier draft of the report. The contributions of all are acknowledged and greatly appreciated.

10. APPENDICES

10.1 Appendix 1 - Commercial fishery statistics in 2005, 2006 and 2007

Commercial catches by region and gear type for each of 2005, 2006 and 2007 are presented in Tables A.1, A.2 and A.3, respectively. The total State-wide catch in 2005 was 347,747 kg. A similar total catch was taken in 2006, whilst that taken in 2007 was marginally higher. Handlines were the dominant gear type in each year accounting for 76.3% of the catch in 2005, and up to 83.8% in 2006. The percentage of total catch taken by haul nets fell from 16.5% in 2005 to 11.6% in 2006. The gillnet catch accounted for only 2.7 to 5.1% of the total catch.

In 2005, there were 15,059 handline fishing days and only 618 gillnet fishing days (Table A.1). These are each lower than the effort levels in 2004, as reported by McGarvey et al. (2005). Handline effort increased marginally in 2006 before dropping considerably in 2007. Gillnet effort fell by about 50% in 2006 and then remained low in 2007.

In each year the total catch was highest on the Far West Coast, with Southern Spencer Gulf consistently the second most significant region (Tables A.1, A.2, A.3). Also, in each year Coffin Bay provided the lowest total catch of all seven regions.

Table A.1. Summary of total catch and effort by gear type for each of the seven fishery regions in 2005. (HL=handline, GN= gillnet, HN=haul net). Regions are identified in Table 3.1.

Region no.	Region	Total catch by HL (kg)	Total catch by GN (kg)	Total catch by HN (kg)	Total catch (other gears)	Grand total catch	Total effort HL (fisher-days)	Total effort GN (fisher-days)
1	FWC	106,494	0	319	192	107,005	6,190	0
2	MWC	26,831	5,516	1,303	0	33,650	1,415	188
3	CB	6,121	18	0	40	6,179	316	1
4	SSG	67,474	2,202	8,789	2,640	81,105	3,499	113
5	NSG	20,799	56	23,840	21	44,716	991	9
6	GSV	9,347	6,022	15,339	364	31,072	789	216
7	KI	28,315	4,058	7,937	3,710	44,020	1,859	91
Total		265,381	17,872	57,527	6,967	347,747	15,059	618

Table A.2. Summary of total catch and effort by gear type for each of the seven fishery regions in 2006.

Region no.	Region	Total catch by HL (kg)	Total catch by GN (kg)	Total catch by HN (kg)	Total catch (other gears)	Grand total catch	Total effort HL (fisher-days)	Total effort GN (fisher-days)
1	FWC	100,344	0	408	707	101,459	5,526	0
2	MWC	40,674	0	0	0	40,674	1,731	0
3	CB	9,196	0	0	302	9,498	433	0
4	SSG	71,173	3,150	211	2,774	77,308	3,547	59
5	NSG	21,642	509	22,171	21	44,343	1,124	43
6	GSV	16,719	2,017	10,089	1,266	30,091	1,240	102
7	KI	31,384	3,567	7,388	1,542	43,881	1,839	107
Total		291,132	9,243	40,267	6,612	347,254	15,440	311

Table A.3. Summary of total catch and effort by gear type for each of the seven fishery regions in 2007.

Region no.	Region	Total catch by HL (kg)	Total catch by GN (kg)	Total catch by HN (kg)	Total catch (other gears)	Grand total catch	Total effort HL (fisher-days)	Total effort GN (fisher-days)
1	FWC	89,982	0	45	129	90,156	4,815	0
2	MWC	34,427	0	0	107	34,534	1,649	0
3	CB	18,704	0	0	857	19,561	713	0
4	SSG	74,140	4,464	361	1,729	80,694	3,471	81
5	NSG	20,101	122	26,461	590	47,183	1092	13
6	GSV	12,871	5,107	15,935	1,565	35,478	928	132
7	KI	30,330	2,786	7,826	1,351	42,293	1,742	79
Total		280,555	12,479	50,628	6,328	349,899	14,410	305

10.2 Appendix 2 - Recent modifications to the WhitEst model

The principal modification of the King George whiting model (WhitEst) for this stock assessment was to reduce the number of spatial cells (model subregions) from 13 to 6. The 6th (formerly 13th) subregion includes all outlying areas, including the State's Southeast, where King George whiting catches are minimal. Thus, the effective reduction was from 12 to 5 principal model subregions. This reduction in spatial resolution was undertaken principally because the model in previous versions had difficulties with resolving movement rates due to insufficient tag-recovery data sample sizes, as noted previously (McGarvey et al. 2005). In the West Coast, there was also presumed to be no movement among the three subregions, and thus, retaining them as separate was unnecessary. In the two gulfs, especially in Spencer Gulf, tag recovery data sample sizes were insufficient to precisely estimate the movement rate parameters, of which there could be 12 x 12 = 144 for the model overall. By aggregating the model spatial cells, notably aggregating the three lower Gulf St. Vincent cells and the two lower Spencer Gulf cells each into one lower gulf subregion, the need to describe movement among lower gulf cells was alleviated.

One additional spatial improvement was implemented to address the problem that MFA 40 (formerly spatial cell 9) spanned the lower Yorke Peninsula and thus had area in the lower portions of both gulfs. Partitioning it between the two lower gulf subregions using its three subdivisions (A, B & C) implemented with the new catch and effort logbooks permitted allocation of the catches correctly between the respective lower portions of each gulf.

These spatial model changes did not substantially alter the model estimates. The main effect is to reduce the extent of spatial variation, in particular, since the lower gulf cells, notably in GSV, now include areas of substantial catch, whereas, the area north of Kangaroo Island formerly was principally a spawning migratory destination with little fishing.

We also list the changes made to the King George whiting model in the 2005 assessment. (1) Migration was spread across 3 months (November, December and January) rather than moving all model fish once yearly in January. This noticeably smoothed the changes in stock abundance in upper gulf cells during summer migration, and is a more realistic model description since southward movement occurs over several early summer months. (2) Kernel density (smoothed) curves are now used to characterise length-sample distributions. (3) Three changes were implemented to improve model fits to commercial catch totals, including (i) a more flexible seasonal (i.e. monthly) description of variation in catchability by effort type; (ii)

separate monthly catchability parameters for recreational catch; and (iii) a normal likelihood function for the fits to catches at age, replacing the lognormal likelihood. These changes substantially improved the closeness of fit of model-predicted catches by weight that had previously underestimated the mean data catch values by a few percent. All three changes measurably improved the model fits to monthly catch totals by weight. In addition, (4) the recent change in legal minimum length from 30 to 31 cm in the two gulfs is now programmed into the model slice-growth population array. For fitting to recreational catch, (5) we now fit directly to survey King George whiting numbers landed, which is how catch was estimated and reported from the NRIF survey, rather than fitting to recreational catch in weight landed.

10.3 Appendix 3 - Model fits to data

Parameters and thus stock indicators in the WhitEst model are estimated by fitting to data for commercial catch totals by weight, recreational catch total numbers, and to commercial catch samples calculated as proportions of King George whiting landed by yearly ages (and sex), in each month when sampling occurs. Due to space limitations, only model fits to the reported monthly King George whiting catch totals are shown for the 5 principal subregions, in Fig 10.1 below. Plots of fit to the extensive age samples are available upon request, with a separate age fit plot shown for the five subregions and both sexes, and for each month of the two age and length sampling programs which ran from September 1994 to June 1997, and from July 2004 to June 2007.

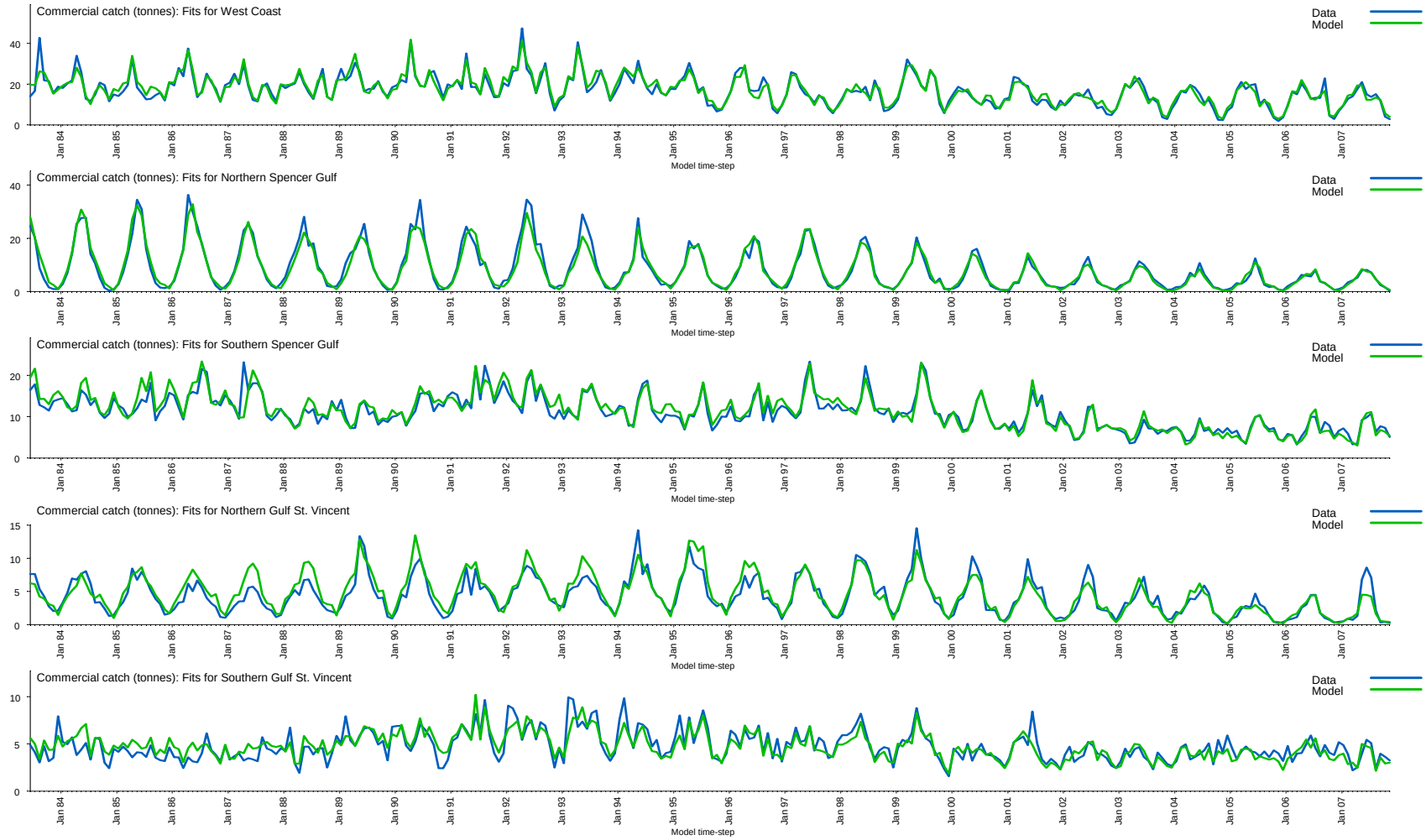

Fig. 10.1. Model and data monthly catch total by weight. Data is total commercial catch (by all gears and target types) reported in monthly logbooks. Model outputs show model fitted values of commercial catch total.