King George Whiting *(Sillaginodes punctata)* Fishery

Fishery Assessment Report to PIRSA Fisheries for
the Marine Scalefish Fishery Management Committee

August 2005

R McGarvey, AJ Fowler, JE Feenstra, WB Jackson and PR Jennings

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1. EXECUTIVE SUMMARY

SUMMARY: The three biological performance indicators of the King George whiting fishery in South Australia show either no change or a marginal increase in 2003 and 2004, suggesting a turn-around from the downward trends that were apparent through 1999 to 2002. In general, regional estimates of commercial CPUE increased marginally in 2003 and 2004. This occurred despite the continuing decrease in commercial catch attributable to the decline in commercial fishing effort. The size and age structures of populations on the spawning grounds have shown no change through the ten years of monitoring. The model-estimated output parameters of recruitment and biomass from the fishery model 'WhitEst', show marginal increases in 2003 and 2004.

Although the indicators for 2003 and 2004 are positive relative to those of the preceding four years, the lack of annual catch totals for the recreational sector obscures time trends in total catch, impeding reliable stock assessment of King George whiting in South Australian waters.

1.1. Biological Performance Indicators

The biological indicators for the King George whiting fishery are: (1) annual regional catch, effort, and CPUE reported by commercial fishers, (2) population age structures from fishery-independent monitoring of the spawning aggregations in southern gulf waters, and (3) outputs from the spatial dynamic fishery model 'WhitEst'. This report covers a time period ending December 2004, extending the previous stock assessment by two years. The new management regulations that were imposed in October 2004 are too recent to have impacted on the outcomes that are reported here.

Indicator 1 - Catch and Effort Statistics

Commercial Sector

Since 1984 the dominant long-term trend in data from the commercial fishery has been a consistent decrease in fishing effort. Between 1984 and 2004 the number of handline fisherdays per year targeted on King George whiting has decreased by 52.7% from 33,062 to 15,638, while the number of gillnet fisherdays decreased by 68.5% from 2,770 to 874. This reduction is due in large part to the reduction in the total number of licensed marine scalefish

fishers from 697 in 1982/83 to 415 in 2003/04. Furthermore, it is likely that some remaining fishers have shifted their effort to other species, since the rate of decline in licence holders who targeted King George whiting has exceeded the overall reduction.

Based on the decrease in fishing effort commercial catches have declined substantially. This is apparent for the haul net sector from 1992 onwards, and for handlines and gillnets for the period of 2000 to 2004. From 1999 to 2004 the total commercial catch of King George whiting declined from 600.5 to 346.4 t, a reduction of 42.3%. Over this six year period the State-wide handline catch decreased by 40.9%, the haul net catch by 46.0% and the gill net catch by 53.7%. These reductions in catch have generally been spread across all seven regions of the State.

In all seven regions there was a steady rise in CPUE from 1984 to 1999, ranging from 13.2 to 71.7% depending on the region, but in 1999 these rising regional trends peaked and then trended downwards. In every region, handline CPUE was lower in 2002 than it was in 1999 and CPUE for haul net catches in some regions also declined. In 2000, handline CPUE dropped in all regions except Gulf St. Vincent with the sharpest declines on the Far and Mid-West Coasts, with smaller declines in Spencer Gulf. There was some recovery in 2001, but in general there were further regional declines in CPUE in 2002. Nevertheless, in most regions the estimates of CPUE were marginally higher in either 2003 or 2004 or both. This has arrested the downward trend of the past few years.

The annual catches of King George whiting in the northern gulfs and west coast bays primarily consist of a single year class (i.e. 3 year olds). Therefore, inter-annual variation in CPUE for the different regions provides an indicator of year class strength, as determined by variation in recruitment. Thus, the falls in CPUE between 1999 and 2002 suggest a period of low recruitment to the fishery, whilst the recent increases suggest a marginal recovery in recruitment.

Recreational Sector

There have been two State-wide recreational surveys in South Australia. A creel survey in 1994-96 provided an estimate of annual harvest of King George whiting of 265.7 t. The later National Recreational and Indigenous Fishing Survey (NRIFS) provided an estimate of 584.7 t for the 12-month period of May 2000 to April 2001. The estimated catch from the creel survey is likely to be an under-estimate because of limitations of that sampling regime. The estimate from the NRIFS is greater than that taken by the commercial sector (i.e. 438.7 tonnes and 43%

of total), for the same period. The estimates of total targeted and non-targeted recreational fishing effort were 1,339,659 hours and 366,912 hours, respectively. Thus, targeted effort constituted about 78.5% of the total recreational effort on King George whiting.

Indicator 2 - Population Structure

The size and age structures of the spawning sub-populations of King George whiting have been sampled by SARDI researchers since the mid-1990s. These spawning aggregations, located in south-eastern Spencer Gulf, Investigator Strait and Tapley Shoal in southern Gulf St. Vincent, support broader size and age distributions than do places in the northern gulfs and west coast bays. The population structures determined from samples from these places collected up to 2004 show no contraction in size and ages relative to data collected in the mid to late 1990s.

Indicator 3 – 'WhitEst' output

The 'WhitEst' stock assessment model integrates biological and fishery information to provide annual estimates of recruitment, legal-size population biomass, and exploitation rate for the three regions of West Coast, Spencer Gulf and Gulf St. Vincent. Model output for 1999-2002 showed declining trends in biomass for both Spencer Gulf and the West Coast. In the last two years, 2003 and 2004, model-estimated recruitment and biomass have stabilised, suggesting marginal recoveries in these regional populations. Estimated exploitation rate has continued to decline, but this reflects lower commercial effort, and cannot account for unknown changes in the recreational catch, which accounts for the larger proportion of the total catch.

Limit Reference Points

Specific biological performance indicators were compared with limit reference points identified in the Marine Scalefish Fishery Management Plan. Several indicators exceeded the limit reference points. Estimates of total commercial catch in both 2003 and 2004 were more than 10% lower than the respective five-year average. Also, in each year the ratio of non-targeted to targeted handline effort differed from that of the previous year by more than 10%. Furthermore, the model-estimated exploitation rates in Spencer Gulf and Gulf St. Vincent exceeded the internationally acceptable level of 28%. These types of results were considered in the discussions through 2004 that led to development of the new management regime. It will take several years before the benefits of this regime are manifested by the stock.

1.2. Implications for Management

The data for 2003 and 2004 for the three biological performance indicators are more favourable than through the period of 1999-2002. It is too early for this turn-around to relate to the new management protocol that was implemented in late 2004, and so must relate either to higher rates of recruitment in 2003 and 2004 due to favourable environmental conditions, or to the lower levels of exploitation of the commercial sector.

1.3. Research Priorities

Two new datasets will provide for more refined analyses when they are incorporated into future runs of the 'WhitEst' stock assessment model. The first is the more refined data on fishing effort that comes from the new commercial catch and effort forms that were introduced in July 2003. These include the number of hours fished per day by handlines and number of hauls per day by haul netters. The second dataset comes from the program of systematic sampling that was undertaken throughout 2004/05, which provided updated estimates of population size and age structures across the different geographic regions of the fishery.

Nevertheless, there remains a major limitation in the data available for undertaking comprehensive stock assessments and providing good advice for fishery management. This principal limitation is the absence of data about change in recreational catch over time. Without data on annual recreational catch, which is now estimated to be larger than the commercial catch, the trend in total annual catch of the South Australian King George whiting fishery will remain unknown.

2. INTRODUCTION

2.1. Stock Assessment

Stock assessments have been produced regularly for King George whiting since 1997 with this being the sixth in that nine-year period. There are two aims of these reports i.e., 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 up to the time for which data are available. The previous stock assessment report was completed in September 2003, which reported on data available up to the end of 2002 (McGarvey et al. 2003).

The information relating to the fishery and the biology of the species is reported in the remainder of this chapter and the following four chapters. The remainder of this chapter provides a description of the fishery, a statement of the management regulations that relate to it, as well as 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.

Chapter 3 presents a summary of the data from the commercial fishery for 2003 and 2004, including State-wide and regional estimates of fishery catch and effort. These data are then placed in their historical context based on similar estimates that have 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 each of the seven fishery regions.

Chapter 4 provides a summary of information about the recreational fishery in South Australia. There have been two large-scale recreational fishing surveys in this State; a creel survey that was done in 1994 to 1996 (McGlennon and Kinloch 1997) and the National Recreational and Indigenous Fishing Survey in 2001/01 (Henry and Lyle 2003). This chapter provides a regional breakdown of the estimates of State-wide recreational catch for each time period, compares the recreational catch with that from the commercial sector, and compares the results between the two surveys.

Chapter 5 provides an analysis of the population size and age structures based on samples collected from the spawning grounds in the gulf regions. These populations are known to have the broadest size and age structures as they receive emigration from elsewhere (Fowler and March 2000, Fowler et al. 20001, Fowler et al. 2002). It is considered that size and age

structures might be a good indicator of stock status, since any evidence of a contraction might constitute evidence for overfishing.

Chapter 6 presents the output from the fishery stock assessment model WhitEst that is used to integrate several types of data from the fishery to output various parameters that relate to 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 between 1995 and 1998. 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 7 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, and comparing the data available for King George whiting against the limit reference points that are also specified in the management plan (PIRSA 2005). Chapter 8 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 June 2004.

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 5 times greater harvested biomass than Victoria and 20 times that of Western Australia (Kailola *et al*. 1993). In South Australia, the species has traditionally been the most valuable marine scalefish species, but in 2000/01 the total value dropped to second behind pilchards (Knight *et al*. 2004). However, King George whiting remains the highest value species by unit weight (Knight *et al.* 2004).

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 yearly 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 peak in July. Movement in winter is not strongly directional. 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. In winter and spring prior to, and then in early summer during, their southern migration, the fish 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.

The fisheries in Gulf St. Vincent, northern Spencer Gulf and the West Coast bays predominantly take smaller, young, immature fish of about 3 years of age just reaching 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 did not show evidence of spawning 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). It is thought that historically the exploitation of spawning aggregations was relatively low, which 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 these 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 gears for taking King George whiting. Recreational catch 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 include: (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 required to acquire an amalgamated licence (from 26 to 24); (4) Also, if a non-licensed person has possession of more than 75 King George whiting then that person may be guilty of an offence, as this is considered a commercial quantity. Decisions about which management measures to implement were, in part, informed by WhitSim management simulations that tested a range of strategies, and the results of which were summarised in the 2003 assessment report (McGarvey et al. 2003).

The principal effort control in the commercial sector of the fishery is the on-going license amalgamation scheme, implemented in 1994. Because of this scheme the number of commercial marine scalefish licenses ('M' and ''B' class) has been reduced from 701 in 1984 to 414 in 2004. Besides the size limit on King George whiting 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 10m in the bunt or pocket. Their use is restricted to waters less than 5 m deep, 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 reasons of resource sharing and/or the protection of nursery areas and spawning grounds (PIRSA 2005).

Previous management changes included a reduction in the State-wide bag limit from 30 to 20 fish per fisher day or from 90 to 60 fish per boat-day 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. Population Biology and Life History

Although the general life history cycle of King George whiting has been known for a number of years (Jones *et al*. 1990), our understanding was further developed through FRDC project 95/008 (Fowler and McGarvey 2000). That study measured and analysed population age structures, adult movement patterns, reproductive biology, characteristics of recruitment and geographic stock structure.

Post-larvae recruit to shallow, protected bays throughout the winter and spring. The most important nursery areas appear to include Barker Inlet, Franklin Harbor, and the West Coast bays. The juveniles reside in this nursery habitat for a year or two before moving 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 about 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). As noted above, the migration is from nursery areas to spawning grounds, although 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. Most tagged fish moving long distances from Gulf St. Vincent were recaptured along the north coast of Kangaroo Island; those from northern Spencer Gulf were recaptured principally in Hardwicke Bay in the south-east, with some found around the islands of the south-western part of the gulf; those from West Coast bays were rarely recaptured, but may end up around offshore shoals and islands. In contrast, fish from around 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 differential 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 fish as old as 18 years of age (Fowler *et al*. 1999, Fowler *et al*. 2000a).

Spawning occurs at the offshore grounds to which the fish migrate, including 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 Port Victoria. Spawning typically occurs between March and May (Fowler *et al*. 1999, Fowler *et al*. 2000a). Patterns of distribution of larvae (determined by sampling plankton through the 1980's), provide further evidence that spawning occurs in these southern locations and that larvae are advected northwards into the gulfs (B. Bruce unpublished data). Locations of spawning responsible for replenishment of the West Coast bays have not been located. Commercially harvested fish from the West Coast bays display minimal gonad maturation suggesting that spawning may occur further offshore from the fishing grounds.

The long pre-settlement duration of 80 to >120 days of larval King George whiting (Fowler and Short 1996), would be expected to provide ample opportunity for advection over long distances by hydrographic processes, as occurs for the 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, presumably influencing the rate of transport of the larvae. This influences recruitment success and productivity to the fishery several years later (Jenkins 2005). However, hydrodynamic modelling for the coastal areas around South Australia suggests that King George whiting larvae are in fact advected over relatively short distances of only 50-100 km (Fowler *et al*. 2000b). Although these results need to be interpreted cautiously due to the spatial resolution of the modelling, nevertheless they do suggest that the South Australian populations are sustained by local spawning. This hydrographic modelling suggested the existence of relationships between particular spawning locations and nursery areas separated only by 100-200km. Hydrodynamic modelling, sampled larval distributions, and adult movement patterns suggest that the two gulfs are largely distinct self-reproducing populations.

However, analysis of stock structure based on mitochondrial DNA and microsatellite primers found no significant phylogeographic structure across the distribution of the species (Haigh and Donnellan 2000). This is consistent with the long pre-settlement duration of the species, and does not counter the above-mentioned subpopulation model because only a minimal but consistent exchange of individuals (two or three fish per year) between subpopulations is sufficient to maintain them as genetically homogeneous (Taylor and Dizon 1996).

3. TRENDS IN COMMERCIAL CATCH, EFFORT AND CPUE

The licence arrangements for commercial fishers in the Marine Scalefish fishery requires that they 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 analysis these data are accumulated across fishers to provide regional, annual totals of catch and effort by gear type, which are then used to calculate annual estimates of catch per unit effort (CPUE) for each region. The data for the three main gear types of handlines, haul nets and gill nets are reported for the seven regions that are normally considered for King George whiting. These regions are shown in Fig. 3.1 and the Marine Fishing Areas that comprise them are identified in Table 3.1

Table 3.1 Fishery regions normally considered in the King George whiting fishery and the Marine Fishing Areas that comprise them.

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

With respect to fishing effort,data are reported by the fishers as fisherdays, which relates the numbers of days fished and number of personnel involved. If two fishers are on board a boat for a day of fishing then this counts as two fisherdays. There are two components of fishing effort for each gear type, i.e. targeted and untargeted effort. For both handlines and gillnets total effort is estimated from targeted effort that is scaled upwards by the proportional additional catch that is taken by untargeted effort. Thus, for handlines and gill nets it is possible to provide annual estimates of total catch and effort and an associated estimate of CPUE. Alternatively, for haul nets the situation is more complex because fishers may catch substantial numbers of King George whiting when they are targeting other species, or when targeting no species in particular. Here, it is not possible to provide single estimates of total catch, effort and CPUE. Rather for haul nets estimates of catch, effort and CPUE are provided for the three different fishing effort categories of: targeted effort; effort targeted at other species; and effort not directed at any particular species.

3.1. Recent Years: Catch and Effort in 2003 and 2004

The regional and gear type breakdown of commercial catch for each of 2003 and 2004 are presented in Tables 3.2 and 3.3. The total State-wide catch for 2003 was 378,963 kg (Table 3.2), which was marginally greater than the catch of 370,328 kg taken in 2002 (McGarvey et al. 2003). However, the catch of 346,364 kg in 2004 was a reduction of 9% from the catch of the previous year (Table 3.3). Handlines were the dominant gear type accounting for about 74% of the total catch in both 2003 and 2004. Haul nets took approximately 18% of the total catch in each year, and remained the second most significant gear type, with haul net catch being marginally higher in 2004. Gillnets, accounting for 7% of the total, remained the third most significant gear type, despite a decrease in catch of 23% between 2003 and 2004.

In 2003, there was a total of 17,828 handline fishing days and 1,128 gillnet fishing days (Table 3.2), which are each similar to the effort levels for 2002 (McGarvey et al. 2003). However, the total effort on King George for each gear type decreased considerably in 2004, with decreases of 12% for handline fishing effort and a 22.5% decrease in gillnet effort, relative to 2003.

Table 3.2 Summary of total catch and effort by gear type for each of the seven fishery regions in 2003. (HL=handline, GN= gillnet, HN=haul net.)

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	110,221	0	571	450	111,242	6,445	0
2	MWC	33,331	5,286	924	26	39,566	2,202	301
3	CB	13,947	0	0	125	14,072	759	0
4	SSG	61,067	2,179	8,447	1,719	73,412	4,118	158
5	NSG	22,238	72	36,310	26	58,647	1,215	13
6	GSV	14,744	18,316	14,783	195	48,038	1,125	573
7	KI	27,712	2,419	3,533	322	33,986	1,963	84
Total		283,260	28,272	64,568	2,863	378,963	17,828	1,128

Table 3.3 Summary of total catch and effort by gear type for each of the seven fishery regions in 2004.

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	101,897	15	299	361	102,572	6,378	0
2	MWC	24,578	5,000	546	0	30,124	1,490	253
3	CB	8,457	0	9	86	8,552	474	0
4	SSG	57,373	4,033	11,339	1,998	74,742	3,567	227
5	NSG	19,167	19	26,266	14	45,466	992	2
6	GSV	10,659	10,264	21,316	187	42,425	847	297
7	KI	29,981	2,564	6,204	3,737	42,485	1,890	95
Total		252,109	21,895	65,978	6,382	346,364	15,638	874

The catches for the King George whiting fishery of South Australia are summarised for seven different regions, i.e. FWC, MWC, CB, SSG, NSG, GSV and KI (Fig. 3.1). In 2003 and 2004 the total catch was highest on the Far West Coast (Tables 3.2, 3.3). Spencer Gulf remained the second most significant region, despite a 22.5% drop in the catch from NSG in 2004. Commercial handline catches declined for all regions except Kangaroo Island between 2003 and 2004 (Tables 3.2 and 3.3).

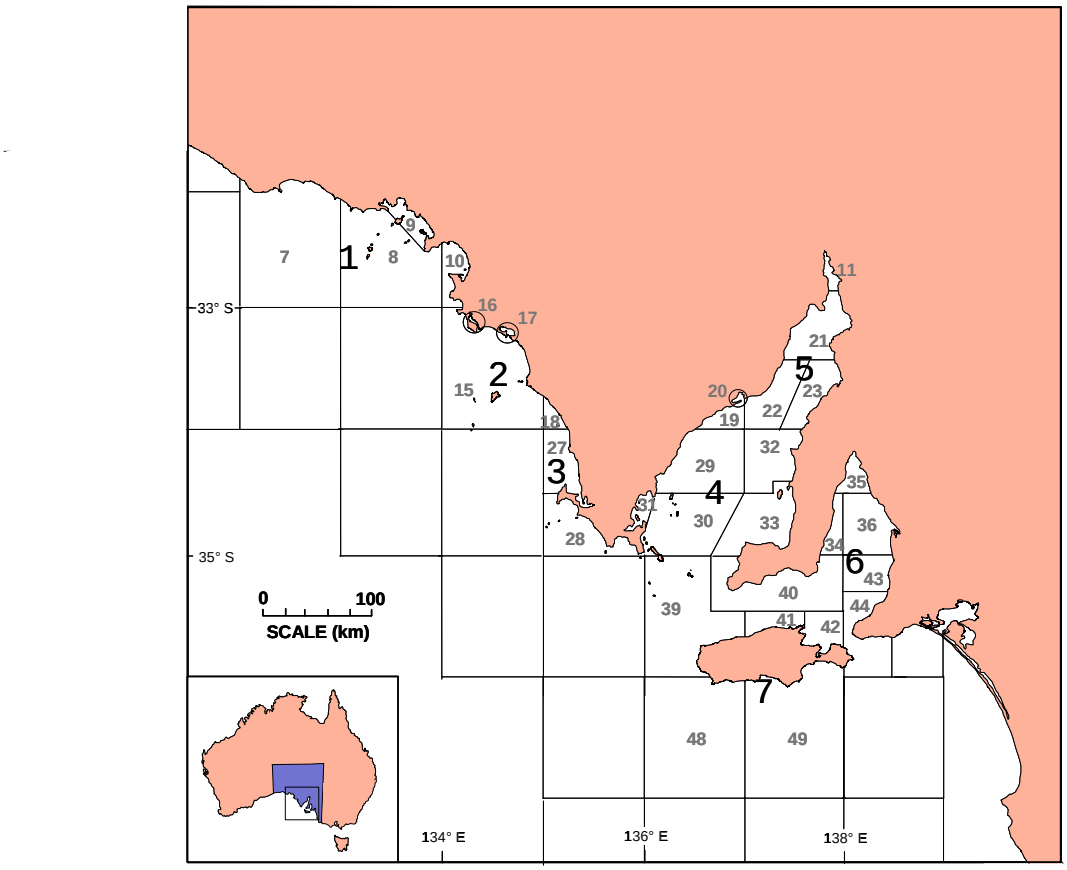

Fig. 3.1 Map of South Australia showing the seven fishery regions for which data are presented in this report. (1 = Far West Coast, 2 = Mid West Coast, 3 = Coffin Bay, 4 = Southern Spencer Gulf, 5 = Northern Spencer Gulf, 6 = Gulf St. Vincent, 7 = Kangaroo Island.)

3.2. Long-term Trends in Catch and Effort

The total commercial catch of King George whiting was variable but roughly stable between 1984 and 1992, when it reached a maximum of 776 tonnes (Fig. 3.2). Annual catch decreased and stabilised at 550-600 tonnes.year^{-1} until 1999, before dropping substantially to below 450 tonnes.year^{-1} in 2000. It dropped again to 370 and 380 tonnes in 2002 and 2003 respectively, and then again to 344 tonnes in 2004. Thus, the commercial catch of King George whiting in 2004 was 42% lower than the catch in 1999 and 55% lower than that taken in 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 data for 2004 are provisional at this stage, but suggest another decrease in total value (Fig. 3.2).

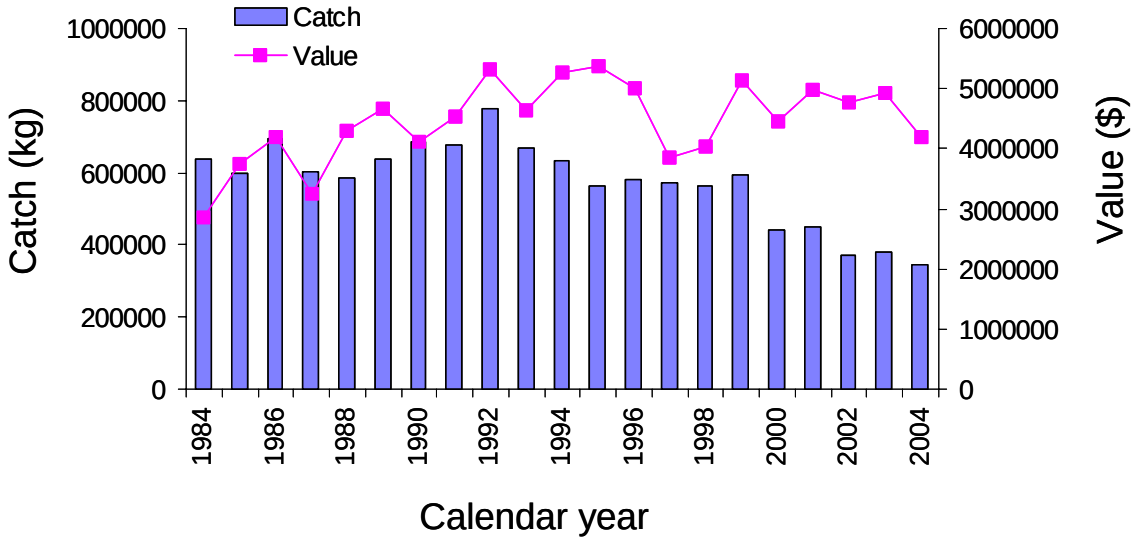

Fig. 3.2 Total annual catch and value of the South Australian King George whiting fishery since 1984 (note – data are provisional for 2004)

Since 1984 handlines have been the dominant gear type in the commercial fishery (Fig. 3.3). Through the period of 1984 to 1999 handline catches were variable, and showed no obvious long-term trend. However, since then they have dropped consistently from 426,408 kg in 1999 to 252,109 kg in 2004, i.e. a drop of 41%, with a decline since 1992 of 45%. Haul nets remain the second most significant gear despite that catches have decreased systematically since the

record catch that was taken in 1992. In 2000, the haul net catch dropped by 21% compared with the previous year, falling below 100,000 kg for the first time since 1984. It then dropped to 85,478 kg in 2001, 69,333 kg in 2002, 64,568 kg in 2003 before increasing marginally to 65,978 kg in 2004. The gillnet catch has always been below 50,000 kg.year^{-1}. In 2000, it dropped by 49% to 24,352 kg and has remained around this level for the subsequent four years.

Handline effort has decreased from 30,458 fisherdays in 1992 to 15,638 fisherdays in 2004, i.e. a reduction of 49% over this 12 year period (Fig. 3.3). Gill net effort has declined by 65% from 2,483 to 874 fisherdays over the same period. These decreases in numbers of fisherdays reflect the declining trend in 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 the numbers of commercial fishers who either take or target King George whiting (Fig. 3.4).

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 considerably in 2000. Since then CPUE has increased dramatically in the gillnet fishery (Fig. 3.3), but the 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 shown a slight upward trend in each of 2003 and 2004 (Fig. 3.3). Overall, between 1999 and 2004 there has been a 17% reduction in the State-wide handline CPUE from 19.4 to 16.1 kg.fisherday^{-1}.

One caveat on a positive status report would be if stable or higher mean catch rates were an artefact of lower-skilled commercial fishers leaving the fishery or targeting other species. In that case, average catch rates from remaining commercial fishers would be optimistic. To address possible biases due to turnover in commercial fishers, we examined the yearly CPUE trends for individual, selected fishers who had each been in the fishery for a long time. These data cannot be presented here for concerns about confidentiality, but the outcome did not differ substantially from the State-wide or regional estimates of CPUE. Spencer Gulf handline fishers showed a modest rise, and haul netters a more substantial increase in CPUE for 2003 and 2004. In Gulf St. Vincent, selected individual haul net and handline fishers both showed a drop in 2003 followed by an increase in 2004 for haul nets, but a stable CPUE in 2004 for handlines. On the West Coast, long-term fishers also showed stable CPUE for the last two years.

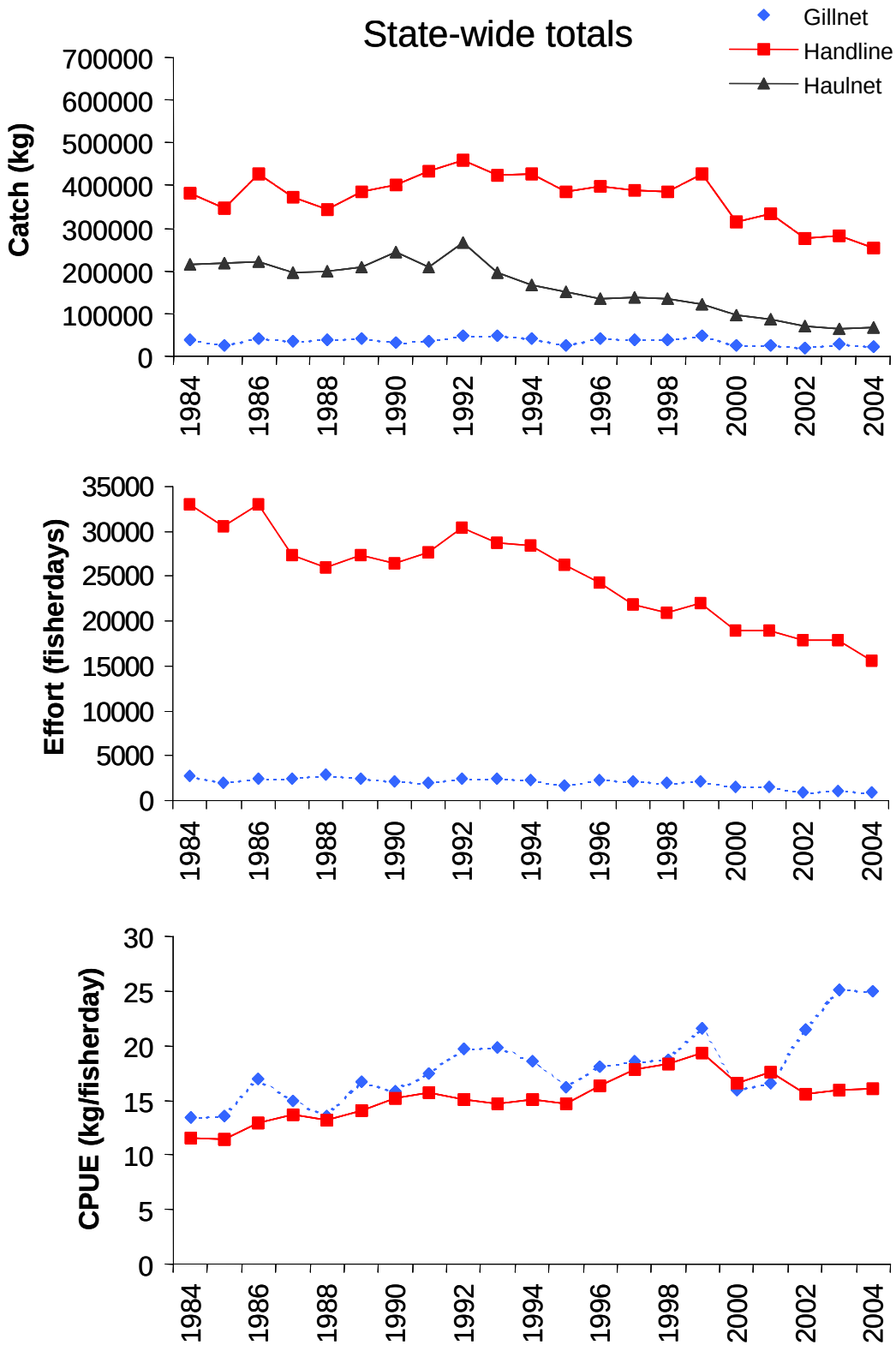

Fig. 3.3 Historical trends in State-wide total for catch, effort and CPUE for the main gear types used by the commercial fishing sector. Note that it is not possible to provide a State-wide estimate of effort on King George whiting for haul nets, which also prevents estimating CPUE.

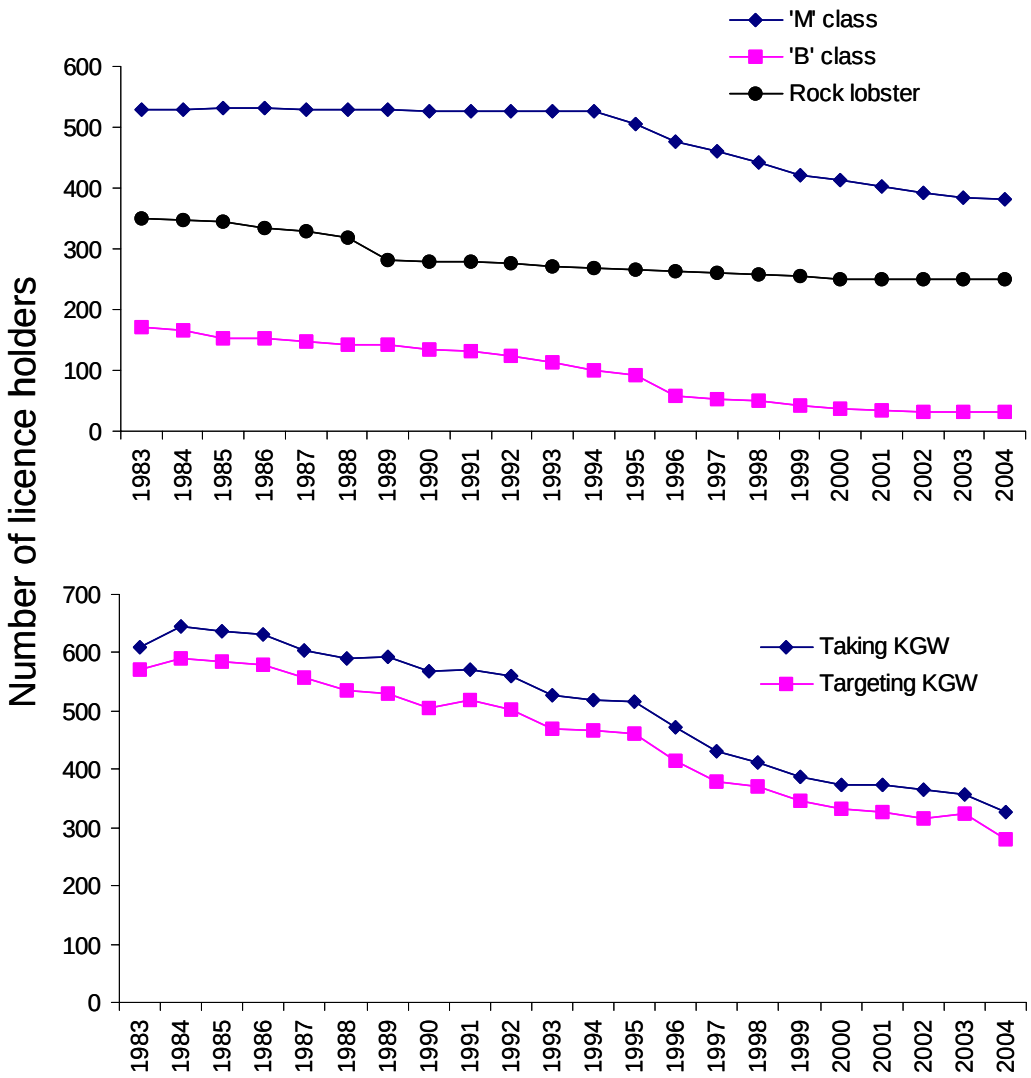

Fig. 3.4 Top graph shows the number of licence holders that could legally take King George whiting in each year. Bottom graph shows the number of licence holders who successfully took some King George whiting and those who targeted this species in each year.

3.3 Seasonality of Catch

The seasonality of the State-wide commercial catch of King George whiting is apparent from monthly totals (Fig. 3.5). For the period of July 1997 to December 2004 monthly catches were highest during winter, and dropped to yearly minima in summer. The monthly totals for targeted effort on King George whiting followed a similar trend.

An annual trend of decreasing commercial catch is also apparent in Fig. 3.5, with peak monthly catches notably lower in 2000 and 2001 than in the two previous years, and with a continuing decline in 2003 and 2004. Monthly effort exhibited a particularly strong decline in 2004 (Fig. 3.1). This does not appear to have been limited to the last three months of that year which followed the imposition of new management regulations for the King George whiting fishery in October 2004.

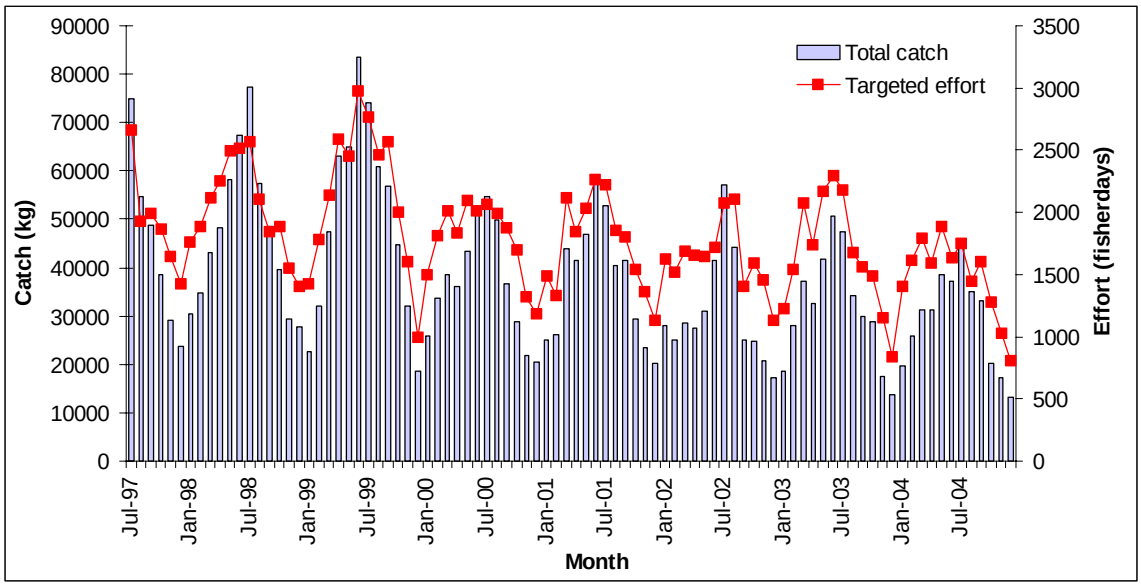

Fig. 3.5 Monthly estimates of total State-wide catch and targeted fishing effort (all gears combined) for the King George whiting commercial fishery between July 1997 and December 2004.

3.4 Regional Catch and Effort Statistics

The remainder of this chapter provides a summary of the catch, effort and CPUE data from 1984 to 2004 for each of the seven fishery regions 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, i.e. SSG, NSG, GSV and KI, 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'.

3.4.1. 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 (Tables 3.2, 3.3). Historically, this catch has been dominated by the handline sector since a netting ban was implemented in 1958. The handline catch for 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, before stabilising at the relatively low level of approximately 100,000 kg.year^{-1}. Between 1984 and 1998 handline effort declined by 44% to 6,000 fisherdays.year^{-1} (Fig. 3.6). It then increased again in 1999 and has been relatively stable since then at between 6,300 and 6,900 fisherdays.year^{-1}.

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 22.4 kg.fisherday^{-1} was recorded. Since then, CPUE has declined substantially, first in 2000 and then again in 2002. Between 2002 and 2004 CPUE has been consistently between 15.9 – 17.1 kg.fisherday^{-1}. Overall, there was a 29% drop in CPUE between 1999 and 2004.

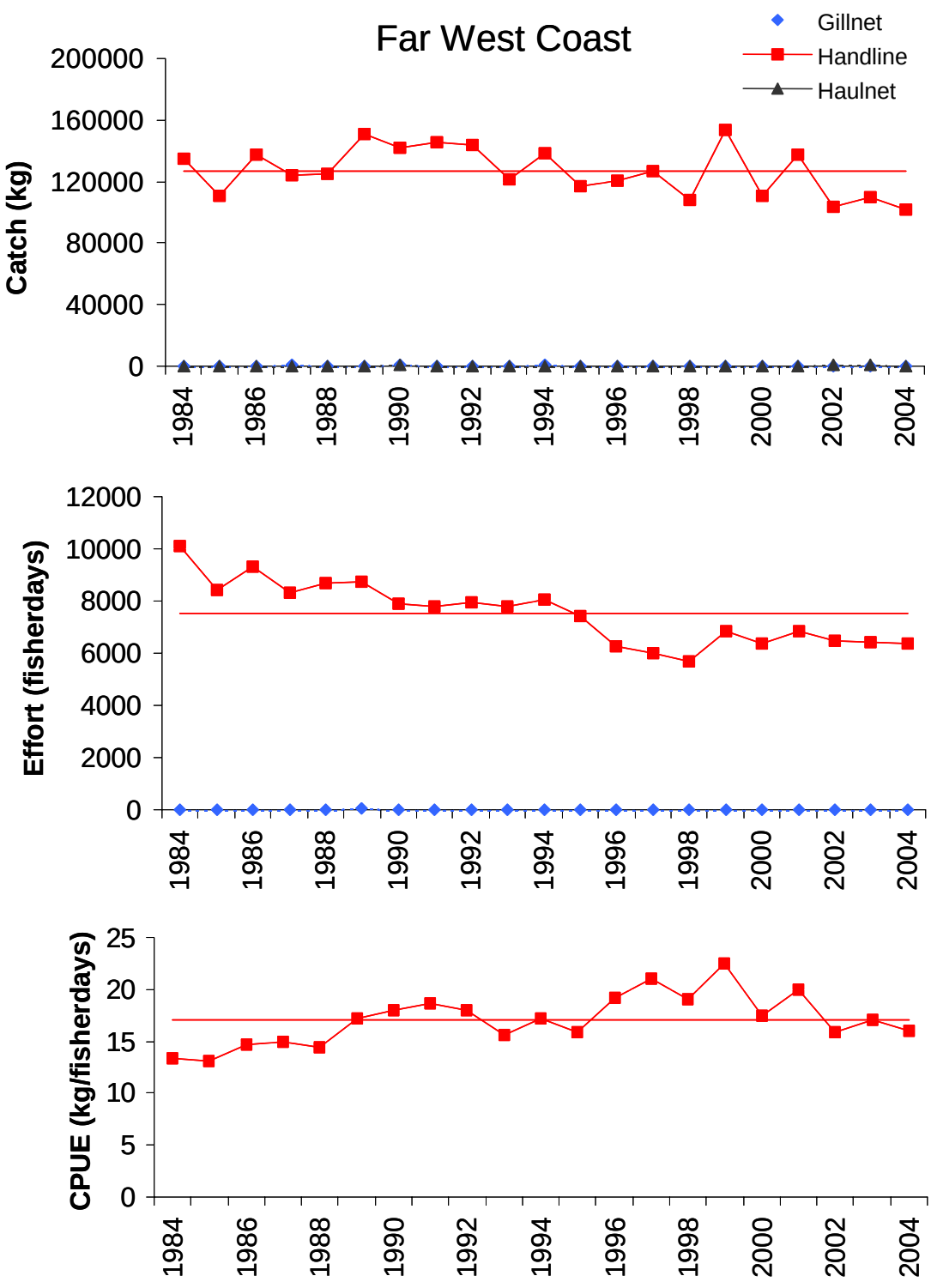

Fig. 3.6 Far West Coast. Top graph – historical trends in total catch by gear type. Middle graph – historical trends in total effort by gear type. Bottom graph – historical trends in CPUE. The long-term mean for the handline fishery is indicated on each graph.

3.4.2. Mid West Coast (Baird and Venus Bays)

The catch from the Mid West Coast is on average approximately one third of that from the Far West Coast (Tables 3.2 - 3.3). Handlines, gillnets and hauling nets have each historically contributed to the catches in these West Coast bays in order of decreasing significance (Fig. 3.7). Since 1990 the handline catch has been highly variable from year-to-year but in 2000 dropped to the lowest recorded level, and in 2001 and 2002 was only marginally higher. It then increased considerably in 2003, before declining again in 2004. The catch from gillnets and haul nets have historically been quite variable, but both dropped to their lowest levels in the period of 2000 to 2002, before increasing marginally in 2003. The catch by the haul net sector has decreased substantially since 1992 and dropped to less than one tonne.year^{-1} since 2000.

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 effort in 2001 and 2002 being the lowest on record (Fig. 3.7). There was a substantial increase in effort in 2003, followed by another fall in 2004. Effort in the gillnet sector has declined significantly since 1992, and in 2002 was at its lowest level since 1984. It then increased marginally in 2003 and 2004.

By virtue of the highly variable annual catch and effort data, the estimates of CPUE for handlines and gillnets have also varied substantially, with there being little evidence of a significant long-term trend (Fig. 3.7). CPUE for handlines has risen considerably through the period of 2000 to 2004, whilst that for gillnets has risen from 2002 to 2004.

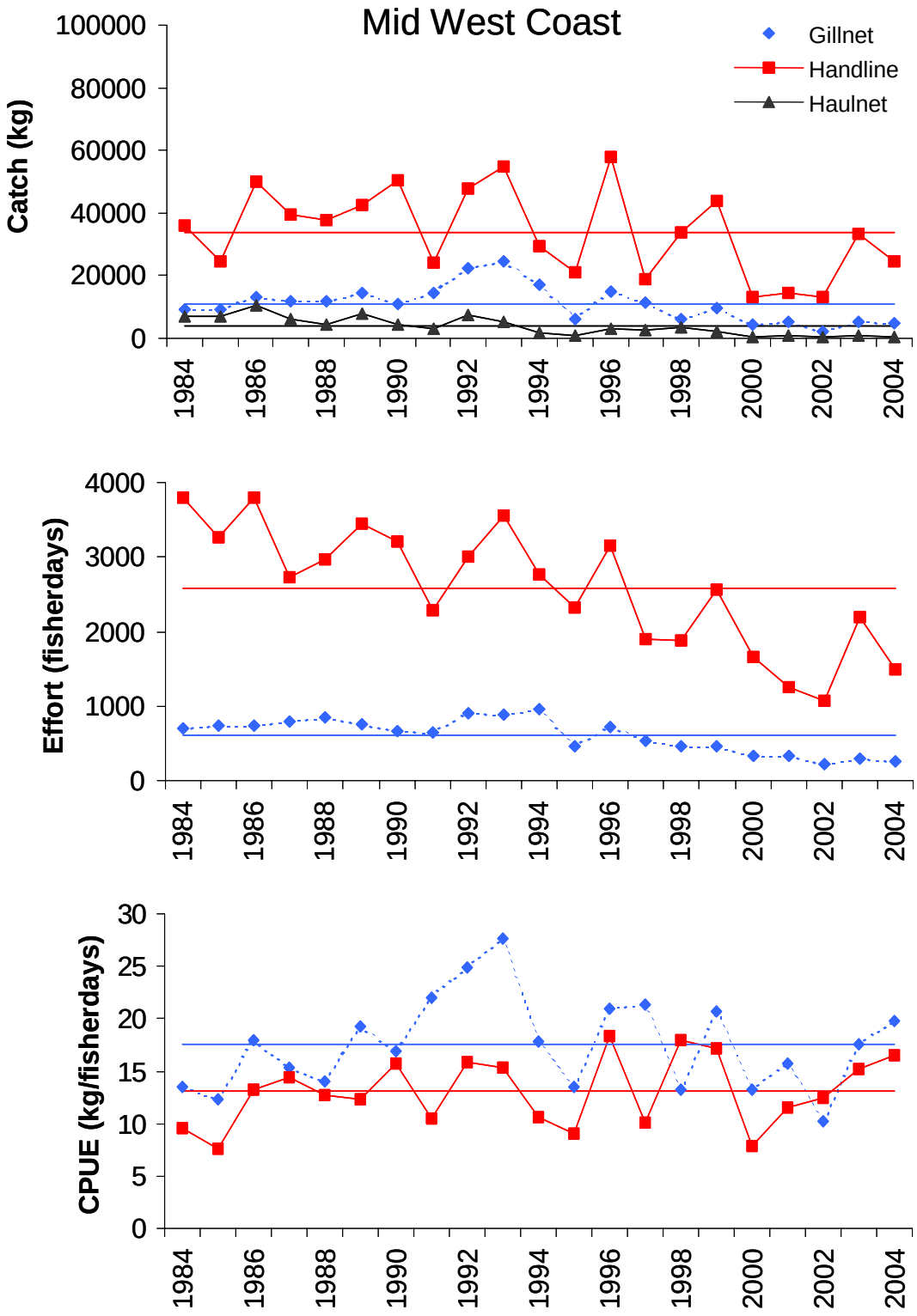

Fig. 3.7 Mid West Coast. Top graph - historical trends in total catch by gear type. Middle graph - historical trends in total effort by gear type. Bottom graph - historical trends in CPUE by gear type. Long-term means are indicated on each graph.

3.4.3. Coffin Bay

Until 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. In 1995 a netting ban was introduced, which resulted in the haul net catch dropping to zero. The handline catch also declined in 1996 but then gradually increased to a maximum in 2000 before decreasing again to 2004 when the lowest ever catch of 8,457 kg was taken.

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 has declined to a minimum of 474 fisherdays in 2004. Effort in the haul net sector was generally high but variable for a long period until 1994, after which it dropped to zero due to the netting ban that was introduced in 1995. 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}. After that, CPUE declined systematically over a four-year period, dropping to a minimum of 17.0 kg.fisherday^{-1} in 2002. Since then there has been a very marginal increase in CPUE.

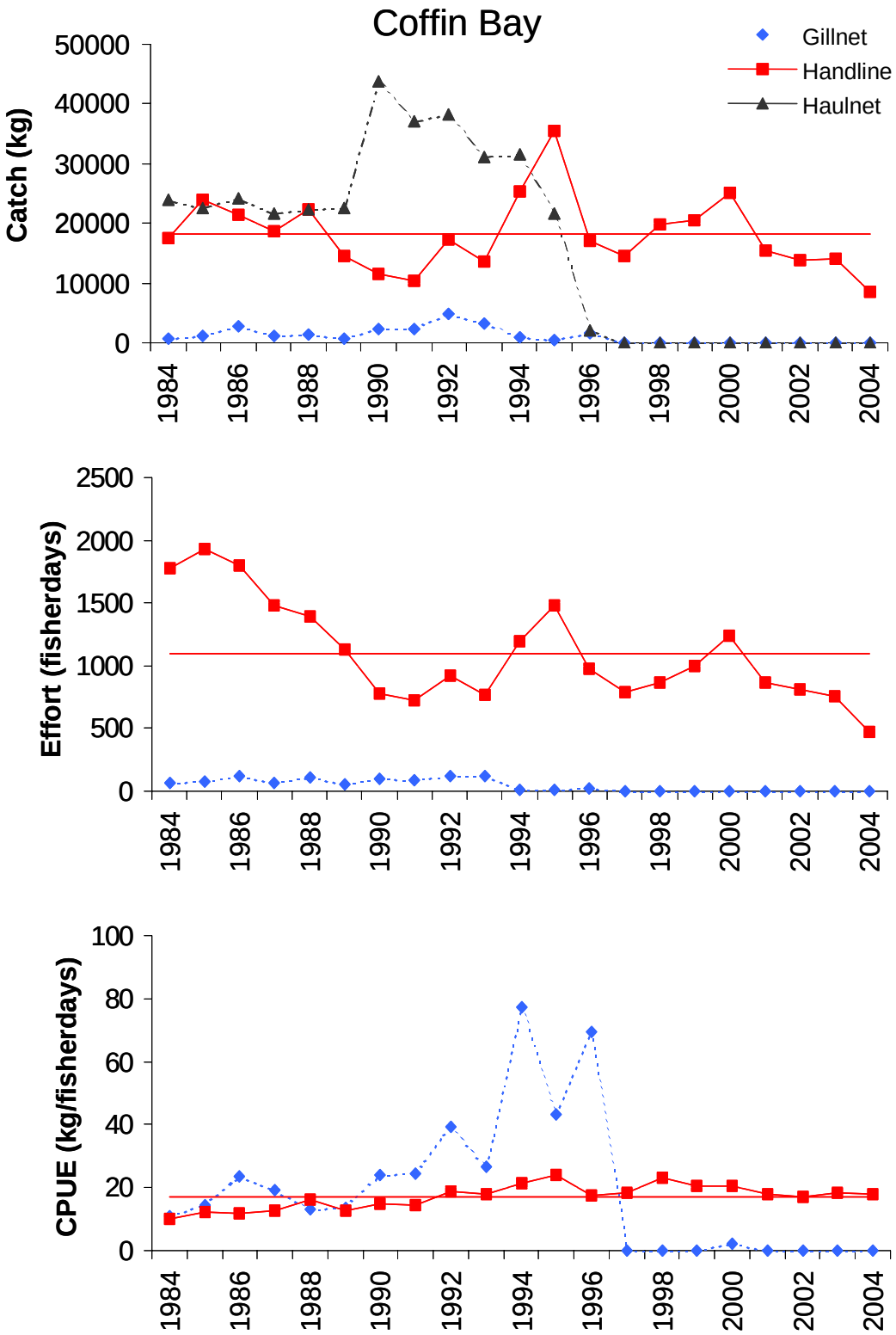

Fig. 3.8 Coffin Bay. Top graph - historical trends in total catch by gear type. Middle graph – historical trends in total effort by gear type. Bottom graph – historical trends in CPUE by gear type. Long-term means are indicated on each graph.

3.4.4. 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 57,373 kg in 2004. Haul net catch declined considerably between 1984 and 2004, particularly through two periods, i.e. 1992 to 1995 and 1999 to 2002. There has, however, been a marginal increase in haul net catch in 2003 and then 2004. Gillnet catches also fell considerably in 2000, and have remained low since then.

Handline effort has been variable since 1984, with peaks in 1986, 1991-92, and a minor one in 1997 (Fig. 3.9). Furthermore, there has been a consistent declining trend in effort since the peak in 1992, when handline effort was 8,713 fisherdays. This declined by 59% to 3,566 fisherdays in 2004. Gillnet effort declined from a maximum of 957 fisherdays in 1999 to 136 fisherdays in 2002, before increasing marginally to 227 fisherdays in 2004.

The estimates of CPUE for handlines increased between 1984 and 1998 (Fig. 3.9). Since then handline CPUE declined consistently to 2003, after which there was a marginal increase in 2004. Nevertheless, the CPUE in 2004 remained approximately 20% less than it was in 1998. CPUE was variable for the gillnet sector between 1984 and 1997, before increasing dramatically in 1998. Since then it has been highly variable.

The annual catches with haul nets through the period of 2000 to 2004 have been the lowest ever recorded, and have also been the years of lowest fishing effort (Fig. 3.10). The estimates of CPUE were highly variable in recent years, which may reflect that the catches and effort were low and variable. The three time series for the different categories of CPUE do not show any consistent trend.

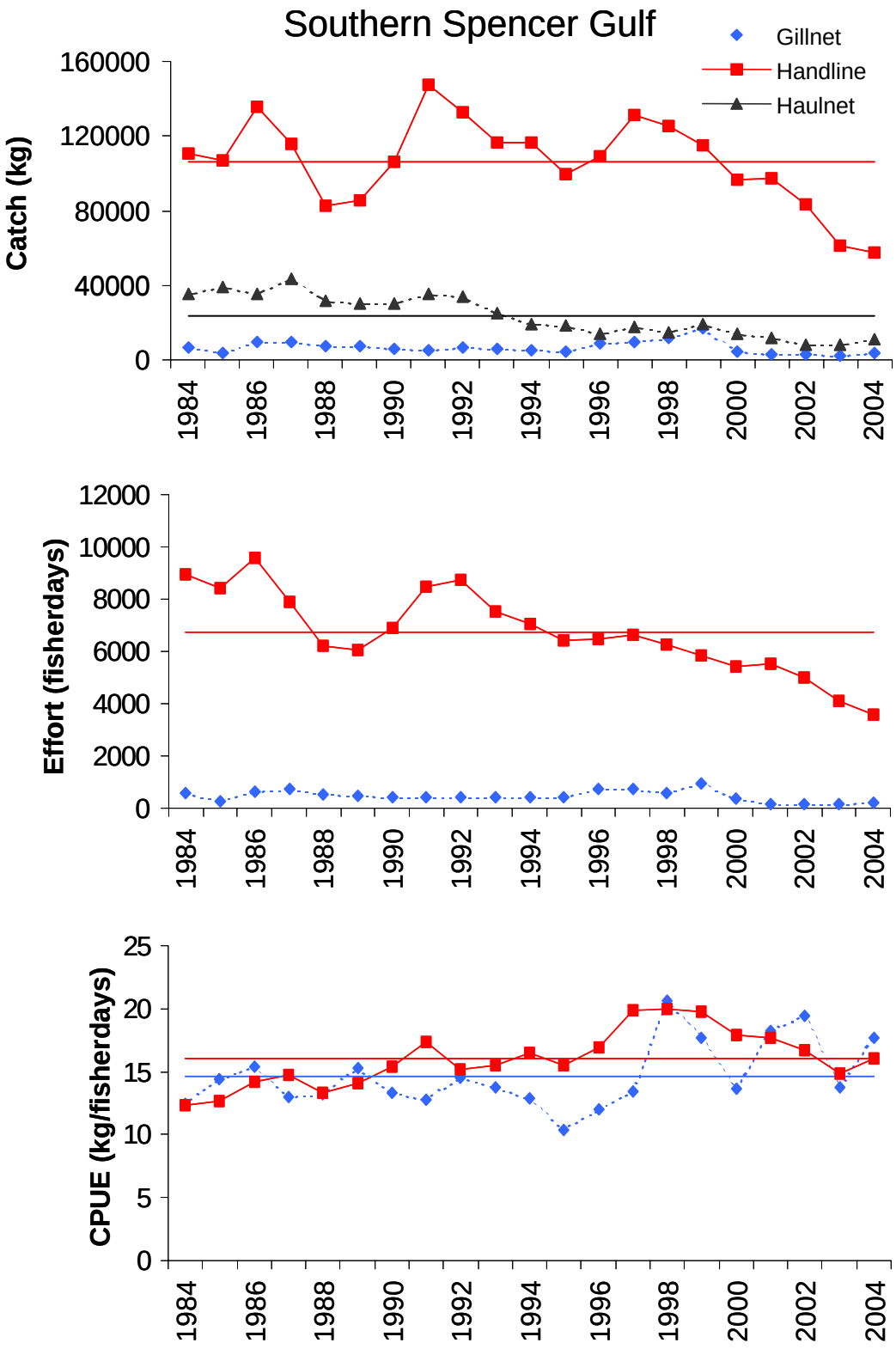

Fig. 3.9 Southern Spencer Gulf. Top graph - historical trends in total catch by gear type. Middle graph - historical trends in total effort by gear type. Bottom graph - historical trends in CPUE by gear type. Long-term means are indicated on each graph.

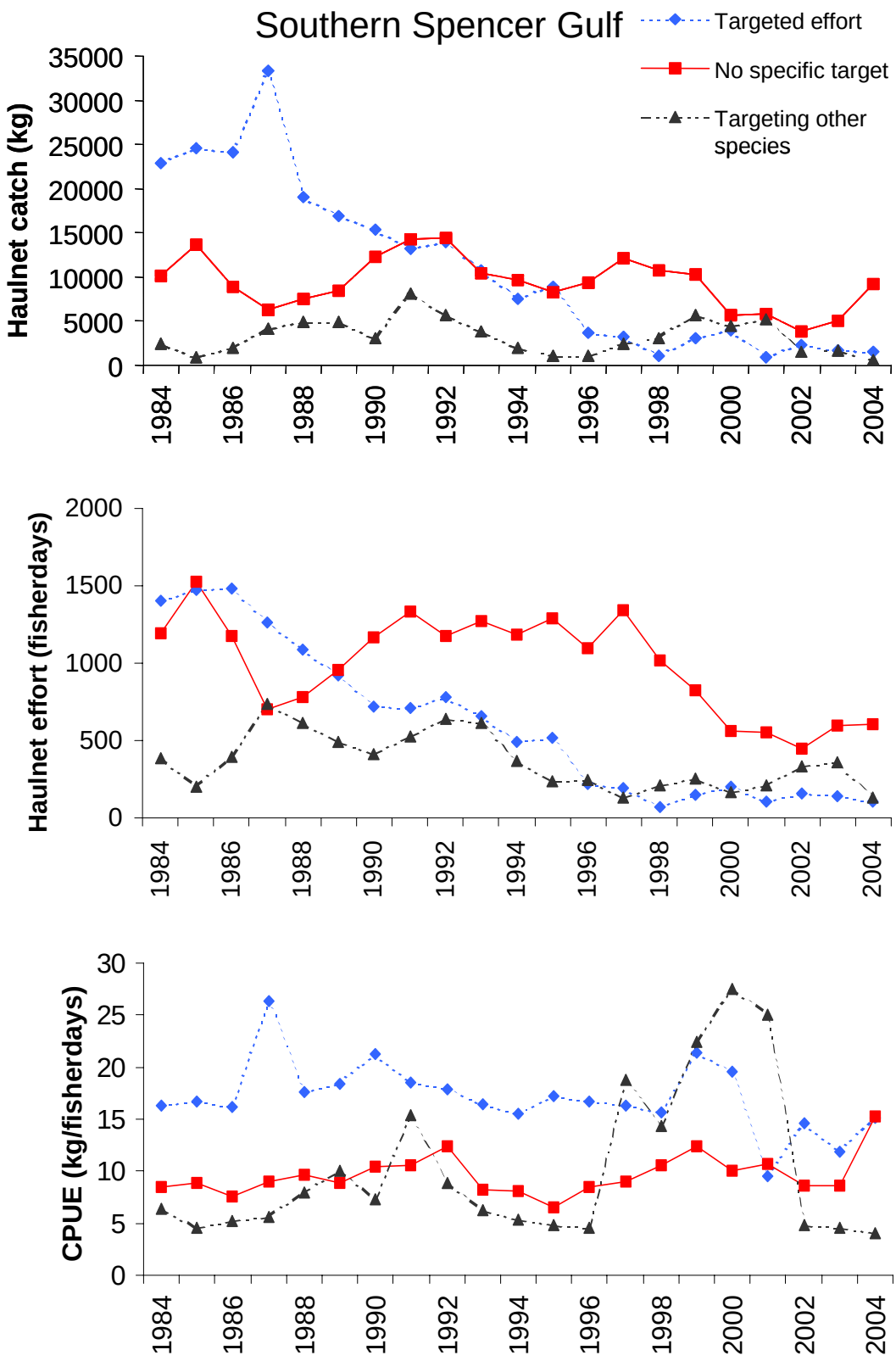

Fig. 3.10 Southern Spencer Gulf. Top graph - historical trends in haul net catch for each of the three effort categories. Middle graph - historical trends in haul net effort for each of the three effort categories. Bottom graph - historical trends in CPUE for each of the three effort categories.

3.4.5. Northern Spencer Gulf

Haul nets have been the dominant gear type in this region since 1984 (Fig. 3.11). Haul net catch was quite variable until 1997 after which there has been a consistent downward trend to the extent that 2004 produced the lowest haul net catch on record (Fig. 3.11). Handline catch has also declined considerably since the high catches of the early 1990s, resulting in the lowest catches on record for 2000, 2001 and 2002, before there was a marginal recovery in 2003. This systematic decline in catch was associated with a consistent decrease in fishing effort, with a particularly significant decline through the period of 1994 to 2001, followed by a marginal increase in handline effort between 2002 and 2004. 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 increased consistently from 10.5 kg.fisherday^{-1} in 1984 to the historic maximum of 21.2 kg.fisherday^{-1} in 2001, after which there was a substantial decline to 16.0 kg.fisherday^{-1} in 2002 (Fig. 3.11). Since then CPUE has increased marginally. CPUE of 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). This reflects 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).

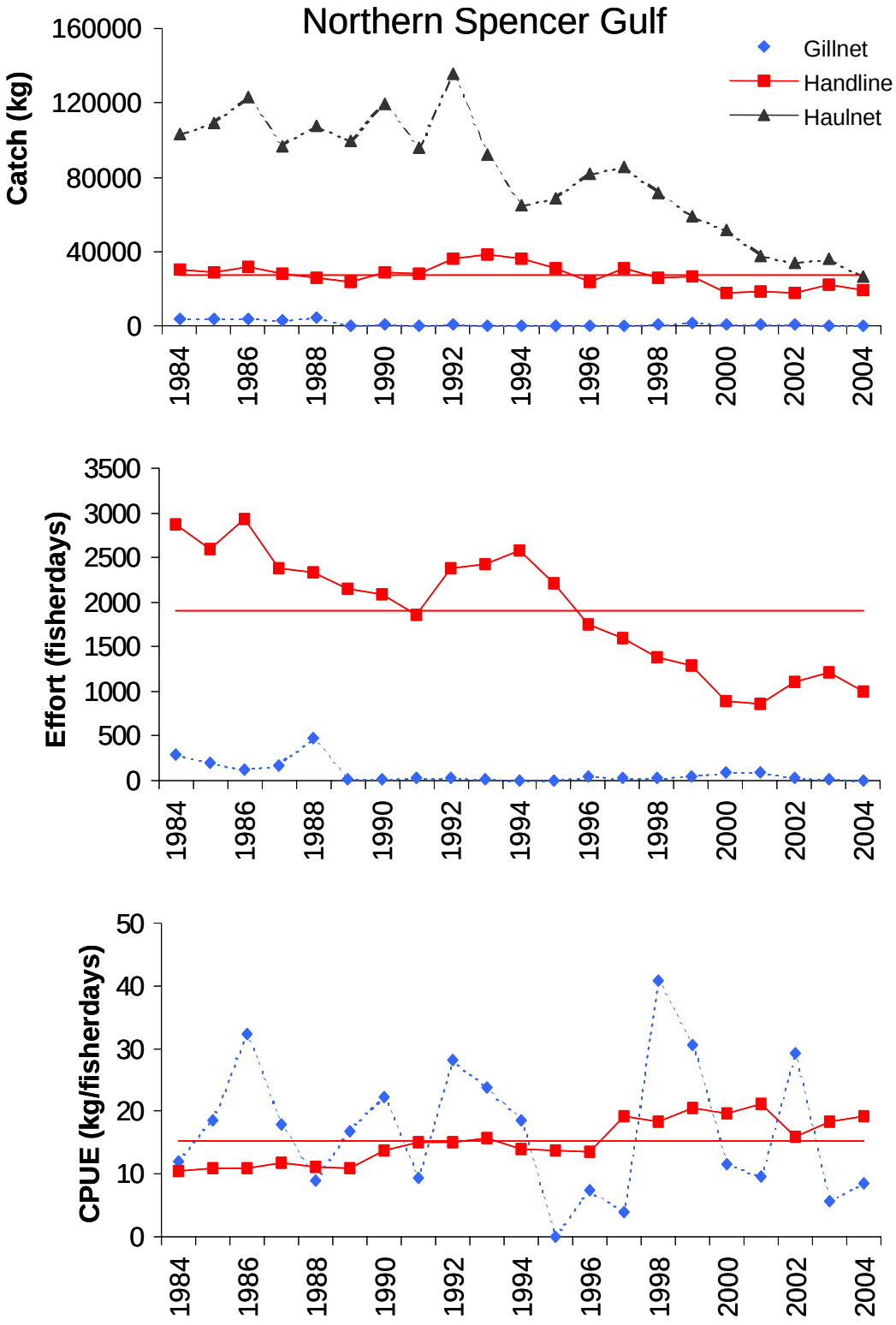

Fig. 3.11 Northern Spencer Gulf. Top graph - historical trends in total catch by gear type. Middle graph - historical trends in total effort by gear type. Bottom graph - historical trends in CPUE by gear type. The long-term mean for the handline fishery is indicated on each graph.

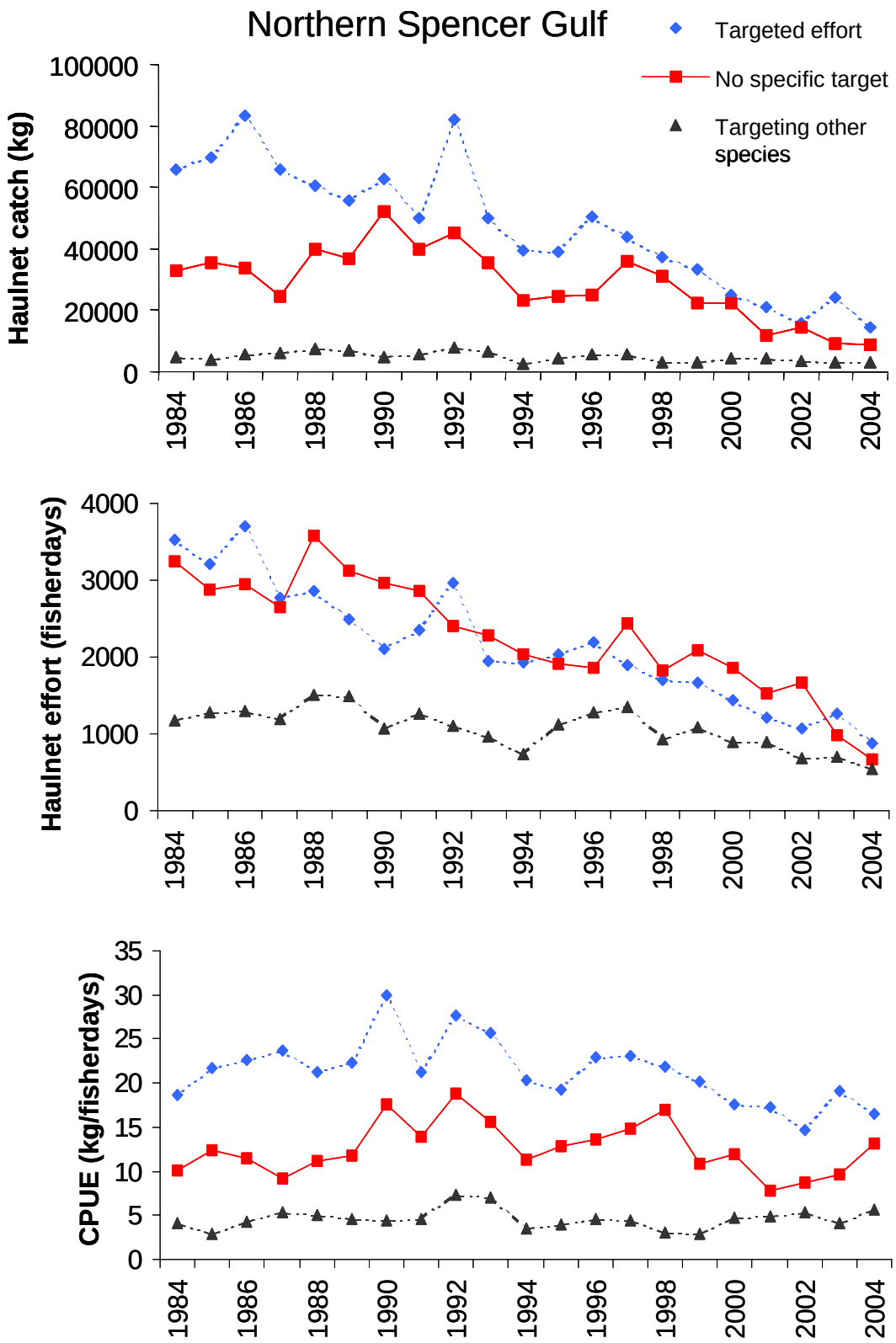

Fig. 3.12 Northern Spencer Gulf. Top graph - historical trends in haul net catch for each of the three effort categories. Middle graph - historical trends in haul net effort for each of the three effort categories. Bottom graph - historical trends in CPUE for each of the three effort categories.

3.4.6 Gulf St. Vincent

Haul nets, handlines and gillnets have each contributed substantially to this regional fishery (Fig. 3.13). The haul net catch was quite variable from 1984 before reaching a peak in 1998. From then, there was a systematic decline of 61% in catch from 37,762 kg to 14,783 kg in 2003, followed by a marginal increase to 21,316 kg in 2004. Handline catches were highest through the early and mid 1990's but have shown a long-term systematic decline from 38,916 kg to 10,658 kg in 2004. The gillnet catches were also relatively low through 2000-2002, increased in 2003, but then decreased again in 2004.

Handline effort was quite variable from 1984 until it reached a peak in 1992, and has since decreased systematically (Fig. 3.13). The peak in effort in 1992 was 3,700 fisherdays, which fell to 847 fisherdays in 2004. Gillnet effort has also declined over the same period, particularly between 2001 and 2004.

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 2004 (Fig. 3.13). The CPUE for gillnets increased to 1999, then decreased substantially in 2000 and 2001, but recovered substantially between 2002 and 2004.

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.

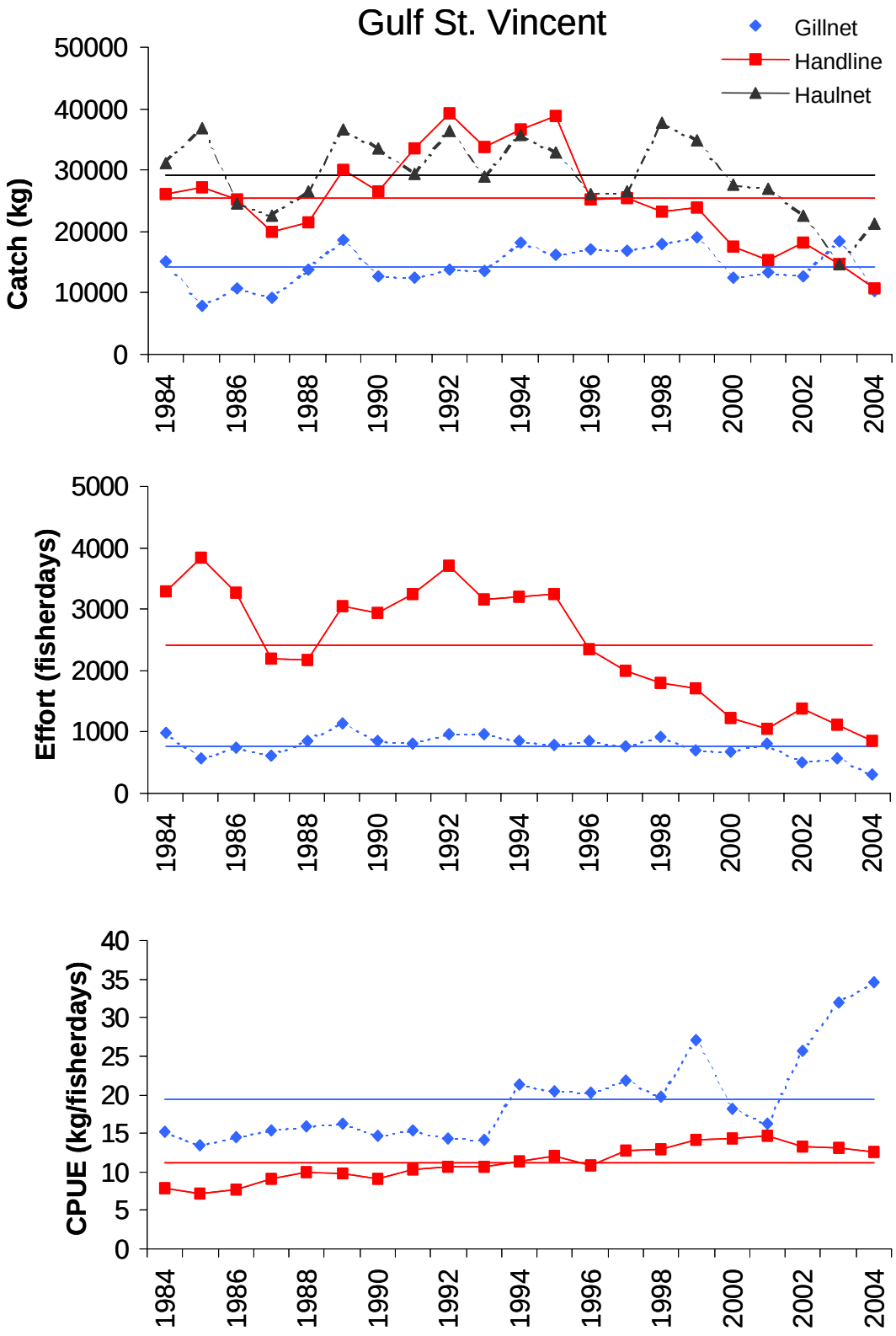

Fig. 3.13 Gulf St. Vincent. Top graph – historical trends in total catch by gear type. Middle graph – historical trends in total effort by gear type. Bottom graph – historical trends in CPUE by gear type. Long-term means are indicated on each graph.

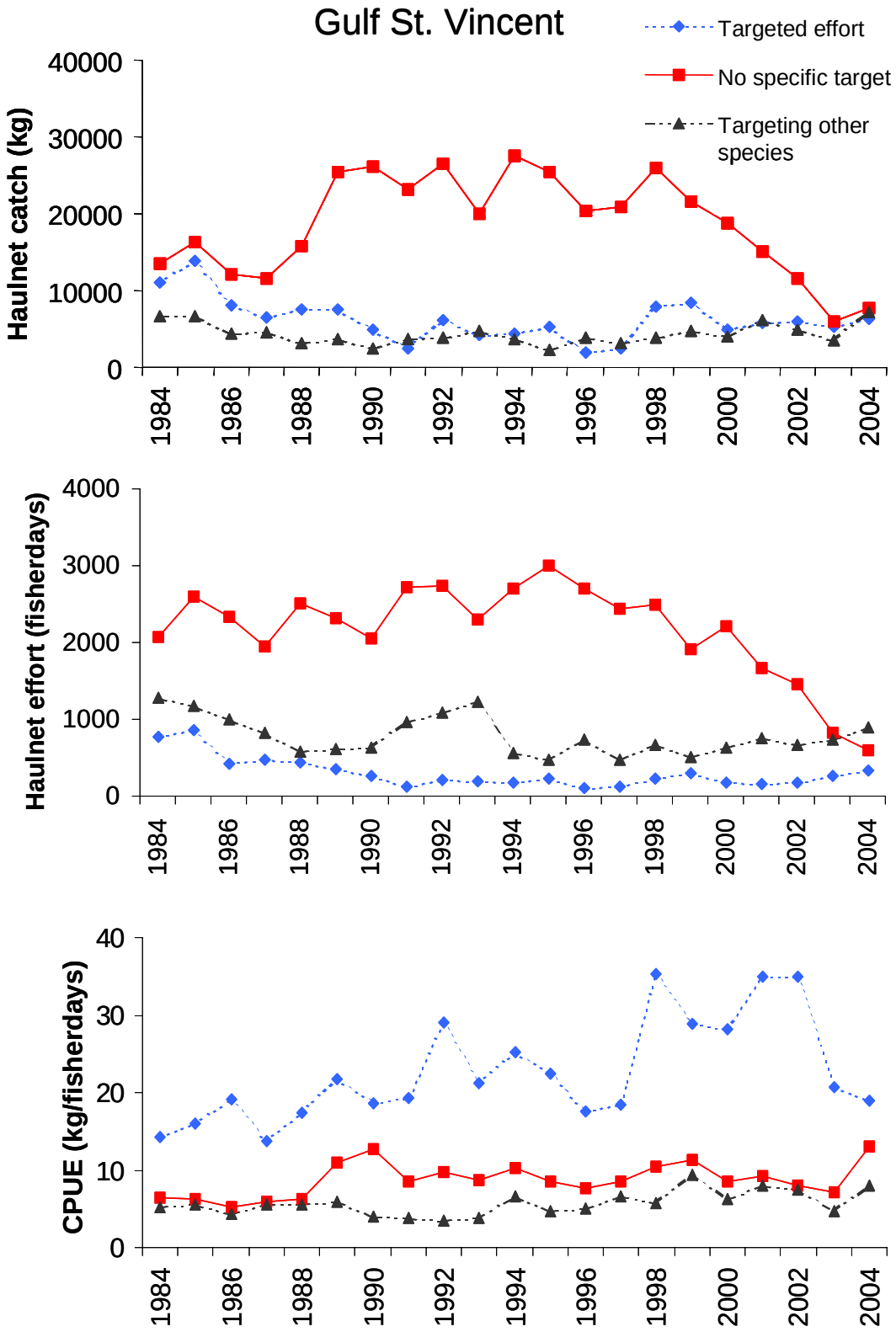

Fig. 3.14 Gulf St. Vincent. Top graph – historical trends in haul net catch for each of the three effort categories. Middle graph – historical trends in haul net effort for each of the three effort categories. Bottom graph – historical trends in CPUE for each of the three effort categories.

3.4.7. 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 marginal increase in annual catch. Haul nets have also been an important gear type for which catches have gradually declined from the peak of 13,594 kg in 1992 to 4,314 kg in 2002. Since then, haul net catch has recovered to 6,204 kg. Gillnets have only ever provided a marginal catch.

Handline effort increased substantially between 1988 and 1992, before declining systematically over the following years (Fig. 3.15). Handline effort in 1992 was 3,768 fisherdays and in 2004 was 1,890 fisherdays, representing a 50% reduction. Effort in the gillnet sector decreased to virtually zero through the early 1990's but has increased moderately since then, and in 2004 accounted for about 95 fisherdays.

The CPUE in the handline sector increased moderately through the years to a maximum of 15.7 kg.fisherday^{-1} in 2000 (Fig. 3.15). Since then CPUE declined by 13% to 13.7 kg.fisherday^{-1} in 2002, but has subsequently recovered to 15.9 kg.fisherday^{-1}.

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 are reported by fishers than a change in fishing methodology. The main reporting category, i.e. "no specific target", has decreased significantly since 1992. CPUE for this sector has been high since 1996, and increased substantially to 102 kg.fisherday^{-1} in 2004.

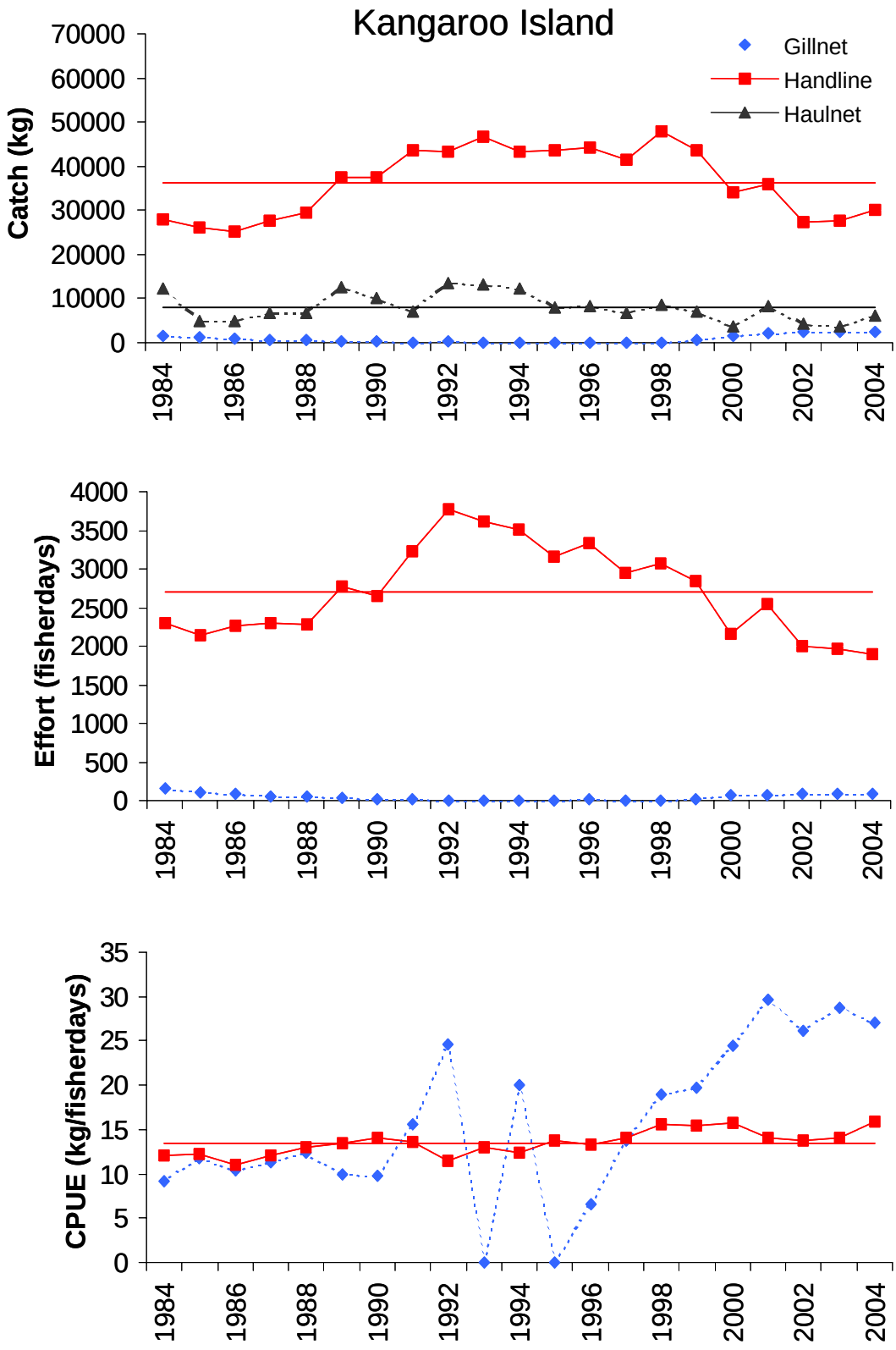

Fig. 3.15 Kangaroo Island. Top graph - historical trends in total catch by gear type. Middle graph - historical trends in total effort by gear type. Bottom graph - historical trends in CPUE by gear type. The long-term mean for the handline fishery is indicated on each graph.

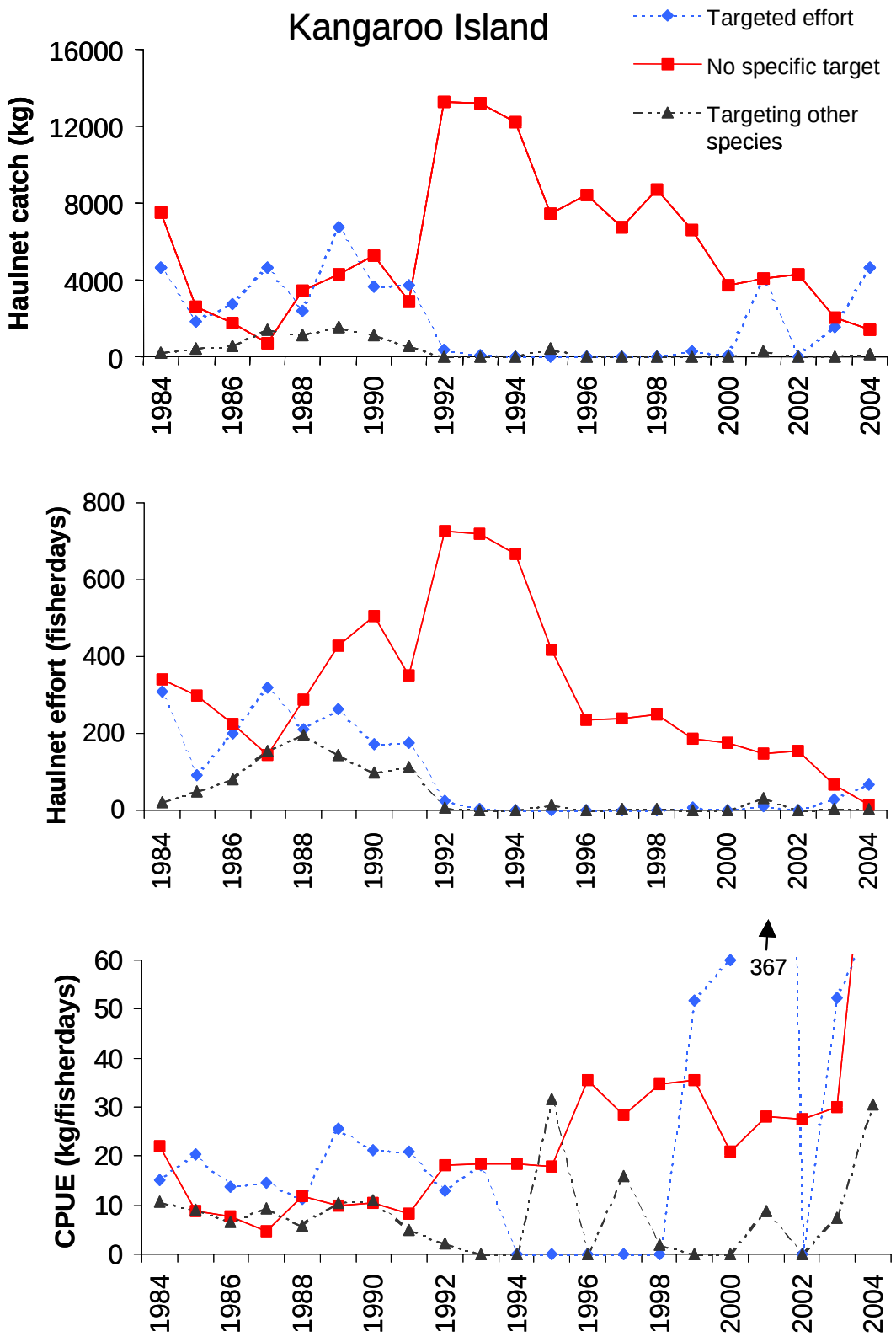

Fig. 3.16 Kangaroo Island Top graph - historical trends in haul net catch for each of the three effort categories. Middle graph - historical trends in haul net effort for each of the three effort categories. Bottom graph - historical trends in CPUE for each of the three effort categories (note the exceptionally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

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 substantially enhanced due to the completion of 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 the two surveys are described below.

4.1. Creel Survey

This was an extensive two-year SARDI/FRDC project, that was aimed at estimating the recreational catch of marine boat-fishers in the main fishery areas of South Australia over one full year (McGlennon and Kinloch 1997). The geographic range of the recreational boat survey was from Victor Harbor to Ceduna, which was divided into the three main geographic regions of Gulf St. Vincent, Spencer Gulf and the West Coast. A total of 62 boat ramps were surveyed throughout this geographic range (McGlennon and Kinloch 1997). Each region was divided into a number of circuits of boat ramps that were surveyed using the "bus-route" method, which involved interviewers travelling around a set of boat ramps and waiting at each ramp for a prescribed period. At each ramp, the number of boat trailers was counted to estimate fishing effort, whilst fishers that returned to the boat ramp during the waiting period were interviewed to obtain estimates of their catch. The results were used to derive estimates of total catch and effort, using the techniques summarised in McGlennon and Kinloch (1997). The survey was done for Gulf St. Vincent from April 1994 to March 1995 and for Spencer Gulf and the West Coast from April 1995 to March 1996.

The creel survey provided estimates of catch that were a subset of the total recreational catch, being confined to catch landed at some public boat ramps during daylight hours. Also, Kangaroo Island and east of Victor Harbor were excluded due to the time and costs of travel.

4.1.1. 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, including 1,154,662 (31% of total) King George whiting.

Of the estimated catch of King George whiting, 98.8% was taken in six of the fishery regions for which commercial fishery data were presented in Section 3. The recreational catch and effort data for these regions are presented in Table 4.1. 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 because of the 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 4.1 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 (kg)	Total catch (numbers)	Targeted effort (boat-days)	CPUE (kg.boat-day^{-1})	CPUE (no.boat-day^{-1})
FWC	21,100	94,039	4,537.1	4.65	20.7
MWC	5,800	35,466	3,871.3	1.50	9.2
CB	21,300	110,184	7,039.4	3.03	15.7
SSG	80,500	274,220	15,605.8	5.16	17.6
NSG	51,900	227,269	12,267.7	4.23	18.5
GSV	85,100	399,536	33,230.9	2.56	12.0
Total	265,700	1,140,714	76,552.2		

In Gulf St. Vincent, the total recreational catch was almost comparable with that of the commercial fishery (Table 4.2). 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.

Table 4.2 Comparison of total catches of King George whiting between the recreational boat and commercial sectors for six fishery regions in 1994 - 96 (McGlennon and Kinloch 1997).

Region	Recreational Catch (tonnes)	Commercial Catch (tonnes)	Total Catch (tonnes)	% of total by rec fishery
FWC	21.1	112.6	133.7	15.8
MWC	5.8	33.2	39.0	14.9
CB	21.3	54.5	75.8	28.1
SSG	80.5	124.5	205.0	39.3
NSG	51.9	96.7	148.6	34.9
GSV	85.1	90.7	175.8	48.4
Total	265.7	512.2	777.9	34.2

4.2 National Recreational and Indigenous Fishing Survey (NRIFS)

4.2.1. Recreational Catch

A national FRDC-NHT funded project for estimating non-commercial catches of marine fish species was undertaken during the year of 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 of 1994-96, which only included boat ramps that were sampled during daylight hours. In particular, the telephone and diary survey also included catches from charter boats, which accounted for 1.7% of the recorded recreational fishing effort.

The national telephone survey provided estimates of the numbers of King George whiting for several regions from around the State. Unfortunately these regions did not correspond directly to those considered in the creel survey described above, or the regions normally considered for the commercial fishery (Fig. 3.1). Nevertheless, by combining results from several different regions it was possible to at least gain some geographic comparison (Table 4.3). The numbers of King George whiting caught in each region were converted to an estimate of biomass based on the estimate of the average-sized fish for each region derived from sampling done from 1995-1997 (Fowler and McGarvey 2000). This is clearly based on the assumption that there was no change to the average size of fish between 1995-97 and 2000-01.

The estimate of total State-wide recreational harvest of King George whiting from May 2000 to April 2001 was 2,238,071 fish, with an estimated total weight of 584.7 tonnes (Table 4.3). Both these estimates were approximately twice those from the creel survey (McGlennon and Kinloch 1997) (Fig. 4.1). In 2000-01 the highest catches were made in (GSV + KI) and SSG. The catches decreased from east to west, as was also the case in 1994-96. In every region the estimated recreational catch in 2000-01 was substantially higher than that of 1994-96 (Fig. 4.1). For the period of May 2000 to April 2001, the total State-wide catch of King George whiting, combining the recreational and commercial catches, was 1,023.4 tonnes. In contrast to 1994-95, the recent estimate of total recreational catch of 584.7 tonnes exceeded that of the commercial catch. In every region except (FWC + MWC) the recreational component of the total catch was greater than the commercial component (Table 4.3). This estimate does not include any of the ‘unspecified whiting’ recorded in the telephone survey. If similar proportions of King George are represented among ‘unspecified whiting’ as in the total catch, the recreational total could be about 100,000 fish, or about 27 tonnes, higher.

Table 4.3 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

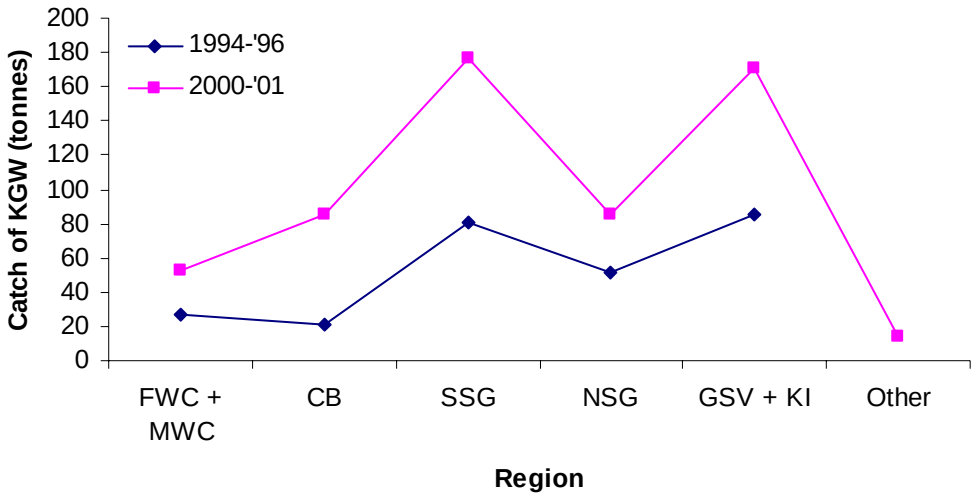

Fig. 4.1 Comparison of regional estimates of recreational catch from the creel survey 1994-96 and NRIF survey in 2000- 01.

The comparison between survey results shown in Fig 4.1, illustrates the higher estimates of catch from the later survey. The question is - how much of this difference is due to uncounted catch from the earlier creel survey, and how much due to increases in total recreational catch over time? To date, we do not know. Since a near doubling in recreational catch since 1994-96 seems improbably rapid, and knowing that public boat ramps in daylight hours constitute only a portion of the total catch, some of the difference must be due to uncounted catch in the creel survey. As such, the different sampling methodologies make it difficult to determine the extent to which recreational catch increased between 1994-96 and 2000-01.

4.2.2. Recreational Effort

The NRIF survey also allowed determination of recreational fishing effort by fishing region (Jones and Doonan 2005). The survey estimated that at that time 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. 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.

The recreational effort on individual species was divisible into both targeted and non-targeted effort. The former was that effort expended when fishers identified that they were specifically fishing for a particular species. Non-targeted effort was that effort expended when a species was caught and retained, but was not reported to have been targeted. When recreational fishers used a range of gear types to catch a number of species during the same fishing event it was not possible to differentiate the total effort into that directed at individual species.

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 4.4). Thus, targeted effort constituted about 78.5% of the total on King George whiting. The highest levels of effort were in the two gulfs. Furthermore, Spencer Gulf received the highest levels of targeted effort. The West Coast also received a high level of recreational effort, the majority of which was targeted 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.

Table 4.4 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 – targeted on KGW	Effort – KGW not targeted, but landed	Total effort 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

5. SPAWNING POPULATIONS: SIZE AND AGE STRUCTURES

King George whiting are distributed unevenly throughout South Australia's coastal waters with respect to size and age (Fowler 1998, Fowler *et al*. 2000a, Fowler and McGarvey 2000). Catches from Gulf St. Vincent and northern Spencer Gulf, as well as the bays of the West Coast tend to be almost exclusively of small fish from the 3+ age class. Alternatively, along the northern coast of Kangaroo Island in Investigator Strait and in southern Spencer Gulf the populations show a much broader size and age range. These populations that occupy deeper water in more exposed places consist of multiple year classes of fish of up to approximately 20 years of age, with some of the older age classes being well represented in the population (Fowler et al. 2000). It has also been determined that these are the spawning populations, with the larger fish likely to contribute substantially to egg production (Fowler et al. 1999). As such, we consider that the age structures of these populations may be an important indicator of egg production in South Australia. Therefore, we monitor these spawning populations at least every few years.

Size and age structures were first developed from samples of these populations that were collected between 1995 and 1998. These structures were presented in the King George whiting FRDC final report (Fowler and McGarvey 2000), stock assessment reports (Fowler and McGarvey 1997, Fowler 1998, Fowler and McGarvey 1999, McGarvey et al. 2000) and peer-reviewed publications (Fowler et al. 1999, 2000). In 2001, the sampling program was reinitiated with the aim of producing population size and age structures for the same key areas, to compare with the data from the mid-late 1990s. Between 2001 and 2004, samples were collected from Investigator Strait and Tapley Shoal in southern Gulf St. Vincent and from Hardwicke Bay in South-eastern Spencer Gulf. Sampling took place during the spawning season, from March to as late as June, and focussed on developing population structures from as many small samples as possible. Small samples were obtained by purchasing whole fish from commercial fishers, collecting fish frames from recreational fishers and from research fishing in particular locations where spawning is known to occur.

In 2001, some commercial fishers who normally fish in the nominated places were asked to provide only a representative sub-sample of 8 - 10 fish from one day's total catch on a fortnightly basis through the spawning season. Fishing by SARDI personnel targeted 2 particular spawning grounds, i.e. the North-west lumps off Corny Point and Tapley Shoal in Gulf St. Vincent using either hook and line, or demersal gill nets with three different mesh sizes. SARDI sampling was also carried out in 2002. In 2003, samples were collected only

from the North-west lumps off Corny Point. In 2004, samples were collected from both Investigator Strait and from South-east Spencer Gulf.

5.1. South-east Spencer Gulf - (Corny Point / Wardang Island)

In 2001, the 317 fish sampled from this region ranged from 320 - 500 mm TL (Fig. 5.1). The modal sizes for both sexes were 380 mm TL. The ages were distributed from 3 - 13 years, but only one individual was >9 years old. Most fish were in the 3 - 5 year age classes, with a relatively higher abundance of 3 year olds compared with the samples of 1997 and 1998. In 2002, 205 fish were sampled which were mostly in the 3 – 5 year age classes, but also included some fish of greater than 11 years of age (Fig. 5.1). The modal sizes of both sexes were 380 mm TL in 2001 and marginally less in 2002. In 2003, a total of 314 fish were sampled, with both sexes dominated by the 4-6 year olds. There was a small number of older fish that were up to 16 years old. The modal size of the males was 400 mm TL, and females were 420-440 mm TL. In 2004, a total of 494 fish were sampled from this region. A broad age range was represented, i.e. from 3 to 15 years with the dominant age class being the 4 year olds. Most fish were in the 3 – 8 year age classes. Whilst the modal size for the males was 380 mm TL, there were several modes for the females, i.e. 380 and 420 mm TL. The females dominated the larger size groups.

Strong year classes appear as relatively more abundant age classes, this age increasing with the cohort in successive years of sampling. The south-eastern Spencer Gulf (Fig. 5.1) shows evidence of two strong year classes. The strong 1993 year class was evident as abundant 4 year olds in 1997, 5 year olds in 1998 and then 8, 9, 10 and 11 year olds in 2001-2004. A second moderately strong year class, 1998, is apparent as 3, 4, 5 and 6 year olds in consecutive years between 2001 and 2004 (Fig. 5.1).

There is no evidence of a significant contraction in the size and age structures from the samples collected in the latter three years relative to those from the late 1990's. Thus, these age samples suggest no evidence of depletion in the principal Spencer Gulf spawning subpopulation.

5.2. Tapley Shoal

The total of 138 fish from this location in 2001was significantly biased towards females (Fig. 5.2), that ranged in size from 36 to >50 cm TL, and had a modal size of 420 mm TL (Fig. 5.2). They included the age range of 3 - 15 years, but only very few individuals were older than 6

years of age. Most fish, regardless of sex, were in the 3 - 4 year age classes, and the age structures of both sexes were very similar to the historic ones from 1995-97. In 2002, 134 fish were sampled and the sex ratios and size and age structures were very similar to 2001, thus indicating no recent contraction. No sampling was done at Tapley Shoal in 2003 or 2004.

5.3. Kangaroo Island

A total of 208 King George whiting were sampled from Investigator Strait through the 3-month autumn sampling period of 2001. They ranged in size from 340- >500 mm TL, with a modal size for both sexes of 400 mm TL (Fig. 5.3). These fish were distributed in age from 3 to >17 years. There was a long tail with relatively low numbers of fish in the age classes of 6 years and older. The 8 year old fish constituted a small evident mode in 2001, as was also the case in southern Spencer Gulf. In 2002, 215 fish were sampled that were dominated by the 3 – 6 year age classes (Fig. 5.3). The age structures of both sexes extended to >17 years, with most age classes represented. There was a distinct peak of 9 years olds for both sexes. The males had a modal size of 380 mm TL, whilst the modal size for females was similar but also included the 400 mm TL size class. In 2004, 422 fish were sampled. Whilst the modal ages for both sexes were 5 year olds, the age structures were dominated by fish that were 4 to 8 years old, with the distributions having long tails to the older age classes. The two oldest fish were 17 and 18 years old. The females had a modal size of 400 mm TL, and the males 400 – 420 mm TL.

The series of age structures from 1996 to 2004 show evidence of several strong year classes, including a strong 1993 year class (Fig. 5.3), which was also observed in the south-east Spencer Gulf samples (Fig. 5.1). This 1993 year class was strongly evident as 3, 4 and 5 year olds in 1996, 1997 and 1998, and as 8 and 9 year olds in 2001 and 2002, and finally as 11 year olds in 2004. More recently, there is some sign of a stronger-than-average 1997 year class as 4 and 5 year olds in the 2001 and 2002 age samples respectively (Fig. 5.1) and for a stronger-than-average 1996 year class as 8-year-olds in the larger 2004 age sample.

Overall, older (>6 years) and much older (>11 years) King George whiting observed in this Kangaroo Island spawning population are more numerous than elsewhere in the two Gulfs. Migration studies have shown that most of these fish have migrated from the upper and inshore waters of Gulf St. Vincent, and from the north-eastern bays of the island (Fowler et al. 2002). Thus, while some migration to spawning grounds on Tapley Shoal occurs where King George whiting are younger and dominated by females, it appears that these fish eventually continue southward to the Kangaroo Island spawning grounds, and remain or return there in subsequent spawning years.

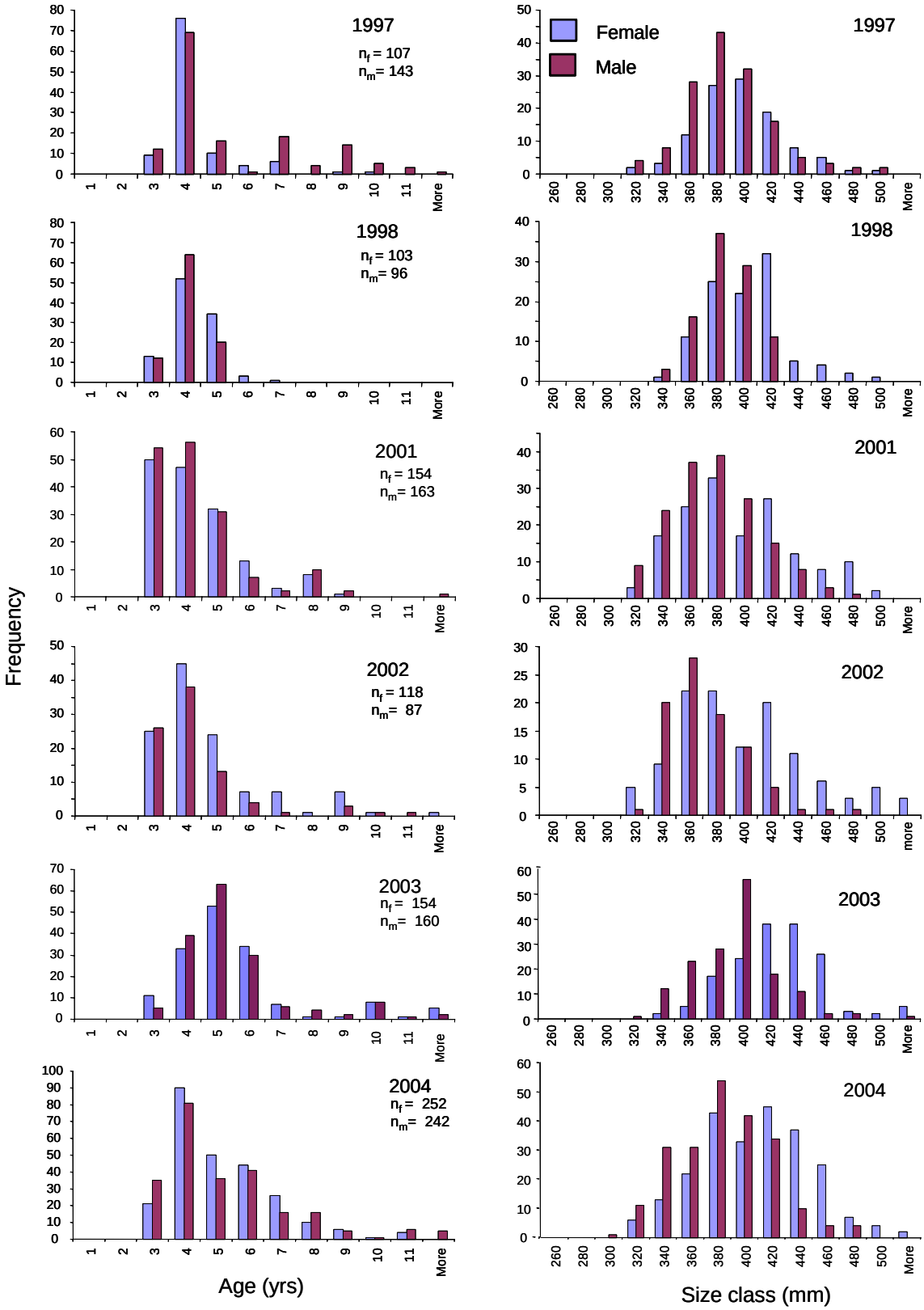

Fig. 5.1 Age and size structures of samples of King George whiting collected from south-eastern Spencer Gulf through March to May of 1997, 1998, 2001, 2002, 2003 and 2004 (n_f = number of females, n_m = number of males).

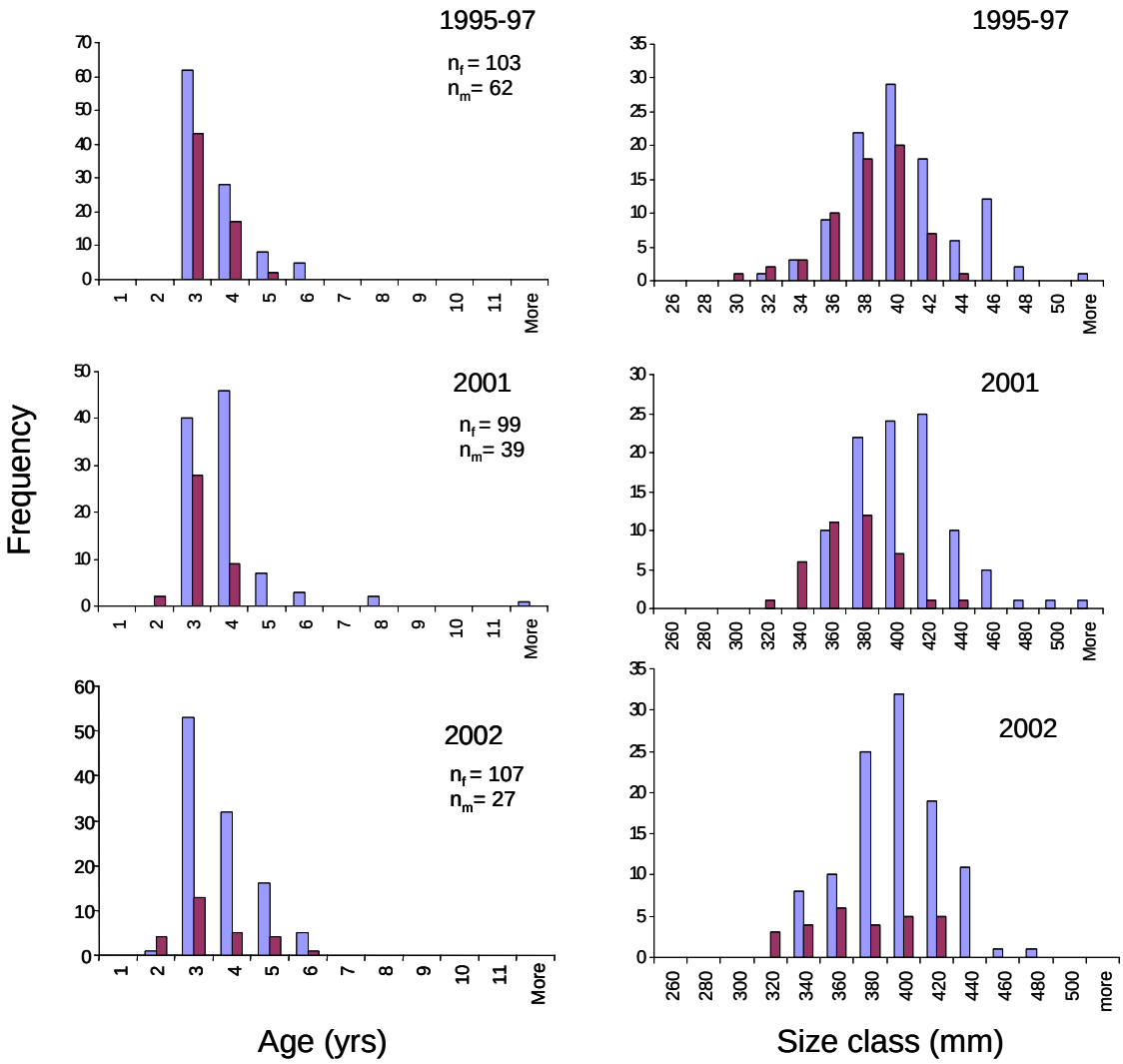

Fig. 5.2 Age and size structures of samples of King George whiting collected from Tapley Shoal in southern Gulf St. Vincent through March to May of 1995 to 1997, and again in 2001 and 2002 (n_f = number of females, n_m = number of males).

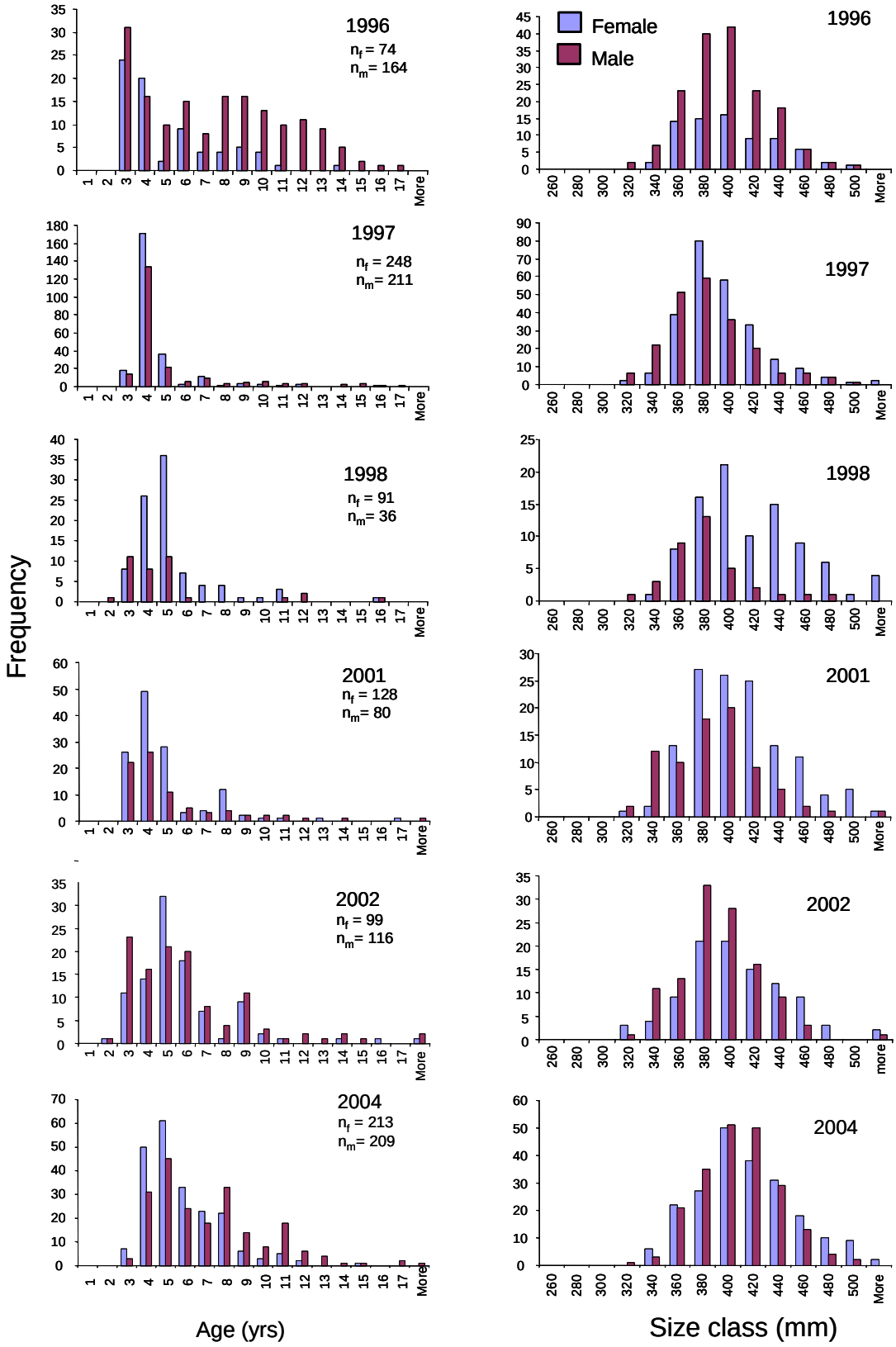

Fig. 5.3 Age and size structures of samples of King George whiting collected from Kangaroo Island through March to May of 1996, 1997, 1998, 2001, 2002 and 2004 (n_f = number of females, n_m = number of males).

6. MODEL ASSESSMENT OF BIOLOGICAL PERFORMANCE INDICATORS

6.1. WhitEst model: description and input data

For King George whiting in South Australia the primary management objective remains to ensure the 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 13 spatial cells (Fig. 6.1), which means that it can take into account yearly summer migration from inshore areas in the northern gulfs to the spawning regions in the southern gulfs. Furthermore, the spatial facility allows the model to keep account of the exploitation that varies in space and time. Exploitation is high in the upper gulfs and inshore, and is 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 period of 1995-1998, (3) a growth curve of estimated length-at-age (McGarvey and Fowler 2002), (4) estimated migration rates among the 12 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 is created each monthly model time step, a 'slice' being defined as the proportion of each cohort that reaches legal size each month. These slices permit a model describing monthly growth, which (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, undertaken in this year's WhitEst update, are summarised in Appendix A.

The model is fitted to monthly catches, conditional upon the associated effort in fisher days, partitioned into 4 gear types (handline, haul net, gillnet, and all other gears combined) and 3 target types (targeting King George whiting, targeting any other specific marine scalefish species, and not targeting any species in particular), as these are 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, Section 5 above). Further details of this model are included in the FRDC final report (Fowler and McGarvey 2000). The King George whiting model was externally reviewed in detail by Dr André Punt (University of Washington, Seattle, USA).

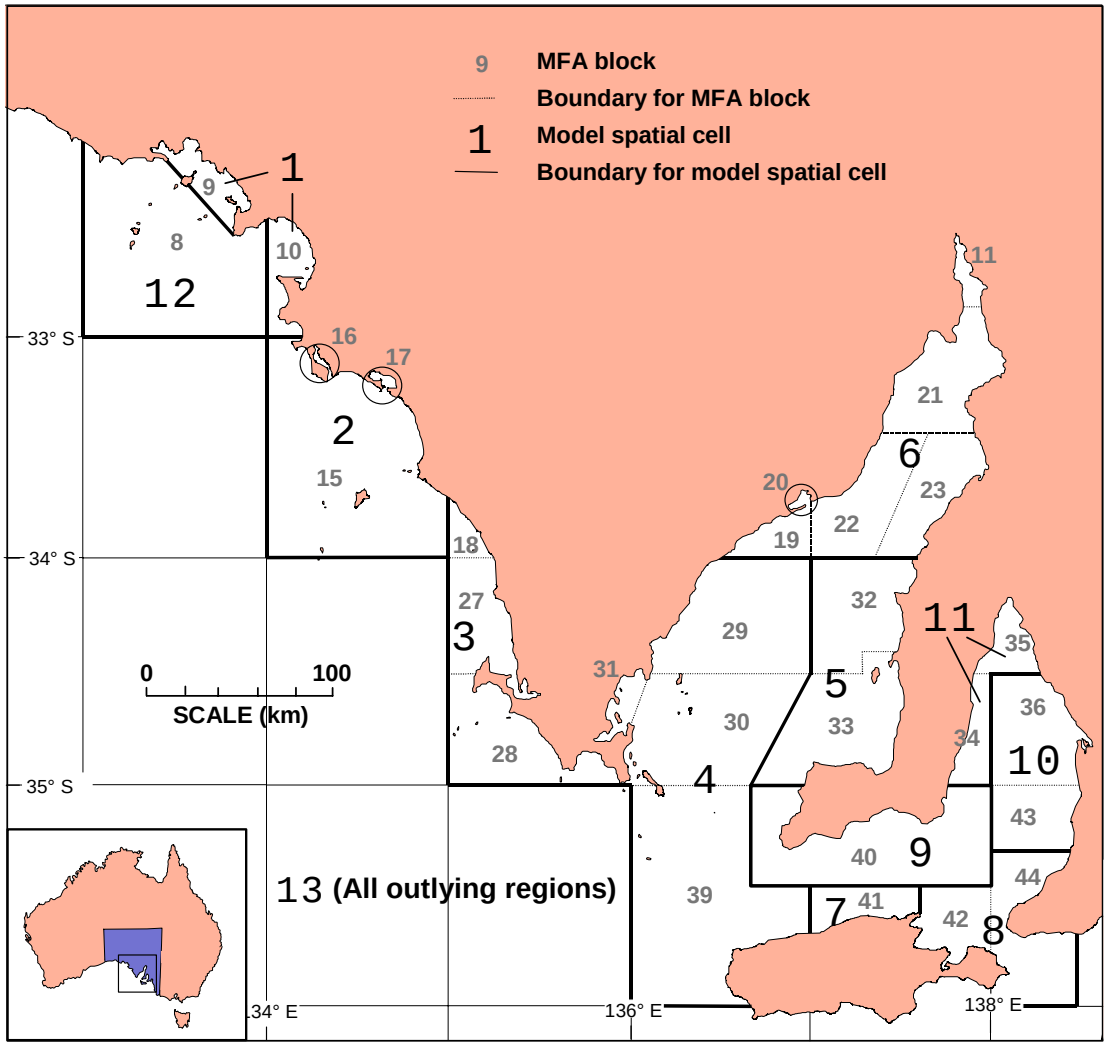

Fig. 6.1 Map of South Australia showing the Marine Fishing Area blocks in which commercial catch and effort are reported, and the 13 spatial cells used in WhitEst, the King George whiting stock assessment model.

6.2. WhitEst model indicators: recruitment, biomass and exploitation rate

The model outputs three principal biological performance indicators: recruitment; legal-size population biomass; and exploitation rate (also known as harvest fraction, which is defined as the fraction of legal biomass harvested over any specified time period). Yearly biomass is that estimated by the model for 1 January of 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 they enter the fishable stock at age 3.

Recruitment is shown as a yearly indicator in all model output figures (Figs. 6.2-6.5). Biomass and harvest fraction were estimated for each monthly model time step, and these monthly

estimates are first presented broken down among the three main fishery regions (Gulf St. Vincent, Spencer Gulf and West Coast; Fig. 6.2). To examine long-term trends, biomass and exploitation rate are also shown as yearly quantities in Figs. 6.3-6.5, specifically yearly State-wide totals (Fig. 6.3) and yearly regional totals (Fig. 6.4). In addition, we present preliminary (sensitivity) model outputs for a model run that utilised the first 6 months of data from the re-initiated catch-at-age sampling program (Fig. 6.5), covering only the last 6 monthly model time steps (July-December 2004). Estimated model population indicators for South Australian King George whiting show the following features:

1. Seasonal variation: The model estimates of fishing mortality and biomass show high seasonal variation (Figs. 6.2), with the yearly cycle in abundance preceding similar seasonality in commercial catch and effort. The seasonal peaks in abundance occur in late summer and autumn at the times of fastest growth, which therefore are the months when the highest numbers recruit into 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: Overall, since model catch and effort data were first collected in July 1983, yearly model population indicators for South Australian King George whiting (Figs. 6.3 and 6.4) have been relatively stable. The State-wide model estimates of recruitment and biomass have shown roughly flat time trends with modest yearly variation.

3. 1999-2002: More recently, State-wide biomass and recruitment (Fig. 6.3) trended downward over the four year period of 1999 to 2002. By region (Fig. 6.4), the gulfs showed different patterns. A declining trend in recruitment is evident for Spencer Gulf since the 1996 year class (1999 fishery catch). In Gulf St. Vincent the most recent recruitment peak was later, in 1999, with no declining trend evident. The gentle rise in biomass estimated for Gulf St. Vincent reflects a similar trend in CPUE, which is subject to some potential biases, as noted.

4. Last two years: In the two years since the last stock assessment report, 2003 and 2004, both recruitment and biomass have stabilised, both for the State overall (Fig. 6.3), and for the three regions (Fig. 6.4). Modest rises over these two years are detectible, but are not statistically significant. Nevertheless, the model outcome for these two years is favourable and indicates a population that is not declining, and possibly even making a slow recovery.

5. Long-term overall exploitation rate trends uncertain: Estimated declining exploitation rates (Figs. 6.3 and 6.4) are likely to be an artefact of steadily declining commercial effort since the early 1990's. These may, however, not reflect overall exploitation rate, since there is no time-series data on annual catch by the recreational sector. Nevertheless, recreational catch now exceeds the commercial catch (Section 4). The WhitEst model assumes that recreational catch and effort vary proportionally with the South Australian human population. The model does not take account of potentially rising effective effort that would relate to the increase in use of fish-finders, GPS and of published hot spots.

6. Comparison of model recruitment with age samples: The model yielded annual estimates of recruitment for the two gulfs (Fig. 6.4) that were, in part, consistent with the age structures presented in Section 5. The age samples from spawning aggregations displayed evidence of a strong 1993 year class in both Spencer Gulf (Fig. 5.1) and Kangaroo Island (Fig. 5.3). The model output showed high recruitment to the two gulfs in 1996, i.e. for the 1993 year class as 3 year olds (Fig. 6.4).

7. Sensitivity to adding recent half-year age samples: Sensitivity testing to the model outcomes when the newest, still-preliminary, age sample data covering July-December 2004, were added to the fitted data set (Fig. 6.5) showed much stronger evidence of a recovery in both gulfs in 2003 and 2004. With these added catch-at-age data, model-estimated recruit numbers were substantially higher in 2004. This result may be an artefact of adding age data for only 6 months rather than that from a full year, and so the result from the model may not be fully comparable with those based on using age compositions sampled in 1995-98. The uncertainty in interpretation of this positive model outcome is heightened by the fitting of these new age samples at the end of the model time series.

   Because increases in effective effort would bias CPUE as a measure of relative biomass, in effect, declines in biomass would be measured as less substantial declines in CPUE, sensitivity analysis of the potential strength of this bias was undertaken using the model. In particular, we re-estimated the yearly biomass time series using three different reasonable assumed levels of rising gear catchability, namely of 1%, 2% and 3% per year. The results presented for Spencer Gulf in the 2003 report (Fig. 7.4 in McGarvey et al. 2003), showed that incorporating rising effective effort does shift the biomass trend more steeply downward, but the effect was not strong enough to imply large differences from the estimates from the baseline run of the model.

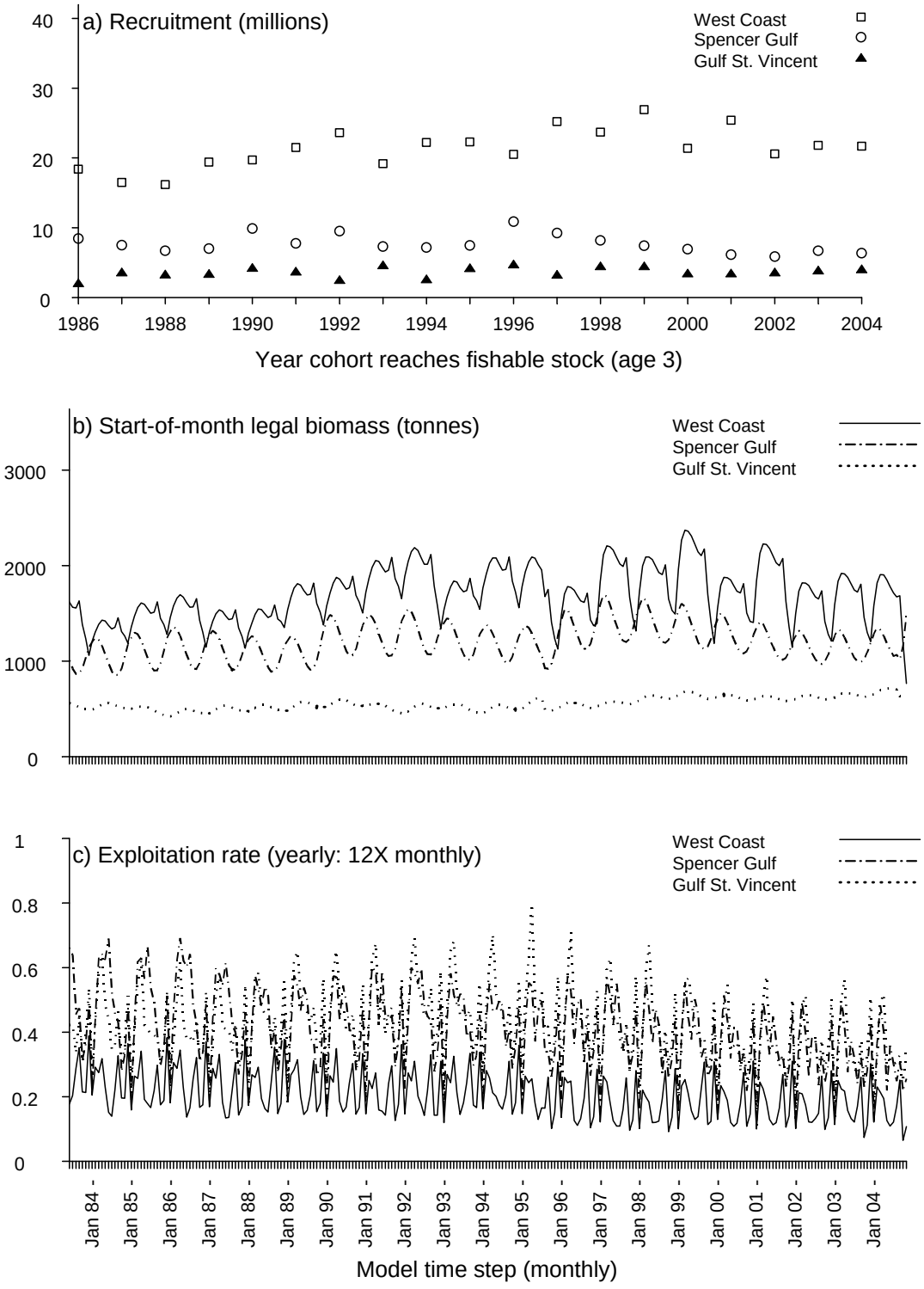

Fig. 6.2 Monthly regional biological indicators 1984-2004 for the South Australian King George whiting population. These performance indicators of (a) yearly recruit numbers, (b) legal biomass on the 1st of each month, and (c) harvest fraction as the monthly catch divided by the start-of-month legal biomass multiplied by 12 to give yearly equivalent values, are estimated by the FRDC-sponsored spatial dynamic stock assessment model (WhitEst).

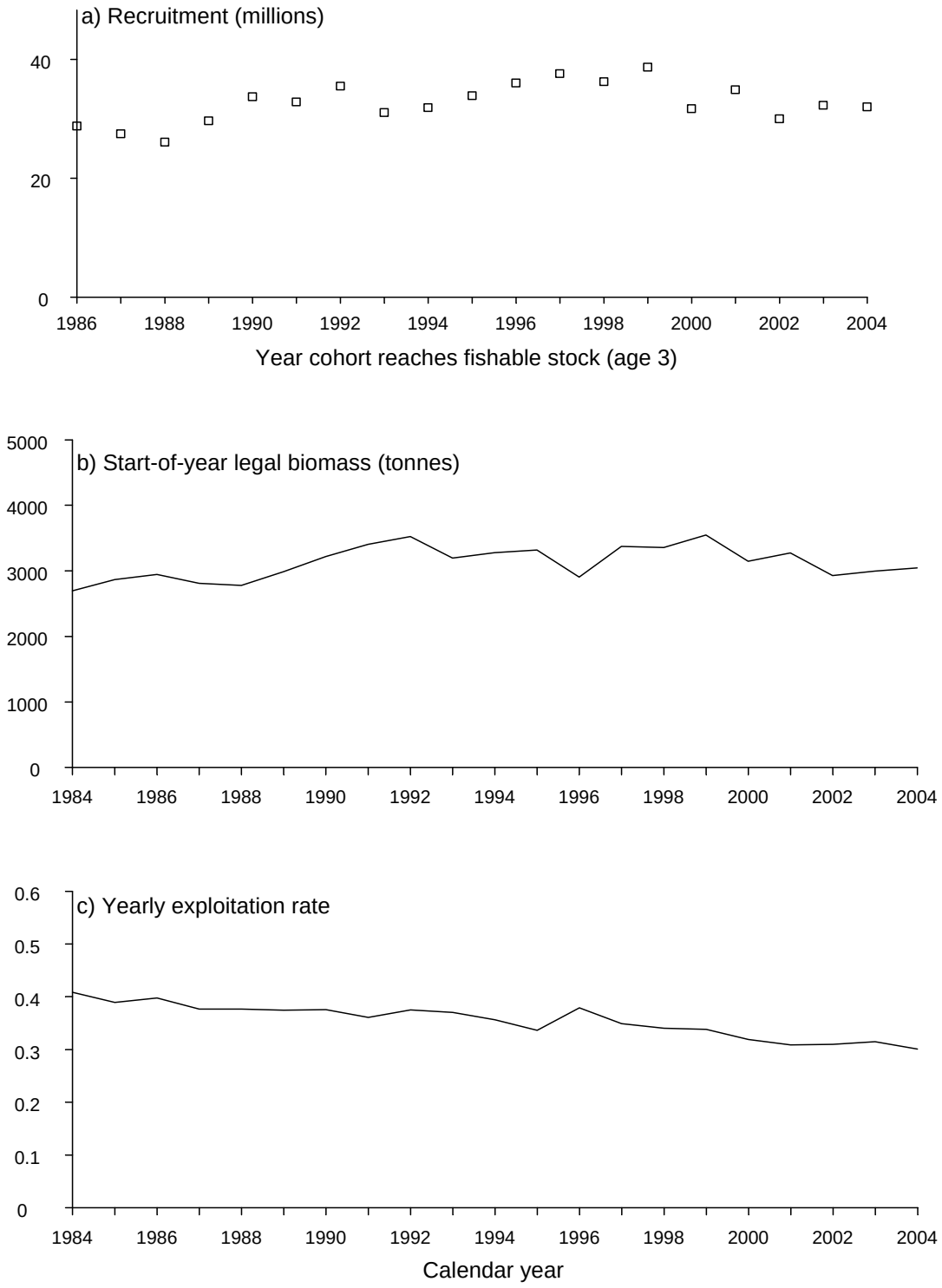

Fig. 6.3 Yearly State-wide (excluding spatial cell 13) model biological indicators 1984-2004 for South Australian King George whiting. These performance indicators of (a) yearly recruit numbers, (b) legal biomass on the 1st of January, and (c) harvest fraction as the yearly catch divided by the start-of-year legal biomass, are estimated by the FRDC-sponsored spatial dynamic stock assessment model (WhitEst).

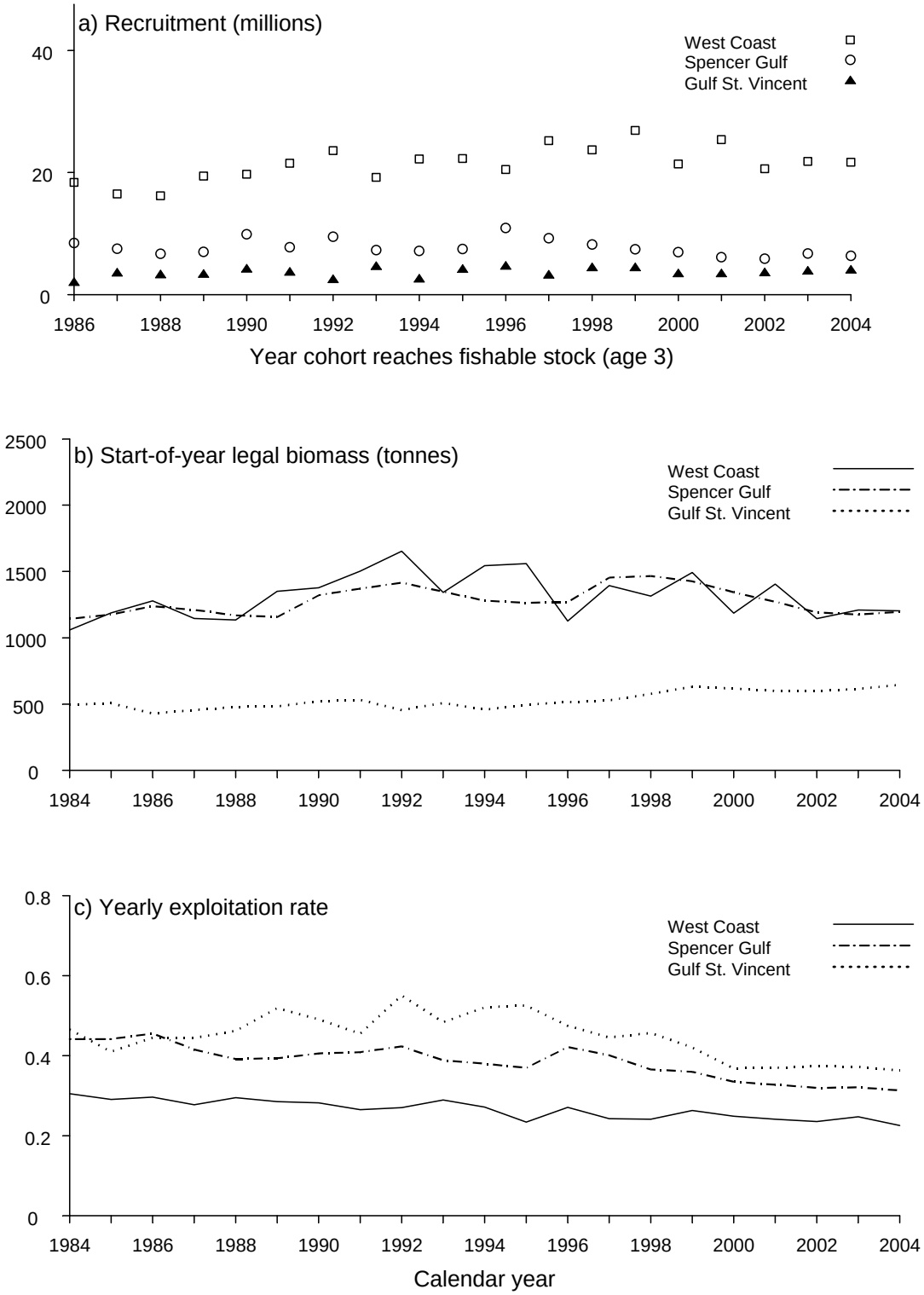

Fig. 6.4 Yearly regional model biological indicators 1984-2004 for South Australian King George whiting. Regions are the West Coast (including Far and Mid West Coast, and Coffin Bay, model cells 1,2, 3 & 12 shown in Fig. 6.1), Spencer Gulf (Fig. 6.1, model cells 4-6), and Gulf St. Vincent and Kangaroo Island (Fig. 6.1, model cells 7-11).

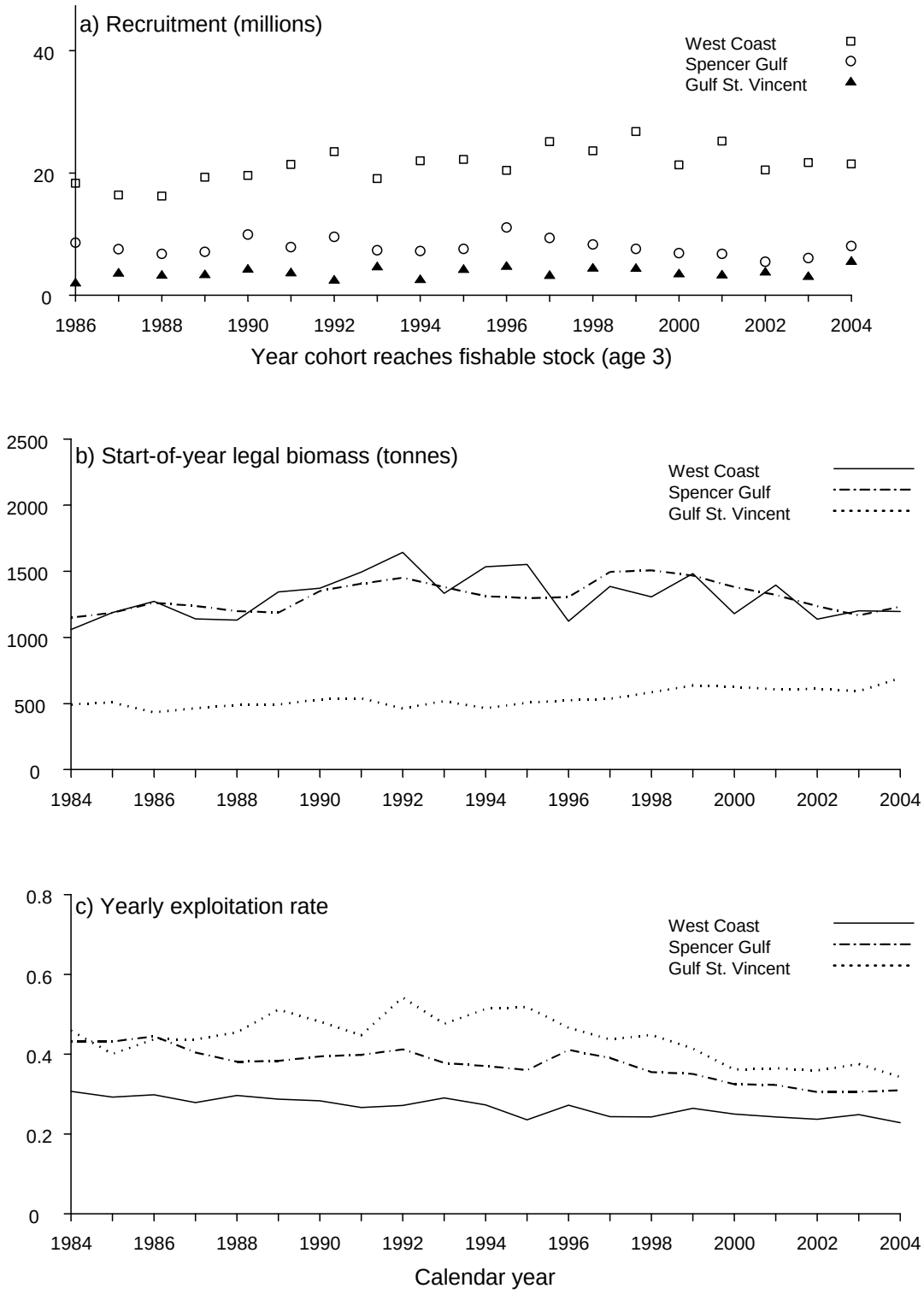

Fig. 6.5 Sensitivity analysis: Yearly regional biological indicators from a WhitEst run which incorporates preliminary catch-at-age samples from the last 6 months of the model time series.

7. ASSESSMENT OF BIOLOGICAL PERFORMANCE INDICATORS

The new management plan for the Marine Scalefish Fishery of South Australia provides a strategic framework to guide fishery management decisions (PIRSA 2005). This framework links the management goals with the assessment process and identifies the appropriate response to the outcomes of the assessment. Essential to this process is a set of biological performance indicators that relate to the status of the fishery, with respect to the management objectives. These biological performance indicators should be considered for each primary target species and objectively assessed by comparison with appropriate limit reference points.

Here, the two management objectives that relate to 'ensuring a sustainable harvest of King George whiting' were considered by comparing the nominated biological performance indicators with the limit reference points specified in the Management Plan (PIRSA 2005). The data considered in this assessment process included fishery-dependent data, biological data and the output parameters from the WhitEst model. Since two new years of commercial catch data are reported in this report, i.e. for 2003 and 2004, then the status of the fishery at the end of both years is considered by comparison with limit reference points.

7.1 Objective 1- Manage total catch and effort in all sectors that take King George whiting to ensure that the fishery is sustainable

The first performance indicator for this objective is 'total commercial catch', for which the limit reference points are; total commercial catch is 25% less than or greater than that of the previous year; and is 10% less or greater than the average catch of the previous five years (PIRSA 2005). The appropriate data for assessment of this performance indicator are presented in Table 7.1

Table 7.1 Assessment of total commercial catch of KGW in 2003 and 2004, as a biological performance indicator (* indicates breached limit reference point).

Year	Total commercial catch (kg)	% variation from previous year	Average catch of previous five years (kg)	% variation from five-year average
2002	370,328			
2003	378,963	+2.33	484,196	-21.7*
2004	346,364	-8.6	447,549	-22.6*

For both 2003 and 2004 the difference in total commercial catch from the preceding year was less than 25%, and so the limit reference point was not breached in either year. Alternatively, when these catches were compared with the respective averages of the preceding five years, the limit reference points were both negatively breached. This relates to the substantial reduction in annual commercial catch since the late 1990s (Section 3.0 this report).

The second performance indicator is 'total commercial fishing effort'. The limit reference points are; total annual target commercial effort is 20% less or greater than the average target effort of the previous five years, and the ratio of non-target to target commercial effort is 10% less or greater than the ratio in the previous year. For King George whiting the assessment of this indicator was confined to consideration of the handline data because of the difficulties associated with the reporting of data from the net sector, where it is difficult to differentiate between targeted and non-targeted effort. Alternatively, it is likely that targeted handline effort is a strong indicator of the fishery.

Although targeted handline fishing effort fell in both 2003 and 2004, the rate of decrease did not exceed the limit reference point of 20% (Table 7.2). Alternatively, the ratio of non-targeted to targeted effort was quite variable, breaching the trigger reference point in a positive direction in 2003 and then negatively in 2004. The non-targeted effort in this sector is relatively small at less than 10% of the total effort, which may account for why the ratio is so variable from year-to-year.

Table 7.2 Assessment of total commercial handline fishing effort on KGW in 2003 and 2004, as a biological performance indicator (* indicates breached limit reference point).

Year	targeted commercial handline effort (fisherdays)	Average targeted handline effort over previous five years	% variation from five-year average	Ratio of non-targeted to targeted handline effort	% variation from previous year
2003	16,982	19,019	-10.7	0.0795	14.6*
2004	15,129	18,363	-17.6	0.0534	-32.8*

The third performance indicator is 'commercial catch per unit effort (CPUE)' for which the limit reference point is - the annual average commercial CPUE is 10% less or greater than the average CPUE of the previous 5 years. This indicator was also assessed for the commercial handline fishery, using the data presented in Table 7.3. The two estimates of CPUE were each lower than the average from the preceding five years, but the differences did not exceed 10%, i.e. the limit reference point.

Table 7.3 Assessment of catch per unit effort (CPUE) for the commercial handline sector for KGW in 2003 and 2004, as a biological performance indicator.

Year	CPUE (kg.fisherday^{-1})	Average catch of previous five years	% variation from five-year average
2003	15.89	17.49	-9.2
2004	16.12	17.00	-5.2

The final biological performance indicator for the nominated objective is – the estimate of the recreational catch and CPUE. The limit reference point is – the combined annual commercial and recreational catch is 25% less or greater than that of the previous year. This biological performance indicator could not be assessed for King George whiting since the most recent estimate of recreational catch available is for the period of May 2000 to April 2001 from the National Recreational and Indigenous Fishing Survey (Section 4.0 this report, Henry and Lyle 2003). Thus, there are no recent data on recreational catch to report here, which seriously compromises the ability to assess total fishery catch across all sectors.

7.3 Objective 2- Ensure that appropriate biological performance and fishery status indicators are measured

The important biological performance indicators for this objective are identified as – 'egg production, fishable biomass, harvest fraction of fishable biomass (exploitation rate), abundance of pre-recruits, and age structure' (PIRSA 2005). The first limit reference point relates to estimates of egg production. WhitEst, the computer fishery model for King George whiting does not provide estimates of egg production. Rather the estimates of egg production that have been provided in the past for this species, such as in the last stock assessment report (McGarvey et al. 2003), and during the management debate that took place throughout 2004, were provided by the simulation model WhitSim. Since it has not been necessary to use WhitSim during the current stock assessment process, there are no estimates of egg production available for 2003 or 2004.

With respect to both fishable biomass and the abundance of pre-recruits, the limit reference points are that both parameters are 10% less or greater than the average values from the previous five years. Here, the estimates of fishable biomass and recruitment that were output from the WhitEst fishery model for 2003 and 2004 were each compared with the model-estimated averages for the preceding five years.

The estimates of fishable biomass in each of 2003 and 2004 were less than the five-year averages, but not sufficiently to breach the limit reference point (Table 7.4). Similarly, the estimates of numbers of three-year old pre-recruits that were about to recruit to the fishery were also lower in the two most recent years, but the differences with respect to the five-year averages did not exceed the 10% level of difference.

Table 7.4 Assessment of fishable biomass and recruitment rates for KGW in 2003 and 2004, as biological performance indicators.

Year	Estimated fishable biomass from WhitEst (kgs)	Average fishable biomass from previous five years	% variation from five-year average	Estimated abundance of pre-recruits from WhitEst (numbers)	Average number of pre-recruits over the previous five years	% variation from five-year average
2003	2,995,316	3,250,076	-7.8	32,296,437	34,312,499	-5.88
2004	3,044,460	3,178,055	-4.2	32,022,919	33,520,195	-4.47

The final parameter that was output from WhitEst for consideration as a performance indicator is exploitation rate. The estimates of exploitation rate are considered here for each of the three main regions that are considered in the fishery model, i.e. West Coast, Spencer Gulf and Gulf St. Vincent. The limit reference is that the exploitation rate should not exceed the international standard, for which an appropriate value is 28% (Caddy 1998). The region-specific estimates of exploitation rate are presented in Table 7.5. Both estimates for the West Coast are less than the limit reference point. Alternatively, for both years the estimates of exploitation rate for Spencer Gulf exceeded the limit reference point, indicating that a higher proportion of the legal biomass was taken than recommended according to the international standard. This situation was exacerbated in Gulf St. Vincent for which it is estimated that even higher proportions of the legal biomass were removed by the fishery in each of 2003 and 2004.

Table 7.5 Assessment of exploitation rate for KGW, as estimated by WhitESt, for the three main fishery regions in each of 2003 and 2004. The values are percentage of fishable biomass removed annually by the fishery, to compare with international standard of 28% (* indicates breached limit reference point).

Year	WC	SG	GSV
2003	24.7	32.0*	37.2*
2004	22.6	31.3*	36.2*

The final limit reference point for consideration relates to any significant change of age structure over the previous five years. The age structures of King George whiting for the populations located on the spawning grounds were considered in Section 5.0 of this report. There were no apparent significant changes in population size or age structures through the period of sampling.

8. DISCUSSION

The last stock assessment for King George whiting expressed considerable concern about the sustainability of the fishery (McGarvey et al. 2003). It suggested that on the basis of several sets of data that the abundance of this species in South Australia had decreased considerably through the period of 1999 to 2002. This evidence included: falling estimates of CPUE in several of the main fishing regions; estimates of CPUE from selected, long-term fishers which displayed more significant declines than was evident for the general regional trends; commercial fishers had shifted considerable fishing effort away from this species to a more diverse range of lower-value species; the output of the stock assessment model 'WhitEst' indicated declining trends in biomass for the West Coast and Spencer Gulf, and a long, declining trend in recruitment in Spencer Gulf since 1996; and anecdotal reports of lower abundance from both recreational and commercial fishers. The concerning status of the fishery that was reflected by these different indicators prompted a review of the management protocol for the fishery through 2004, which resulted in significant changes that came into force on the 1st October 2004.

This report summarises the results of the first stock assessment since the implementation of the new management protocol. Nevertheless, because it has reported on data that were collected only up to the end of 2004 it was too early for the fishery to have manifested any significant benefits that could be attributed to the management changes. Rather, it will take several years for any positive effects of these changes to be manifested by the populations and the fishery catches. Nevertheless, this stock assessment report is significant as it has provided an opportunity to assess whether the downward trends in biological performance indicators that were evident through the period of 1999 – 2002 have continued or not. There were several sets of data presented in this report that relate to the status of the fishery: commercial catch, effort and CPUE data; the age and size structures of the populations on the spawning grounds; and the output parameters from the fishery assessment model 'WhitEst'.

8.1. Commercial catch, effort and CPUE

The most complete and informative data for the status of the King George whiting stocks are the regional estimates of catch and effort from the commercial sector, and the calculated estimates of CPUE. In this report, we presented data for the calendar years of 1984 to 2004, thus providing an additional two years of data subsequent to the downturn period of 1999-2002.

The dominant long-term trend in this 20-year dataset is a steady substantial decline in commercial fishing effort. This has been driven by an on-going reduction in the number of marine scalefish commercial fishers, particularly since 1994 when the licence amalgamation scheme was introduced. Furthermore, commercial fishers have shown a shift away from targeting King George whiting to other fish species. Thus, the reduction in number of licence holders, which has resulted in less fishing days, in association with the remaining fishers diversifying their fishing practises, has meant that there has been a general reduction in the commercial catch of King George whiting over the 20 years or so. Prior to 1999, these reductions in commercial catch and effort were generally associated with estimates of rising CPUE, thus providing no real cause for concern about the status of the fishery at that time. It was the decreases in CPUE that occurred between 1999 and 2002 that raised concern (McGarvey et al. 2003).

Although the commercial catch of King George whiting dropped to its lowest ever recorded level in 2004 of 346 tonnes, nevertheless the estimates of State-wide CPUE increased marginally in 2003 and 2004. Thus, the declining trend evident through the period of 1999-2002 has turned around marginally. This turn-around is evident across a broad geographic area that encompasses several of the fishery regions including: the Mid-West Coast; Coffin Bay; both Southern and Northern Spencer Gulf; and Kangaroo Island. On the Far West Coast the estimated CPUE was relatively stable through the three-year period of 2002 to 2004. Only in Gulf St. Vincent was there some ambiguity from the recent estimates of CPUE of the different gear types.

CPUE from the commercial fishery is thought to be a particularly significant indicator of the status of the King George whiting fishery, because the fisheries in several regions, particularly the northern gulfs and west coast bays are largely based on a single year class of three-year old fish (Fowler et al. 2000). Therefore, these estimates of CPUE effectively constitute measures of year-class strength. Thus, a consistent decline in CPUE across several years in such a fishery could be indicative of declining recruitment, i.e. a possible indication of ‘recruitment overfishing’. The concern expressed in the previous report (McGarvey et al. 2003), was that the declining trends in CPUE through the period of 1999 to 2002 may have been the result of recruitment overfishing. Fortunately, the marginal increases in CPUE in 2003 and 2004 indicate that the declining trend has been arrested, at least temporarily. Furthermore, the management changes that were implemented in late 2004 should provide an enhanced opportunity for the stock to recover, and thus provide greater confidence that the threat of recruitment overfishing has been alleviated at this time.

8.2. Age and size composition at the spawning grounds

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 small, young fish, others support a broader age and size range of individuals. These latter populations that are supplemented by movement of small, young adults from the inshore areas (Fowler et al. 2002), form the spawning aggregations during the reproductive season (Fowler et al. 1999). We consider that the size and age structures of the populations on the spawning grounds provide a significant indicator of stock status. This is because overfishing in other fisheries has been manifested as a contraction in size and age structures, as the larger, older individuals are removed from the population by fishing.

The broad-scale sampling for King George whiting that was done through the 1990s provided base-line population size and age structures for places such as Hardwicke Bay in Spencer Gulf, along the north coast of Kangaroo Island in Investigator Strait and Tapley Shoal in southern Gulf St. Vincent (Fowler et al. 2000a, Fowler and McGarvey 2000). At that time, there already existed considerable differences in population structure between these places. Whilst the population at Tapley Shoal was dominated by 3-5 year olds, that at Hardwicke Bay included older fish to approximately 11 years of age, whilst the population in Investigator Strait involved fish that were up to 20 years of age (Fowler et al. 2000a, Fowler and McGarvey 2000). These differences may be natural or may reflect historical fishery influences. Nevertheless, here we are interested in any changes in population structure at each place that may have occurred since the 1990s that could represent an effect of fishing pressure.

It has not been possible to sample these three places in each year since the 1990s. Nevertheless, based on the sampling that has been done, there is no evidence of a change in population structure at any of the three places over the decade or so since sampling commenced. Thus, over this period there is no demonstrable reduction in the spawning stocks. This was the only biological performance indicator that did not cause concern in the previous assessment (McGarvey et al. 2003). It may be the case that population size and age structures are conservative relative to other indicators. As such, it may take several years for them to manifest any effects from the downturn through the period of 1999 to 2002.

8.3 Fishery stock assessment model 'WhitEst'

The negative trends that were evident in the estimates of recruitment and biomass from the WhitEst model that were reported in the last stock assessment report (McGarvey et al. 2003) are no longer apparent. Model-estimated recruitment for each model region, i.e. West Coast, Spencer Gulf and Gulf St. Vincent, increased marginally in 2003 and 2004. In Spencer Gulf this has ended a long period of declining recruitment, whilst for the West Coast the recruitment estimates have stabilised after several years of particularly high variability. For Gulf St. Vincent recruitment is estimated to have increased very marginally on an annual basis since 2000.

The estimated biomass in Spencer Gulf was high in the late 1990s but then decreased from 1999 to 2003. The model indicated that this situation turned around marginally in 2004. The model-estimated biomass for the West Coast was quite variable but nevertheless decreasing through the period of 1997 to 2002. It increased marginally in 2003 and was similar in 2004. The estimated biomass in Gulf St. Vincent has also increased marginally since 2002.

8.4 Biological Performance Indicators and Limit Reference Points

A number of the biological performance indicators that were discussed above were assessed against specific limit reference points that are provided in the Marine Scalefish Fishery Management Plan (PIRSA 2005). A summary of the results of these comparisons is provided in Table 8.1. Whilst the majority of indicators did not exceed the limit reference points, several did. In both 2003 and 2004, total State-wide catch was more than 20% less than the average catch of the previous five years. This highlights the extent to which commercial catch has declined in recent years relative to the catches of the late 1990s. It is now evident that this decrease is a reflection of decreasing fishing effort, as well as lower catch rates. The ratio of non-targeted to targeted fishing effort also varied considerably in 2003 and 2004 with respect to the level of each respective preceding year. The significance of this is difficult to interpret but may reflect the tendency of commercial fishers to target different fish species depending on their relative availability.

The most concerning of the limit reference points that were breached was exploitation rate in each of Spencer Gulf and Gulf St. Vincent in both 2003 and 2004. In both regions, the model-estimated rates of exploitation exceeded the international standard of 28% (Caddy 1998). This

breach was recognised in the management discussions that took place through 2004, and as such was taken into consideration during the discussions to develop the new fishery management regime that was introduced in 2004. These new management arrangements were designed to decrease the exploitation rates and to increase the rates of egg production in these two regions.

Table 8.1 Summary of the results of the comparisons between biological performance indicators and limit reference points indicated in the Marine Scalefish Fishery Management Plan (PIRSA 2005).

Biological Performance Indicator	Limit Reference Point	Year	Region	Limit exceeded?	Comments
Total commercial catch	% variation from previous year	2003 2004	State	No No	
	% variation from 5 yr average	2003 2004	State	Yes Yes	
Total commercial effort	%variation from 5 yr average	2003 2004	State	No No	
	Non-targeted : targeted effort %variation from previous year	2003 2004	State	Yes Yes	
CPUE	% variation from 5 yr average	2003 2004	State	No No	
Total catch = (commercial + recreational)	% variation from previous year	2003 2004	State	n.a. n.a.	No new estimate of rec catch No new estimate of rec catch
Fishable biomass	% variation from 5 yr average	2003 2004	State	No No	
Recruitment	% variation from 5 yr average	2003 2004	State	No No	
Exploitation rate	% variation from international standard	2003	WC SG GSV	No Yes Yes	
		2004	WC SG GSV	No Yes Yes	
Age structures	Significant change over Previous 5 yrs	2003	SG GSV/KI	No No	
		2004	SG GSV/KI	No No	

8.5. Uncertainty with the stock assessment

The strongest evidence for the turn-around in the status of the King George whiting fishery comes from the estimates of CPUE for 2003 and 2004 from the commercial sector. On the

basis of these, the 'WhitEst' model has indicated both an improvement in the recruitment to and the biomass of the stock. These positive assessments of the fishery are based on data from only one fishery sector because there is no time-series of information on catches from the recreational sector. This is despite the fact that the recreational sector now accounts for the higher proportion of the catch of King George whiting. This lack of data was accommodated in the 'WhitEst' fishery model by assuming that the annual catch and effort of the recreational sector tracked human population change in South Australia, extrapolating forward and backward from the single set of regional estimates from the NRIF survey (Henry and Lyle 2003). It is unlikely that this really provides a satisfactory time-series of recreational catch, 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 more powerful boats and better electronic equipment.

Two hypotheses were presented in the previous stock assessment report to account for the downturn in the fishery that occurred through 1999 to 2002 (McGarvey et al. 2003). These were recruitment overfishing and a negative environmental effect on recruitment. It is not possible to discriminate between these hypotheses in the absence of real data on recreational catch. Although these two hypotheses were based on the decreasing catches and catch rates by the commercial sector, there is no way of knowing whether the recreational catch also decreased over the same period. In fact, if recreational catch actually increased over that period at a rate higher than the rate of decrease in commercial catch, then total catch would have also increased. This is possible since the recreational sector now accounts for the higher proportion of total catch. As such, the lack of data on recreational catch results in considerable uncertainty regarding the real trend in total catch, and thus uncertainty about the status of the stocks of this species.

8.6. Management considerations

It has been pointed out in previous stock assessment reports that the appropriate management strategy for the King George whiting fishery must be based on understanding the life history of the species (Fowler and McGarvey 1997; Fowler 1998; Fowler and McGarvey 1999; McGarvey *et al.* 2000; McGarvey *et al.* 2003). The life history depends on spawning that occurs at specific locations such as in South-east Spencer Gulf and Investigator Strait (Fowler *et al*. 1999). These spawning populations are sustained by annual immigration of relatively young adults from the inshore nursery areas of the two gulfs. Such inshore fish are heavily targeted by both sectors of the fishery as the fish move throughout the gulfs and west coast bays. Thus, from a management perspective, it is fundamental to ensure that sufficient fish

make it through this fishing gauntlet to replenish populations at the spawning grounds. Furthermore, once fish join these populations they must not be overfished, particularly when they are aggregated for spawning. The improvements to boating technology and increasing fishing pressure, including the flourishing charter boat fishery, have potentially increased the vulnerability of the two geographically-separated stages of the life history.

To reduce the risk of recruitment overfishing, the Marine Scalefish Fishery Management Committee recommended a series of measures to increase both stock biomass and egg production, and to lower exploitation rate. In response, the new, more stringent management regulations, which were implemented in October 2004, raised the minimum legal size, reduced recreational bag and boat limits, and sought to accelerate the rate of commercial license amalgamation. While it is too early to gauge the success of these measures, the simulations with the 'WhitSim' simulation model suggest that they should have a strong effect. The outcomes of these simulations were strongly dependent on the increase in legal minimum size. The possible problem with this management strategy is that many undersize fish will be caught and released. If release mortality is high, then the conservation benefit will be low. Anecdotal reports suggest that King George whiting are quite robust to capture and release, compared to other species such as garfish and snapper. If this is true then egg production should rise in future years. Alternatively, if release mortality rates are higher than is thought then the benefits of the increase in minimum legal length will be limited.

8.7. Future work

Through the year of 2004/05 data on population size and age structure were collected across the geographic range of the fishery in South Australia. These data will provide a single year up-date to the previous data on population structure that were collected through the period of 1995-97. These new data were collected using a systematic sampling regime where most spatial cells identified in the WhitEst model were sampled in each month. These data will be incorporated in future runs of this model.

The WhitEst model is sensitive to estimates of the rates of movement of fish through the gulfs from the northern regions to the spawning grounds. The tag-recapture data that were used in the model to describe movement were collected between the 1960s and the early 1980s, mostly before the current commercial catch and effort data set was initiated. Since data on fishing effort was not collected through this period, the value of the tag-recapture data for understanding fish movement is limited. Thus, there is a need for a new tagging program to

provide better estimates of the rates of movement of fish among the South Australian Marine Fishing Areas.

We argued above that the most crucial lack of critical information for effective stock assessment of South Australian King George whiting is an annual time series of recreational catch and effort. Such data are necessary to identify the trend in total catch. A second national recreational fishing survey is currently planned for 2006-07, to be partly funded by the Fishery Research and Development Corporation. It is expected that this survey would be largely compatible with the NRIF survey (Henry and Lyle 2003), and would thus provide comparable data to that collected in 2000-01. This would make a significant contribution to determining the trend in recreational catch and effort in this State, and thus contribute to understanding the trend for total catch.

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10. ACKNOWLEDGEMENTS

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11. APPENDIX A: RECENT MODIFICATIONS TO THE WHITEST MODEL

The following is a list of major improvements to the WhitEst Model since the last stock assessment report (McGarvey et al. 2003). (1) Migration has been 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 almost certainly a more realistic model description since southward movement is known to occur over these 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.

12. APPENDIX B: 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, and to commercial catch samples calculated as proportions of King George whiting landed by yearly ages, in each month when sampling occurs. Examples of data and the model fits, for Spencer Gulf, are shown in Figs. 12.1-12.3e below.

Monthly catch by weight and model time series are in Fig. 12.1. The new sample data, used only for the sensitivity test model run (Fig. 6.5), are shown in Figs. 12.2a-12.2c. Fits to earlier age samples, from the model baseline run (Figs. 6.2-6.4), are in Figs. 12.3a-12.3e.

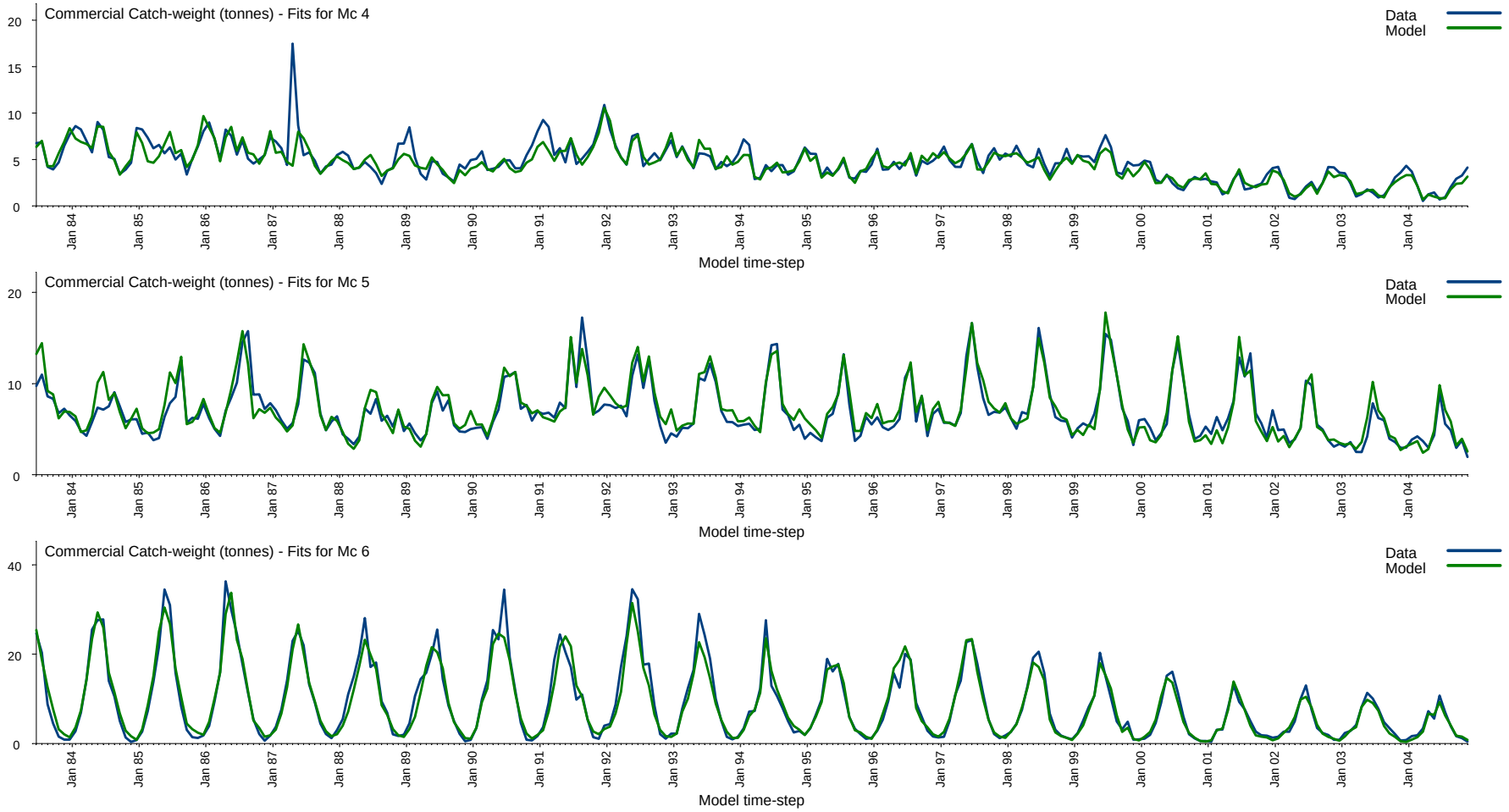

Fig. 12.1. Model and data monthly catch total by weight. Data is total commercial catch (by all gears and target types) reported in monthly logbooks. Model outputs show model fitted values of commercial catch total are from the baseline WhitEst run. The three Spencer Gulf spatial cells Mc 4, Mc 5 and Mc 6 are shown in Fig 61.

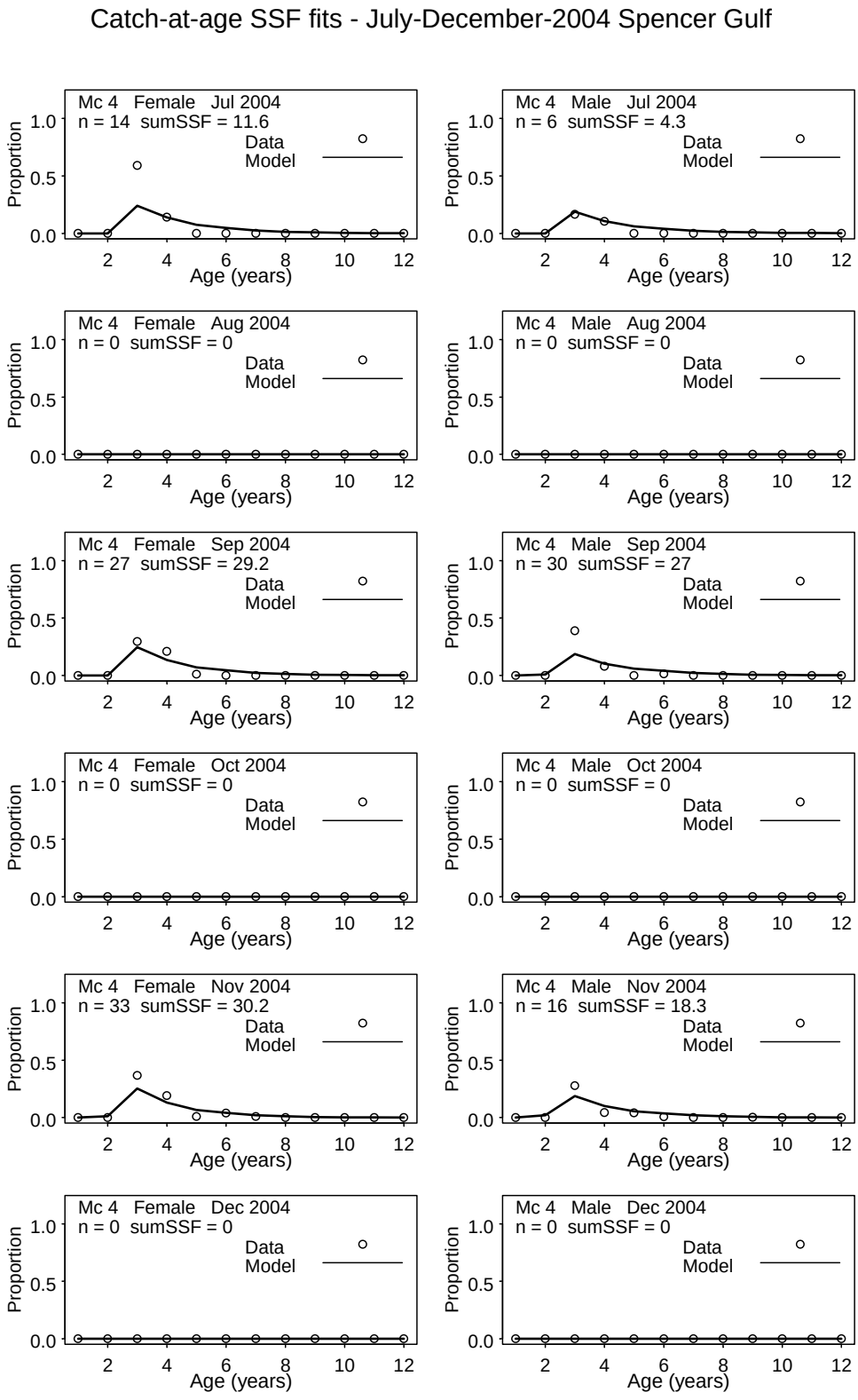

Fig. 12.2a. Spencer Gulf catch proportions at age. WhitEst model-predicted values from the sensitivity-test WhitEst run are shown as a solid line. Data proportions at age in sampled catches are shown as open circles.

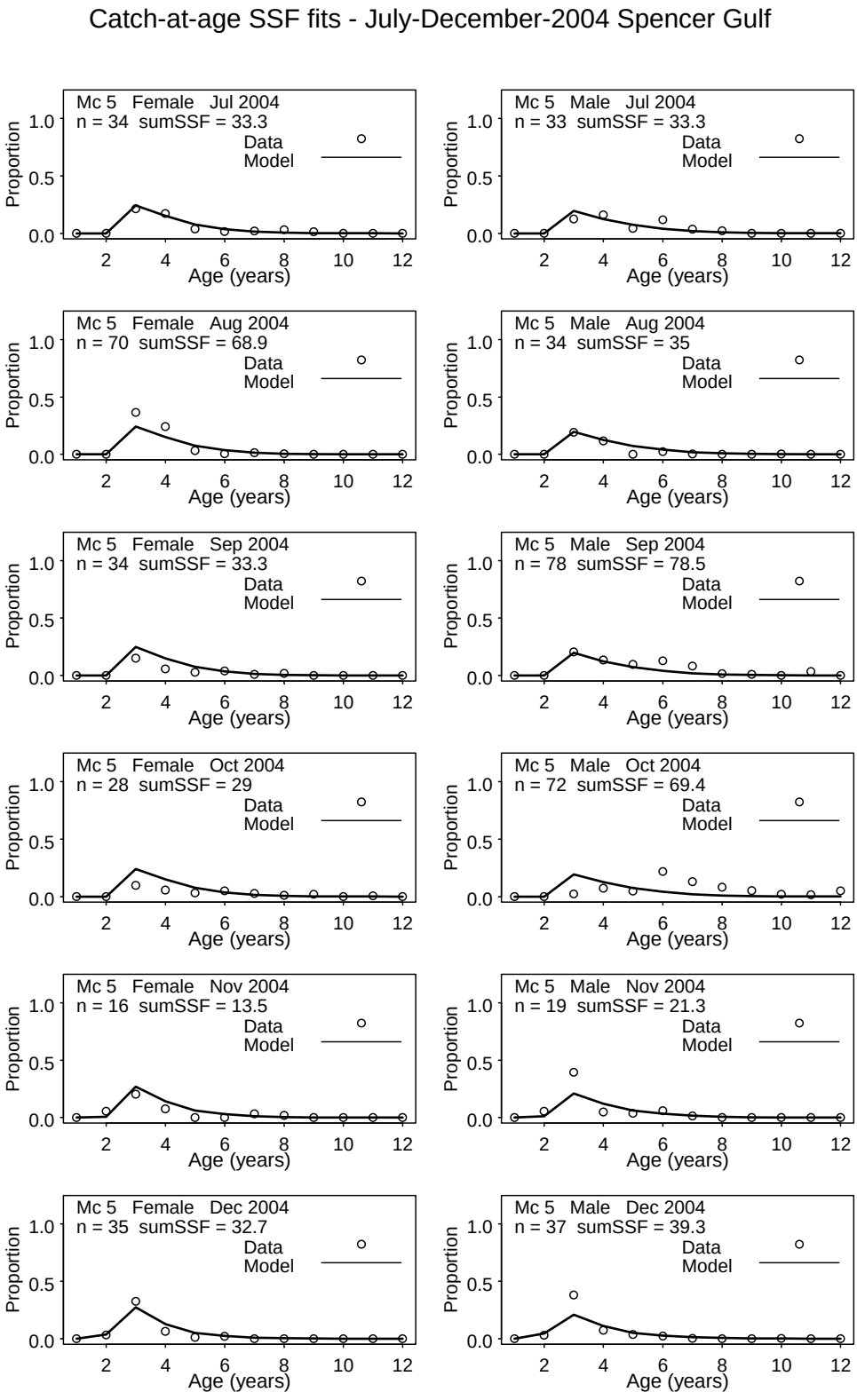

Fig. 12.2b. Spencer Gulf catch proportions at age. WhitEst model-predicted values from the sensitivity-test WhitEst run are shown as a solid line. Data proportions at age in sampled catches are shown as open circles.

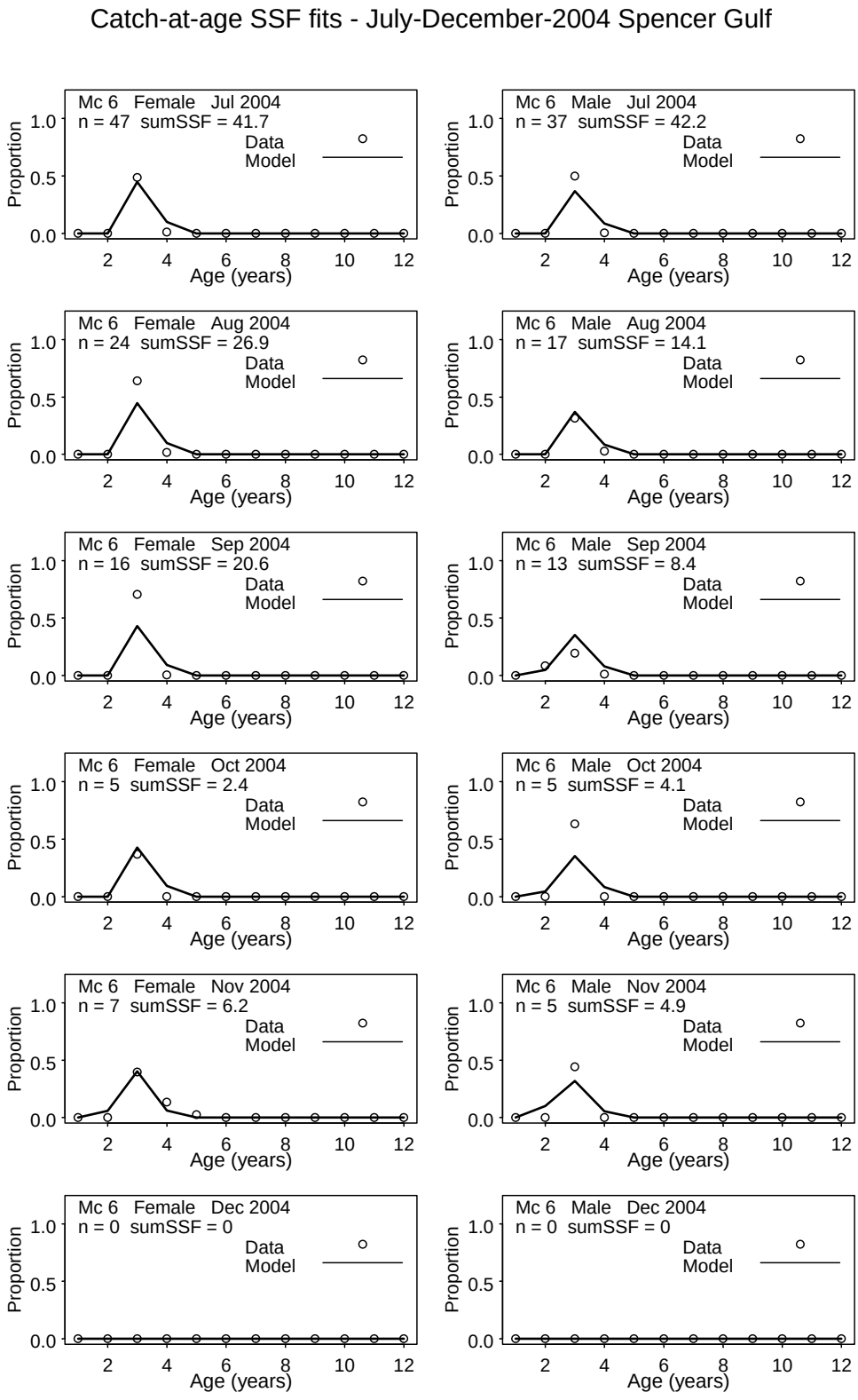

Fig. 12.2c. Spencer Gulf catch proportions at age. WhitEst model-predicted values from the sensitivity-test WhitEst run are shown as a solid line. Data proportions at age in sampled catches are shown as open circles.

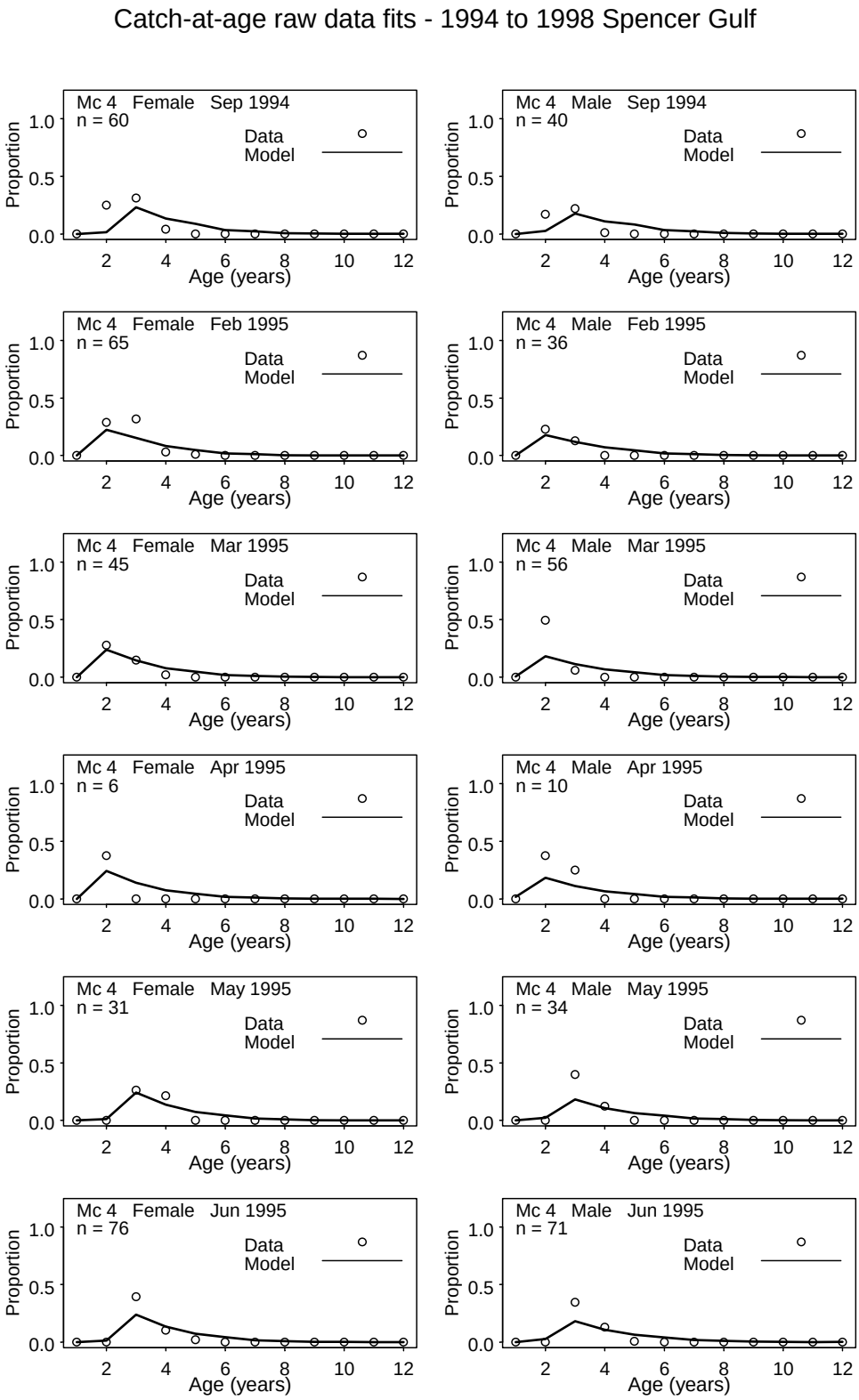

Fig. 12.3a. Spencer Gulf catch proportions at age. WhitEst model-predicted values for the baseline WhitEst run are shown as a solid line. Data proportions at age in sampled catches are shown as open circles.

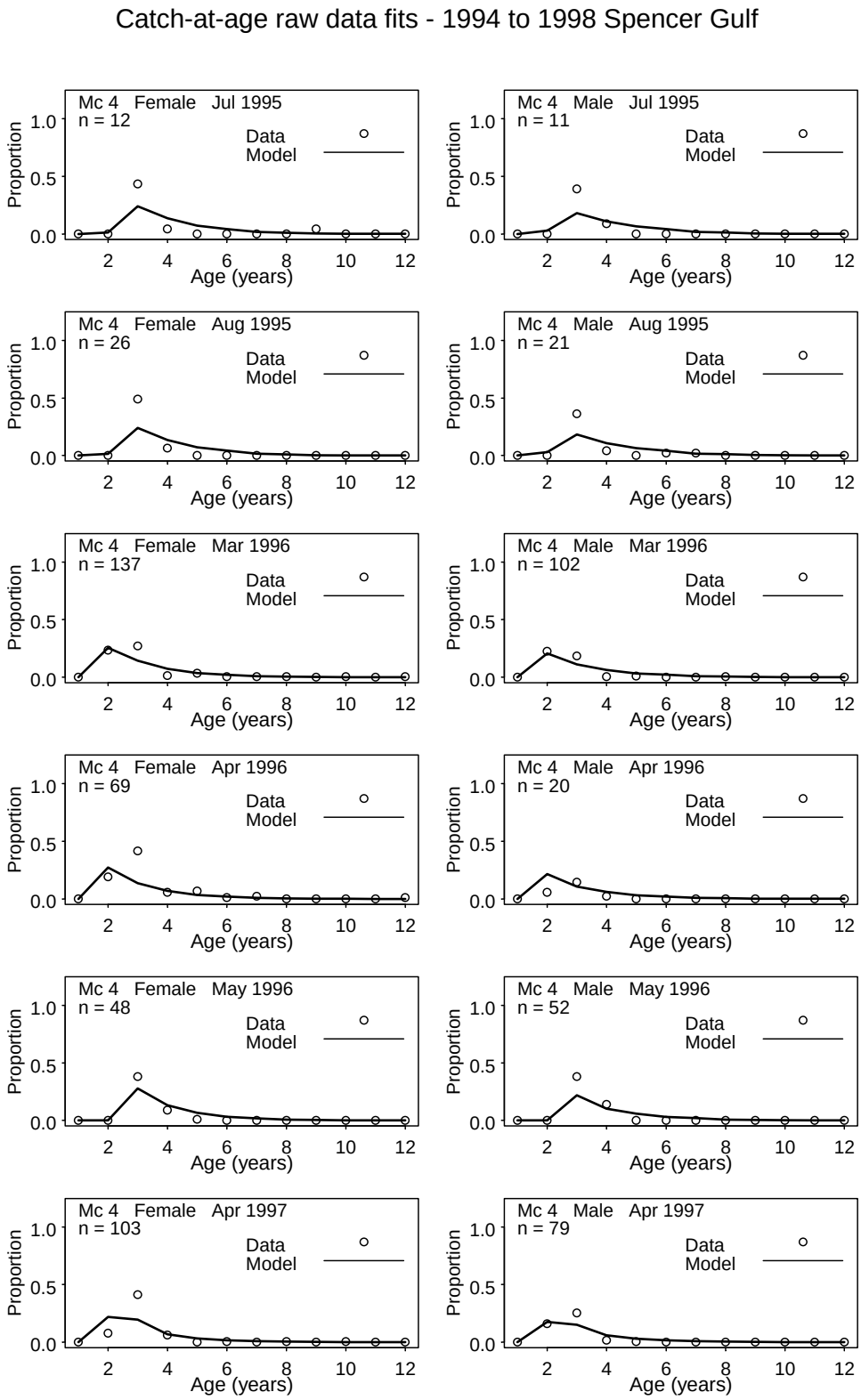

Fig. 12.3b. Spencer Gulf catch proportions at age. WhitEst model-predicted values for the baseline WhitEst run are shown as a solid line. Data proportions at age in sampled catches are shown as open circles.

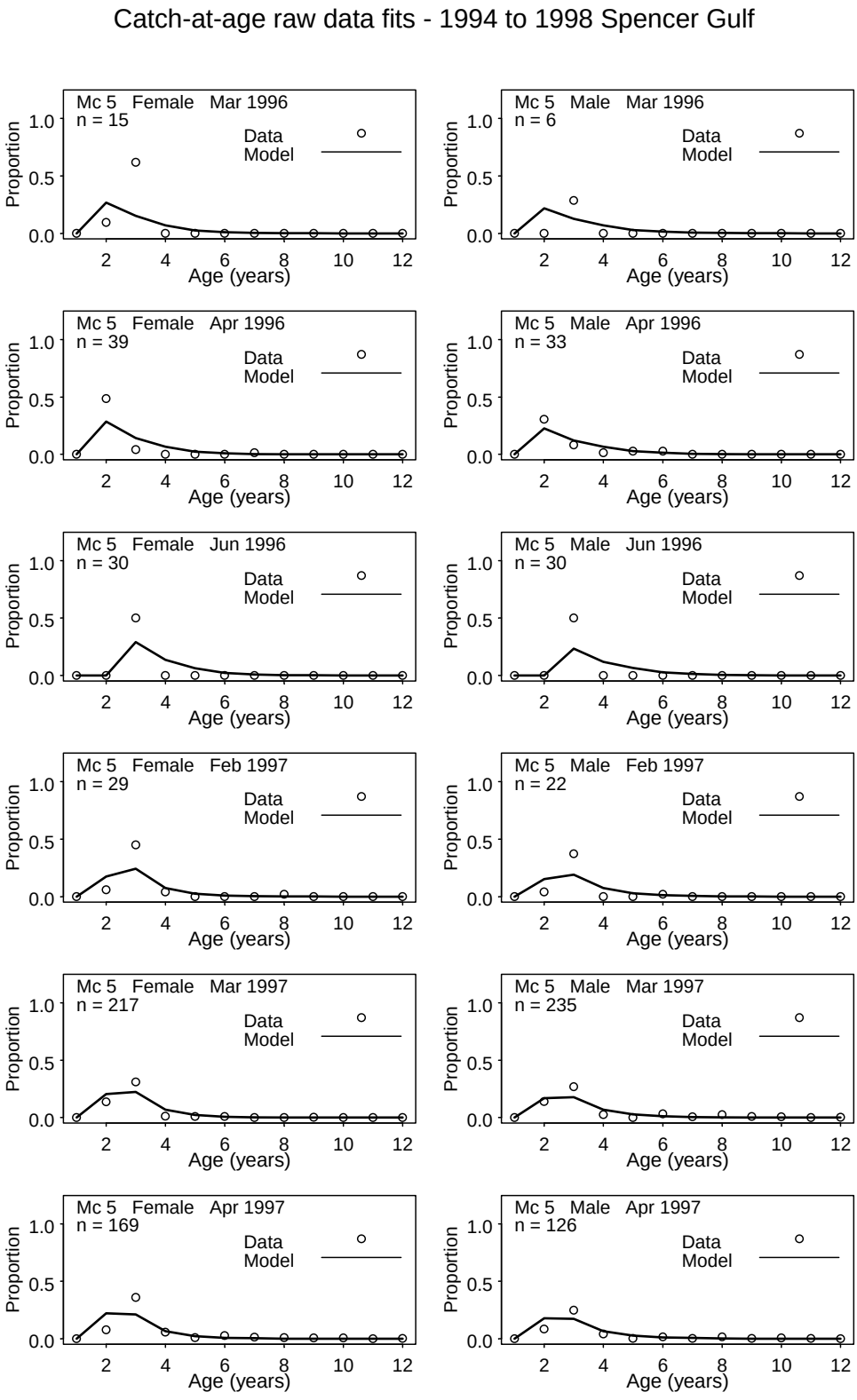

Fig. 12.3c. Spencer Gulf catch proportions at age. WhitEst model-predicted values for the baseline WhitEst run are shown as a solid line. Data proportions at age in sampled catches are shown as open circles.

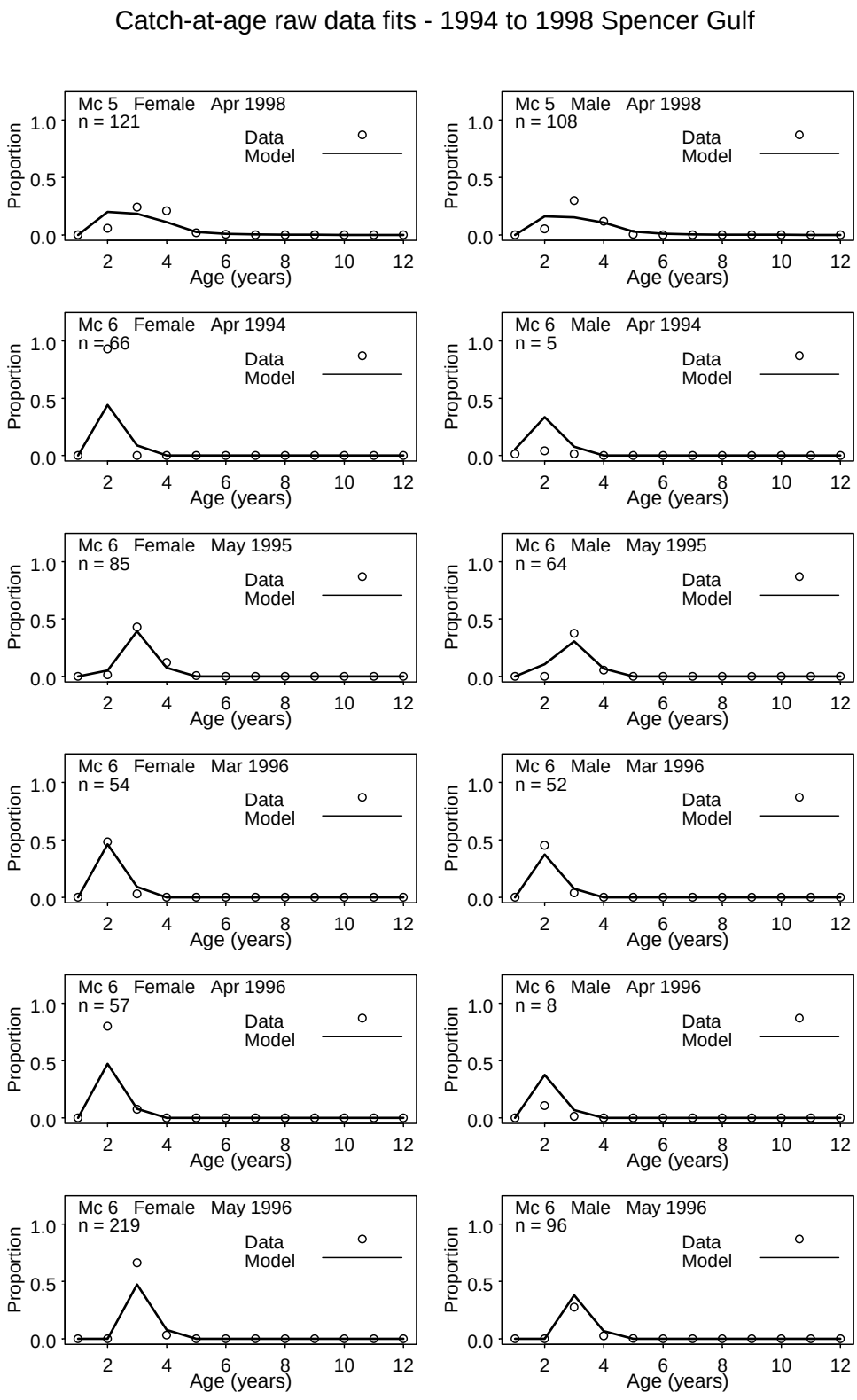

Fig. 12.3d. Spencer Gulf catch proportions at age. WhitEst model-predicted values for the baseline WhitEst run are shown as a solid line. Data proportions at age in sampled catches are shown as open circles.

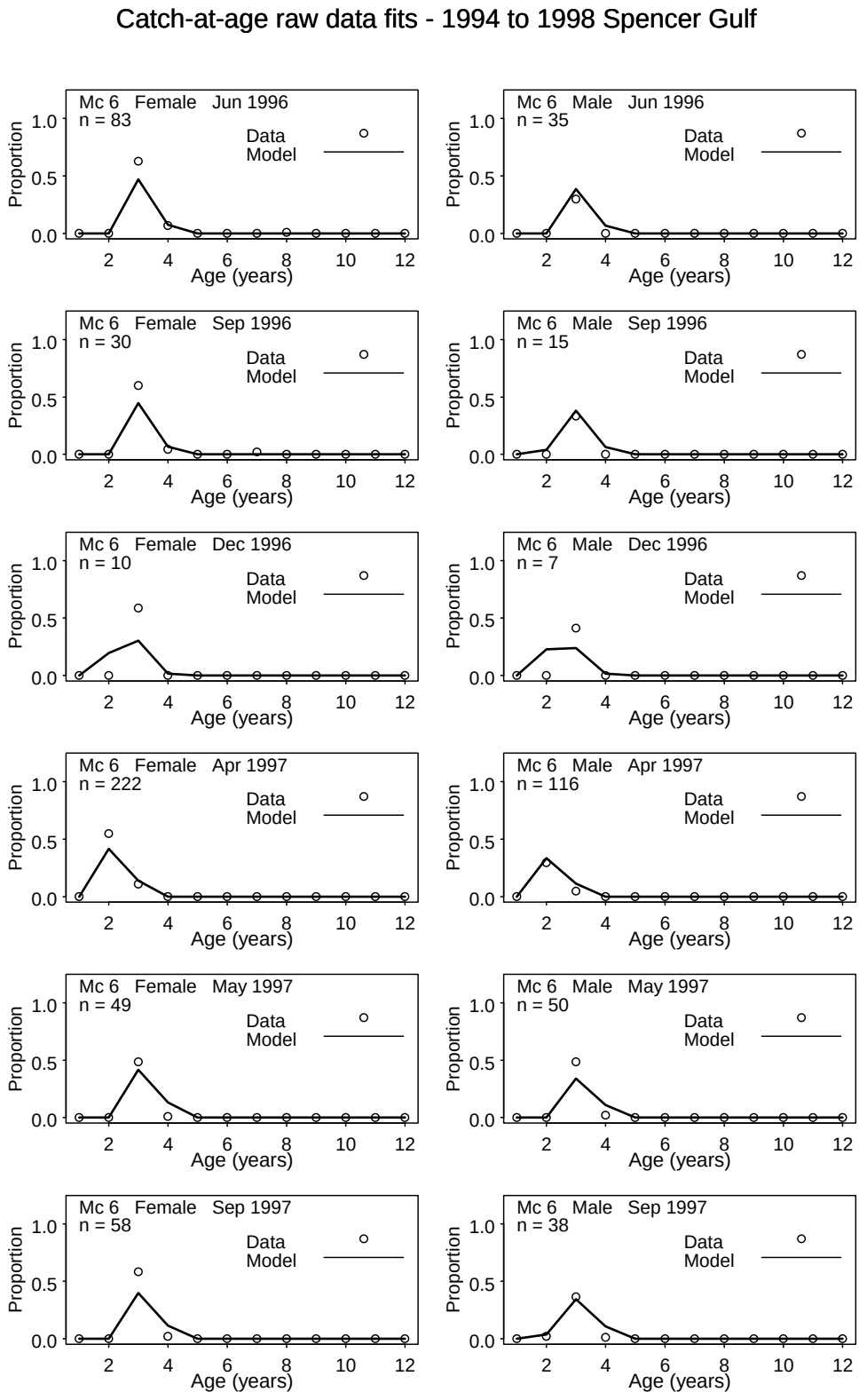

Fig. 12.3e. Spencer Gulf catch proportions at age. WhitEst model-predicted values for the baseline WhitEst run are shown as a solid line. Data proportions at age in sampled catches are shown as open circles.