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Victorian King George Whiting Bay and Inlet Stock Assessment 2010

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Victorian King George Whiting Bay and Inlet Stock Assessment 2010

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Executive Summary

Trends in the fisheries
Fluctuations in commercial catch rate data available up until June 2009 for Port Phillip Bay, Corner Inlet and Western Port (until the closure of commercial netting in December 2007) suggests variable recruitment of King George whiting to these fisheries.

Commercial catch rates of King George whiting show an eight to ten year cyclic trend, with peaks observed in 1989/90, 1997/98 and 2007/08. The next peak season for King George whiting is expected to occur between 2015/16 and 2017/18.

Commercial catch rates have exhibited a long-term increasing trend from a low of 2.5 kg/day taken in 1984/85 to 23 kg/day taken in 2007/08 (all Victorian waters, all gear types combined).

Variable recruitment to Victorian bays and inlets is influenced by the survival of the larval stages of King George whiting; survival is influenced by variation in the oceanic environment which has implications for the short-term dynamics of King George whiting fisheries.

Between 1998/99 and 2008/09, total commercial fishing effort targeting King George whiting has declined. This decline coincides with a reduction in the number of licensed fishers in Victorian waters by a third between 1986/87 and 2008/09.

Commercial netting was closed in Western Port in December 2007 in accordance with a Government policy decision to create a recreational fishing haven. There was a marked increase in the use of Western Port by recreational fishers between 2000/01 and 2006/07.

It is estimated that ~155 tonnes of King George whiting are harvested from Victorian waters by recreational fishers annually.

A peak in recreational catch rates of King George whiting in Port Phillip Bay was observed in 2007/08 (4.1 fish/angler hour). This peak was also observed in commercial haul seine and mesh net catches in Port Phillip Bay. A peak in recreational catch rates of King George whiting in Western Port was observed in 2008/09 (2.9 fish/angler hour).

The abundance of post-larval King George whiting from 2006 to 2009 has been relatively low. This suggests that fishery catches are likely to remain consistently average for at least the next year or two.

Research and assessment needs include:
- Determine where the spawning areas are that supply Victoria’s whiting fishery. The spawning location of Victorian whiting stocks has implications for the short-term dynamics of King George whiting fisheries. It is not known whether Victorian King George whiting are coming from South Australian spawning stocks, and what the contribution of Victorian fish is to these spawning stocks
- Estimate the post-release mortality of King George whiting
- Investigate the potential effects of climate change on whiting spawning and the delivery of larvae to Victorian bays and inlets
- Investigate the relationship between climatic/environmental variables and variation in commercial and recreational catch rates. For example, explore if, and how, changes in seagrass abundance affect King George whiting production.
- Investigate patterns of movement of immature whiting between Victorian bays and inlets and whether juvenile migration is the source of recruitment to Corner Inlet
- Determine the impact of fishing in Victorian bay, inlet and coastal waters on the sustainability of adult populations.
- Develop a method to validate the size and age composition taken by recreational research anglers. This would allow for comparisons to be made between research angler indicators and fishery independent pre-recruit and commercial fishery indicators
- Assess the selectivity of haul seine and mesh nets for King George whiting
- Develop appropriate performance measures and reference points to track the status of the whiting fishery. Also identify
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- Evaluate the potential for adapting the stock assessment model developed for King George whiting in South Australia to the Victorian fishery
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Introduction

A formal assessment of King George whiting stocks in Victoria was conducted at the Department of Primary Industries in Queenscliff, Victoria in April 2010.

The workshop was attended by commercial and recreational fishing sector representatives, Fisheries Victoria fishery managers, fisheries scientists, and experienced anglers.

Management

Fisheries Victoria, a Division of the Department of Primary Industries, is responsible for managing fisheries and fish resources under the provisions of the Fisheries Act 1995 and the Fisheries Regulations 2009.

National guidelines for ecologically sustainable development (ESD) of fisheries are used to identify environmental, biological, economic, social and governance dimensions for individual fisheries.

These ESD principles underpin the three key strategic goals of Fisheries Victoria:
- ‘Securing’ fisheries resources
- ‘Sharing’ fisheries resources
- ‘Growing’ or developing the value of the resource for the benefit of the community.

Management goals

In accordance with ESD principles and in a manner that is sustainable and which provides optimum social and economic benefits to all Victorians, the overarching goal of fisheries management is:
- To manage King George whiting stocks in Victoria and the fisheries they support
- To identify and promote protection of important fish habitats that supports the production of King George whiting.

Management objectives

- **Social**: To maintain and where possible enhance recreational fishing opportunities
- **Biological**: To conserve and ensure sustainable use of key fish stocks
- **Environmental**: To promote protection of the habitats and environments which are essential for production or maintenance of key fish stocks
- **Governance**: To achieve maximum community participation, understanding and support for the management of fishing in Victorian waters.

Stock assessments

Stock assessments are designed primarily to provide information on the status of fish stocks in Victoria’s bays and inlets to help address the biological sustainability and governance objectives.

Fish habitat protection and recreational fishing enhancement objectives require different types of information (e.g. ecological, environmental, economic and social data) and will be addressed in different processes.

Fisheries Victoria has developed a process to conduct periodic formal assessments of the status of key marine and estuarine finfish stocks and the fisheries they support. This process involves:
- The synthesis of all relevant fisheries data
- Evaluation of fisheries-independent monitoring and research data, where available
- Convening of a workshop involving scientists, resource users and resource managers to assess the status of the stock/fishery in question
- Production of an assessment report which provides scientific information and advice to facilitate fishery management decision making.

The assessment process:
- Provides unbiased scientific evidence of the status of the fish stocks and the environmental factors and harvest pressures that influence stock abundance
- Underpins evidence-based decisions in an ESD management context
- Complements Victorian fisheries management planning processes
- Improves stakeholder understanding and acceptance of assessment outcomes
- Ensures the fishery assessment process is accountable and transparent.
Current objectives
This report provides a review of the status of King George whiting stocks in Victorian waters in 2010.

It also includes a record of previously unpublished findings of a King George whiting workshop conducted in June 2006.
Stock structure, biology and life-history

Distribution
King George whiting, *Sillaginodes punctatus* occurs along the southern coastline of mainland Australia and the north coast of Tasmania (Kailola *et al.* 1993). The species supports an important commercial and recreational fishery. Unlike most fisheries, the King George whiting fishery in Victoria is primarily based in bays and inlets on sub-adult fish of two to four years of age (Jenkins 2005).

Biology
Life-span
King George whiting have an estimated longevity of 15 years and reach sexual maturity at 3 to 5 years at a size of 30 to 35 cm (Scott 1954; Jones *et al.* 1990; Potter *et al.* 1996; Fowler and McGarvey 2000; Jenkins 2005).

Spawning
South Australia
King George whiting spawning in South Australian waters has been observed occurring when seawater temperatures are between 17°C and 19°C (Fowler *et al.* 1999). King George whiting are multiple batch spawners that spawn at least 20 times during the spawning season (Fowler *et al.* 1999; Fowler and McGarvey 2000).

In South Australian waters, individuals have been estimated to produce as many as 40,000 to 60,000 eggs per spawning event (Fowler *et al.* 1999), with an estimated annual fecundity ranging from 112,000 to 6,000,000 eggs (Scott 1954; Fowler and McGarvey 2000).

In South Australia, spawning is known to occur near coastal reefs in autumn/early winter (Fowler *et al.* 2000).

Victoria
King George whiting in spawning condition have rarely been recorded in Victorian waters (Hamer and Jenkins 2004). Of 1600 fish frames collected from Victorian waters, only one was confirmed as a fish in spawning condition (taken off Flinders, was a size of 60 cm TL, 1.8 kg, and 11 years of age), though some of the fish taken were showing signs of early reproductive development (Hamer and Jenkins 2004).

The age and size of King George whiting have been shown to increase in a westerly direction along the Victorian coastline (Hamer and Jenkins 2004). Coupled with the absence of spawning activity in Victorian waters, this suggests that the species gradually migrates to the west towards South Australian waters to spawn (Hamer and Jenkins 2004). However, the spawning sources that supply larval stages to Victoria’s bay and inlet fisheries are yet to be confirmed by definitive techniques.

Spawning grounds
The only known significant spawning areas for the species are in South Australian waters (Fowler *et al.* 2000).

Larval dispersal
Spawning in coastal waters is followed by a protracted larval phase of three to five months (Jenkins and May 1994; Fowler and Short 1996; Jenkins *et al.* 2000; Jenkins and King 2006).

King George whiting eggs are buoyant and hatch after a few days at a size of 2 to 3 mm (Bruce 1995). In laboratory experiments, six days after hatching at 19°C, larvae (3.5 mm in length) absorb the yolk sac and their mouth and eyes open (Partridge 2001).

The length of time King George whiting larvae spend in the water column has been shown to increase from west to east for post-larvae entering Port Phillip Bay, Western Port and Corner Inlet (Jenkins *et al.* 2000), suggesting that larvae are derived from a similar spawning location to the west of central Victorian bays and inlets.

Post larvae, juvenile and adult
Post-larvae enter Victorian bays and inlets in spring (Jenkins and May 1994; Jenkins *et al.* 2000). Post-larvae at this stage are approximately 16 to 20 mm in length (Jenkins and May 1994; Jenkins *et al.* 2000) and settle in shallow seagrass and algal habitats (Jenkins *et al.* 1997b; Jenkins and Wheatley 1998).

As King George whiting approach maturity at 3 to 5 years of age they permanently leave the bays and inlets and take up residence in open coastal waters (Jenkins 2005).
Critical Habitats

Seagrass appears crucial to newly settled larvae through protection from predators (Hindell et al. 2000) and the provision of food (Jenkins and Hamer 2001). Young juvenile King George whiting feed on crustaceans, and larger benthic organisms (including polychaete worms) dominate the diet of older fish.

From five to six months old, most fish are found on sand amongst vegetated habitats (Jenkins and Wheatley 1998). In Port Phillip Bay, seagrass in the southern and western areas of the bay have been identified as critical habitat for King George whiting (Morris and Ball 2006). Shallow bare areas on fine sediment in the northern part of the bay as well as reef areas along the north eastern shores of the bay have also been identified as critical habitat for this species (Morris and Ball 2006).

Influence of predicted climate change on King George whiting

A significant relationship has previously been found between the abundance of post-larvae in Port Phillip Bay and the strength of zonal westerly winds in south-eastern Australia (Jenkins 2005). The winter circulation along the Victorian coastline is also characterised by a west to east coastal current (Cirano and Middleton 2004). Environmental variables and hydrodynamics are important in larval advection and subsequent recruitment into bays and inlets of central Victoria, given the long duration of the larval stage in this species (Jenkins and May 1994; Jenkins et al. 2000; Jenkins 2005; Jenkins and King 2006).

The zonal westerly wind index has shown a long-term downward trend since about 1970, suggesting that the strength of the westerly wind flow over Victoria has decreased over the past 40 years; it is possible that this could negatively influence the long-term catch of King George whiting (G. Jenkins pers. comm.). The decline in zonal westerly winds is consistent with the prediction that westerly winds will weaken in southern Australia under climate change due to a southward migration of the high-latitude westerly wind belt south of Australia (Cai et al. 2005).

Reverse modelling based on larval distributions suggests that most post-larvae that enter Port Phillip Bay, Western Port and Corner Inlet are derived from a spawning area along the west coast of Victoria (Jenkins et al. 2000), but there is evidence for slight deviations for each bay and inlet (Jenkins et al. 2000). Port Phillip Bay recruits are predicted to be derived from spawning in western Victoria and south-eastern South Australia with a very low level of spawning predicted from the western boundary of Bass Strait (south of Cape Otway in Victoria) (Jenkins et al. 2000). Post-larvae that enter Western Port show a similar pattern to Port Phillip Bay recruits, although there is a greater level of spawning predicted to occur along the western boundary of Bass Strait (Jenkins et al. 2000). The simulation for Corner Inlet recruits gives a markedly different pattern, with predicted spawning not extending as far west along the coast, but showing high levels along the western boundary of Bass Strait and low levels in central and eastern Bass Strait (Jenkins et al. 2000). It has been suggested that the Corner Inlet fishery may be replenished from a different spawning source than Port Phillip Bay and Western Port (Jenkins et al. 2000; Jenkins 2005).

Uncertainties

The link between spawning in South Australia and recruitment to fisheries in Victorian bays still requires confirmation by more definitive methods. The spawning source responsible for recruitment into the Corner Inlet fishery also remains unclear, and while small post-larvae occur commonly in both Port Phillip Bay and Western Port, they are apparently rare in Corner Inlet. This may suggest that recruitment of older juveniles to the Corner Inlet fishery may be derived from immigration of fish from other bay/inlet nursery areas or even coastal waters.

It is unclear whether juvenile and sub-adult King George whiting move between bay fisheries before taking up residence in ocean waters as adults.

Uncertainties over spawning sources that supply the Victorian bay and inlet fisheries are a major impediment to ensuring that key adult spawning aggregations in coastal waters, potentially outside of the Victorian State waters, are afforded adequate protection from fishing. Understanding the level of movement between bays is important for predicting how recruitment fluctuations, fishing and environmental impacts in one bay might influence the dynamics of fisheries in other bays.
Description of King George whiting fisheries

Commercial fisheries
The main commercial fishery for King George whiting is in South Australia, from Gulf St Vincent to Ceduna, with smaller fisheries in central Victoria and south-western Western Australia (Kailola et al. 1993). In South Australia, 329 tonnes of King George whiting were taken in 2007/08 with an estimated value of $4,704,000 (ABARE 2009).

Main fisheries
Port Phillip Bay and Corner Inlet are the major commercial fishing areas in Victoria with ~60 and ~35% of the total Victorian commercial catch coming from these areas, respectively.

Commercial netting of King George whiting ceased in Western Port in December 2007, in accordance with a Government policy decision to create a recreational fishing haven. Commercial line fishing is still permitted in Western Port. Prior to 2007, ~5% of the total Victorian commercial King George whiting catch came from Western Port.

Less than 1% of the total Victorian commercial catch comes from Lakes Entrance, while ~5% comes from coastal waters.

Value
In Victoria, King George whiting is the most valuable commercial finfishery. In 2007/08, 215 tonnes of King George whiting were taken by commercial fisheries with an estimated value of $3,027,000 (ABARE 2009).

Fishing methods
Commercial catches of King George whiting in Victorian waters are primarily taken by haul seine nets (78%), and mesh nets (22%), though some hooking also occurs.

In the multi-species, multi-gear Victorian ocean fishery, whiting is a minor target species taken using haul seine, mesh nets and hand lines. Incidental catches of whiting are also taken in the Victorian inshore trawl fishery and in the ocean purse seine fishery.

By-product catches of King George whiting are taken by Commonwealth fishery licence holders in coastal waters adjacent to Victoria, mainly using Danish seine adjacent to Victoria, mainly using Danish seine.

Catch
Composition
The majority of fishing effort targets two to seven year old fish, with larger individuals caught by hand line (Kailola et al. 1993).

Bycatch
In Victoria’s bays and inlets, commercial haul seine operations take a number of by-catch species, including flounder (Ammotretis spp.), garfish (Hyporhamphus melanochtr), rock flathead (Platycephalus laevisatus), and particularly small snapper (Chrysophrys auratus) in Port Phillip Bay.

Management arrangements
The commercial fishery is currently managed primarily by:

- Input (effort) controls (including limited entry licensing, restrictions on fishing equipment and methods, and closed areas/seasons)
- Indirect catch controls such as a legal minimum lengths (LML). A LML of 27 cm total length (TL) remains in force for both the commercial and recreational fisheries.

The number of licensed commercial fishers in Victorian waters was reduced by a third between 1986/87 and 2008/09. The majority of the licence removals occurred as a result of voluntary licence buy-back schemes conducted in 1999/00 and 2005/06.

In 2009 there were:
- 42 commercial licence holders in Port Phillip Bay
- 18 licence holders in Corner Inlet.

Western Port was closed to commercial haul seine and mesh net fishing in December 2007.
Recreational fishery

King George whiting is a popular species targeted by recreational fishers.

Recreational angler catches account for approximately half of the total catch of ~400 tonnes of King George whiting in Victorian waters (Department of Primary Industries 2008).

Main fisheries

Port Phillip Bay and Western Port are the major recreational fishing areas for King George whiting in Victoria. Approximately 43% of the Victorian recreational catch is taken from Port Phillip Bay, while 30% is harvested from Western Port.

This species is also targeted in Corner Inlet and the Gippsland Lakes.

Victoria’s smaller inlets/estuaries (e.g. Anderson Inlet, Shallow Inlet, Mallacoota Inlet) are recreational-only fisheries. There is limited or no monitoring/assessment information for many of these smaller fisheries.

Catch

Recreational anglers target immature fish (Henry and Lyle 2003).

Fishing methods

Recreational fishing for King George whiting is mostly through boat-based angling (Henry and Lyle 2003; Ryan et al. 2009).

Pipis, squid, pilchard and mussels are generally used as bait, and number 6 long shank hooks are often used followed by 4 or 8 to catch King George whiting.

Management arrangements

Recreational fishing licence

Since 15 July 1999, recreational fishers have been required to hold a recreational fishing licence (RFL) to fish in marine and inland waters. Recreational fishers under 18 years of age or over 70 years of age, or those holding one of a range of concession cards are not required to hold a licence.

Gear restrictions

The use of recreational fishing gear remained unrestricted until 1992, when regulations specified a maximum of four lines per person and two hooks per line when fishing in marine waters, and a maximum of two lines with two hooks per line in inland waters (MacDonald 1997). This regulation was modified in 2009 to include two hooks per line or one bait jig when fishing in both marine and inland waters.

Bag limit

A daily bag and possession limit of 20 King George whiting landed whole or as a carcass per person applies to recreational fishing in all Victorian waters.

Size limits

A LML of 27 cm total length (TL) remains in force for both the commercial and recreational fisheries.
Previous assessments

Previous stock assessments for King George whiting were conducted in:

- March 1996 (Smith and MacDonald 1997)
- June Corner Inlet fisheries assessment 2006.

King George whiting was also a component of previous fishery assessments for:

- Port Phillip Bay in 1998 (Coutin 2000) and 2010 (Kemp et al. in prep.)
- Western Port in 1998 (Kemp et al. in prep.) and 2009 (Kemp et al. in prep.)

This section reviews the information presented at the most recent King George whiting stock assessment (2006).

King George whiting stock assessment 2006

Commercial fisheries

Port Phillip Bay

Commercial fishing effort in Port Phillip Bay with mesh nets and haul seine had declined substantially since 1997/98. Commercial whiting catches had remained below 85 tonnes from 1999/00 to 2004/05. This was after three years of higher catches from 1997/98 to 1999/00 that exceeded 100 tonnes. From 2003/04 to 2004/05, whiting catches increased from 49 to 69 tonnes, which was attributed to improved haul seine catch rates. The mesh net fishery in Port Phillip Bay was reported to be significantly smaller than during the 1980s and 1990s following a decline in fishing effort, catch rates and catches.

Western Port

Commercial haul seine catches in Western Port had remained low (<5 tonnes) since 2000/01, but an increase was observed in 2004/05 to 8 tonnes. Haul seine catch rates were variable with peaks occurring in 1999/00 and 2004/05. Mesh net catch rates had improved considerably since 1995/96 and were at a 20 year high.

Corner Inlet

Between 1993/1994 and 2002/2003 fishing effort in Corner Inlet mesh net fishery fell by half from 1000 to 500 km-lifts. Mesh net catches and catch rates reached their lowest levels on record in 2001/02 but rose sharply in 2003/04.

The haul seine fishery is larger and fishing effort has remained above 2500 km-lifts since 1995/96. Haul seine catches and catch rates had been variable and had improved since 2001/02, with a peak observed in 2003/04.

Commercial catch composition

Commercial catches in Port Phillip Bay, Western Port and Corner Inlet were dominated by 2+ and 3+ year old fish, along with a smaller number of 1+ and 4+ year old fish.

It was highlighted that given the small number of whiting year classes that are susceptible to fishing at any one time, fishery catches and catch rates are likely to vary substantially from year to year, and that recruitment of a single strong year class would only have a short-term (2 to 3 years) impact for fisheries.

Recreational fishery

Catch rates

Onsite access point surveys revealed that retained catch rates of King George whiting in Port Phillip Bay and Western Port had been between 0.4 and 0.6 fish/angler hour from 2002/03 to 2004/05.

From 2001/02 to 2004/05, angler diary catch rates in Port Phillip Bay, Western Port and Corner Inlet were reported as being relatively low.

Catch composition

The size and age composition of catches taken by angler diarists showed that the lower catch rates observed between 2001/02 and 2004/05 were the product of low recruitment over successive years.

Like the commercial fisheries, recreational catches were dominated by 2+ and 3+ year old fish, along with a smaller number of 1+ and 4+ year old fish.

Post larval recruitment

Monitoring the annual entry of post-larval whiting to the bays was providing a good predictor of catches two to three years later.
Settlement of King George whiting post-larvae in Victorian bays in 2005 was the strongest recorded, suggesting that a major upturn in the fishery could be predicted from 2008.

**Conclusion**

The 2006 King George whiting stock assessment concluded that Victoria’s whiting stock had been highly variable in the short term but was stable over the long term.

There was no evidence of persistent declines in fisheries catch or catch rates in Victorian bays and inlets that could be attributed to the impacts of fishing on whiting stocks.

The main concerns highlighted for the future of Victorian whiting fisheries were:

- The potential impacts of climate change on spawning success and the delivery of whiting larvae to bays and inlets
- The potential impacts of climate change and/or local human development activities on seagrass beds in Port Phillip Bay, Western Port and Corner Inlet, which may negatively impact successful settlement, survival and growth of juvenile whiting.

The perspectives of the commercial and recreational fishing sectors for the 2006 King George whiting stock assessment workshop are outlined in Appendix I.
Data and methods

This section describes relevant research and monitoring used to provide information for the 2010 King George whiting stock assessment. For more detail on the data and methods used, see Appendix II. This report focuses on describing the following indicators of stock status:

- Catch rates from the commercial and recreational fisheries
- Length and age distributions from the commercial and recreational fisheries
- Fishery-independent pre-recruit surveys

Commercial fishery

Victorian commercial fishers are required as a condition of their licence to record their fishing activities in a logbook and to submit this information to the Department. Commercial fishers provide the following information:

- Area/s fished
- Port of landing
- Gear
- Number of shots
- Fishing Time
- Weight of King George whiting caught and not returned live to the water

Recreational fishery

There have been three programs monitoring recreational King George whiting fishing in Victorian bays and inlets:

- Off-site telephone diary surveys of recreational fishing in 2000/01 (Henry and Lyle 2003) and 2006/07 (Ryan et al. 2009) to provide regional and state-wide estimates of total recreational catches of King George whiting and other key target species
- On-site (shore-based) access point surveys of recreational fishing have occurred annually in Victorian waters since 1995 to provide a time series of information on catch rates and size structure for King George whiting and other species. For Port Phillip Bay, onsite surveys were conducted in 1995/96 and 1996/97, and ongoing annual surveys have been carried out from 2002/03 to present. For Western Port, annual onsite surveys have been carried out from 1998/99 to present.
- Establishment of a voluntary angler diary program in 1997 to provide a time series of data on catch rates, and catch size/age composition for diarists targeting King George whiting and other species

Fishery-independent surveys

Sampling for post-larval King George whiting has been conducted in shallow (approximately 0.5 m depth) sub-tidal seagrass beds (Heterozostera nigricaulis) at eight sites around Port Phillip Bay from 1998 to present. Two sites are located in the southern part of the bay (Blairgowrie and Rosebud), three sites are located in the north of the Bay (Ricketts Point, Altona and Kirk Point) and three sites are located in the western part of the Bay (Eastern Beach, Grand Scenic and Grassy Point).

Post-larval Sillaginodes punctata are collected approximately monthly between August and November. Sampling is conducted over a 5 h period on either side of a day-time low tide. Sampling is usually conducted over three consecutive days. Samples are gathered using a seine net of 10 m in length, a 2 m drop, and a mesh of approximately 1 mm². Four replicate hauls, haphazardly placed and non-overlapping, are made at each site. The sampling method is described in detail by Jenkins et al. (1997a).

Length and age monitoring

Since the 1990s there has been routine sampling of length and age distributions of King George whiting landed by Victorian bay and inlet commercial fishers.

Age distributions are estimated by applying age-length keys to length-frequency distributions. A nominal birth date of 1 July is assigned when ageing King George whiting. Age-frequency information is presented by spawning year so abundant year-classes can be identified and tracked across multiple sampling years. Ages referred to in this report represent the age of a particular year-class of whiting as of 1 July.

Most King George whiting samples for ageing have been taken from research fishing surveys and from recreational and commercial catches. Research fishing surveys increase the number of fish below the LML. The relative strength of year
classes is used as a measure of relative abundance.
Trends in the fisheries

George outlined with waters; recreational discussed were Commercial Total Trends Victorian commercial highest from 2008/09, other between 1986/87. This a 30% reduction in days George was 5% from 2008/09, a 30% of total Victorian waters came from Port Phillip Bay and 38% came from Corner Inlet. Since the late 1970s King George whiting catches from Victorian waters have fluctuated; the highest catch was 274 tonnes taken in 1989/90 and the lowest was 58 tonnes taken in 1984/85 (Figure 1). Effort From 1978/79 to 1998/99, total commercial fishing effort targeting King George whiting and other species in Victorian waters fluctuated between 24,506 days in 1979/80 and 19,137 days in 1986/87 (Figure 1). Between 1998/99 and 2008/09, total commercial fishing effort declined to a 30 year low of 8,548 days in 2008/09 (Figure 1). This coincided with a reduction in the number of licensed fishers in Victorian waters by a third between 1986/87 to 2008/09. The majority of the licence removals occurred as a result of voluntary licence buy-back schemes conducted in 1999/00 and 2005/06.

Catch Rates Since 1978/79, the annual catch and catch rates for King George whiting have been variable. Catch rates have exhibited a long-term increasing trend from a low in 1984/85 of 2.5 kg/day to a high of 23 kg/day in 2007/08 (Figure 1).

King George whiting commercial catch and catch rates show an eight to ten year cyclic trend, with peaks observed in 1989/99, 1997/98 and 2007/08. The decrease in catch and catch rates from 2007/08 to 2008/09 appears to be the beginning of the downward trend in this eight to ten year cycle (Figure 1).

Recreational fishery

The National Recreational Fishing Survey carried out in 2000/01 estimated that Victoria’s recreational fishery for King George whiting took an annual catch of 215 tonnes (Henry and Lyle 2003). Using a similar phone-diary method in 2006/07, the Department of Primary Industries produced what is considered to be a more precise estimate of 155 tonnes (Ryan et al. 2009). The commercial catch of King George whiting in 2006/07 was 166 tonnes.

Between the National Recreational Fishing Survey carried out in 2000/01 (Henry and Lyle 2003), and the recreational fishing survey in 2006/07 (Ryan et al. 2009), there was a marked increase in the use of Western Port by recreational anglers. In 2000/01:

- 43% of the catch came from Port Phillip Bay
- 30% from Western Port
- 20% from Victorian coastal waters west of Wilson’s Promontory
- 4% from Corner Inlet
- 3% from the Gippsland Lakes.

In 2006/07:

- 30% of the catch came from Port Phillip Bay
- 50% from Western Port
- 9% from Victorian coastal waters west of Wilson’s Promontory
- 2% from Victorian coastal waters east of Wilson’s Promontory
- 4% from Corner Inlet
- 5% from the Gippsland Lakes.

The 2006/07 recreational fishing survey results show that King George whiting catch was mainly taken by angling from boats, during summer/autumn, and 27% of the whiting caught was released (Ryan et al. 2009).
Port Phillip Bay

Commercial fishery

Fishing method

In 2008/09, 76% of the King George whiting catch taken in Port Phillip Bay was by haul seines and 24% was by mesh nets.

Trends in catch, effort and catch rates

Catch

Since the late 1970s, King George whiting catches from Port Phillip Bay have fluctuated; the highest annual catch for haul seines was 97 tonnes taken in 1989/90 and the lowest was 21 tonnes taken in 1978/79 (Figure 1). For mesh nets, a high of 35 tonnes was taken in 1999/00 and a low of 6.5 tonnes was taken in 2004/05 (Figure 1). Synchronised fluctuations in commercial catches for hauls seines and mesh nets suggest variable recruitment of King George whiting to the Port Phillip Bay fishery.

Effort

From 1978/79 to 2008/09, total commercial haul seine fishing effort targeting King George whiting and other species in Port Phillip Bay fluctuated, with a long-term decreasing trend; a high of 4,386 shots was observed in 1978/79 and a low of 2,140 shots was observed in 2006/07 (Figure 1). Total commercial mesh net fishing effort fluctuated, with no clear trends; a high of 2,493 km-lifts was observed in 1998/99 and a low of 799 km-lifts was observed in 2005/06 (Figure 1). From 2005/06 to present, mesh net effort has been increasing.

Catch Rates

Despite a general decline in effort for haul seines since 1978/79, catch rates have fluctuated, showing a long-term increasing trend. From 1978/79 to 2008/09, catch rates were at their lowest in 1978/79 at 4.7 kg/shot and highest in 2007/08 at 35 kg/shot (Figure 1). Catch rates for mesh nets since 1978/79 have been variable with no clear trends; a high of 20 kg/km-lift was observed in 1999/00 and a low of 4 kg/km-lift was observed in 1983/84 (Figure 1).

Peaks in haul seine and mesh net catch rates were observed in 1989/90, 1999/00 and 2007/08, consistent with an eight to ten year cyclic trend. This trend suggests that the next peak season for King George whiting in Port Phillip Bay may occur between 2015/16 and 2017/18.

Size/age composition

Length frequency distributions of King George whiting taken by haul seines ranged from 22 to 41 cm FL (Figure 12). The length frequency distributions of King George whiting taken by mesh nets ranged from 24 to 51 cm FL (Figure 13). A higher proportion of large fish (>35 cm FL) were taken by mesh nets compared to haul seine commercial catches (Figure 12 and 13). The proportion of large fish (>35 cm FL) in mesh net commercial catches has increased in recent years. Between 1994/95 and 2000/01, there were few whiting taken >35 cm FL, whereas from 2002/03 to 2008/09, a significant proportion of the catch was >35 cm FL (Figure 13). This trend was not observed in haul seine catches of (Figure 12).

The age frequency distributions of whiting sampled by haul seines and mesh nets show that the Port Phillip Bay commercial fishery is based on fish that are 1+ to 5+ years of age; most of the catches are made up of 2+ and 3+ year old fish (Figure 14 and 15).

Recreational fishery

Catch Rates

Mean annual recreational catch rates of King George whiting retained and released by shore- and boat-based anglers in Port Phillip Bay have been estimated from onsite access point surveys since 1995/96 (Figure 6). A peak in Port Phillip Bay recreational angler catch rates was observed in 2007/08. This peak was also observed in commercial haul seine and mesh net catches in Port Phillip Bay.

From 1998/99 to 2008/09, mean annual catch rates reported by angler diarists targeting King George whiting in Port Phillip Bay fluctuated between a high of 4.1 fish/angler hour in 2007/08 and a low of 1.4 fish/angler hour in 2002/03 (Figure 7). From 2001/02 to 2004/05, catch rates declined to <2.0 fish/angler hour, but have since recovered, and have been relatively high since 2006/07 (Figure 7).

Size/age composition

Length frequency distributions of King George whiting caught and kept by Port Phillip Bay boat and shore based anglers have been measured as part of annual access point surveys since 1996/97 and ranged in size from 20 to 50 cm TL (Figure 22). Length frequency distributions of King George whiting caught by Port Phillip Bay angler...
diorists have a higher proportion of undersize fish because of the prescribed fishing methods used and because all fish caught are measured (Figure 23). The length frequency distributions of King George whiting caught by angler diarists ranged from 21 to 50 cm TL (Figure 23).

Ageing of whiting sampled from Port Phillip Bay recreational catches during access point surveys show that boat- and shore-based angler catches are dominated by 2+ year old fish (Figure 24). Angler diarist whiting catches are also dominated by 2+ year old fish (Figure 25).

**Western Port**

**Commercial fishery**

**Fishing method**

Prior to the closure of the haul seine and mesh net commercial fisheries in Western Port in 2007, 67% of the King George whiting catch was taken by haul seines and 33% was taken by mesh nets.

**Trends in catch, effort and catch rates**

**Catch**

Since the late 1970s King George whiting catches from Western Port have fluctuated; the highest annual catch for haul seines was 11 tonnes taken in 1990/91 and the lowest was 1 tonne taken in 2003/04 (Figure 2). For mesh nets, a high of 9 tonnes was taken in 1989/90 and a low of 2 tonnes was taken in 2007/08 (Figure 2). Synchronised fluctuations in commercial catches for hauls seines and mesh nets suggest variable recruitment of King George whiting to the Western Port fishery.

**Effort**

From 1978/79 to 2008/09, total commercial haul seine fishing effort targeting King George whiting and other species in Western Port fluctuated, with a long-term decreasing trend; a high of 1,692 shots observed in 1990/91 and a low of 124 shots observed in 2003/04 (Figure 2). Mesh net fishing effort fluctuated, with a long-term decreasing trend; a high of 2,281 km-lifts was observed in 1978/79 and a low of 189 km-lifts was observed in 2007/08 (Figure 2).

**Catch Rates**

Despite the general decline in effort for haul seines since 1978/79, catch rates have fluctuated showing a long-term increasing trend; a high of 18 kg/shot was observed in 2004/05 and a low of 3 kg/shot was observed in 1984/85 (Figure 2). Catch rates for mesh nets since 1978/79 have also been variable with a long-term increasing trend; a high of 14 kg/km-lift was observed in 2004/05 and a low of 1.5 kg/km-lift was observed in 1994/95 (Figure 2).

Peaks in haul seine catch rates were observed in 1989/90, 1999/00, 2004/05 and 2006/07. Peaks in mesh net catch rates were observed in 1989/90, 2001/02, 2004/05 and 2007/08.

**Size/age composition**

There is no length data available for King George whiting taken by haul seines in Western Port.

Length frequency distributions of King George whiting taken by mesh nets ranged from 24 to 48 cm FL (Figure 16). From 2003/04 to December 2007, Western Port mesh net catches of whiting contained a lower proportion of fish >40 cm FL than catches from Port Phillip Bay (Figure 13 and 16).

Age frequency distributions of whiting sampled by mesh nets show that the Western Port commercial fishery was based on fish that are 1+ to 6+ years of age; most of the catches were made up of 2+ and 3+ year old fish (Figure 17).

**Recreational fishery**

**Catch Rates**

Mean annual recreational catch rates of King George whiting retained and released by shore- and boat-based anglers in Western Port have been estimated from onsite access point surveys since 1998/99 (Figure 8). A peak in Western Port recreational angler catch rates was observed in 2009/10.

From 1998/99 to 2008/09, mean annual catch rates reported by angler diarists targeting King George whiting in Western Port fluctuated between a high of 3.8 fish/angler hour in 1999/00 and a low of 1.0 fish/angler hour in 2003/04 (Figure 7). From 2001/02 to 2004/05, catch rates declined to <2.0 fish/angler hour, as was also observed in Port Phillip Bay but have since recovered. Catch rates were relatively high in 2008/09 at 2.9 fish/angler hour (Figure 7). A peak in catch rates was observed in Western Port in 2005/06 that was not observed in Port Phillip Bay; the reasons for the peak in Western Port are unknown.

**Size/age composition**

Length frequency distributions of King George whiting caught and kept by Western Port boat- and shore-based anglers have been measured as
part of annual access point surveys since 1998/99 and ranged in size from 21 to 67 cm TL (Figure 26).

The length frequency distributions of whiting caught by angler diarists ranged from 9 to 50 cm TL (Figure 27). Length frequency distributions of King George whiting caught by Western Port angler diarists have a lower proportion of undersized fish than that observed for Port Phillip Bay (excluding 2008/09) (Figure 27). In 2008/09, no undersized fish were taken by angler diarists (Figure 27), suggesting there may be a low abundance of pre-recruits in Western Port.

Ageing of whiting sampled from Western Port recreational catches during access point surveys show that boat- and shore-based angler catches are dominated by 2+ year old fish (Figure 28). Angler diarist whiting catches are also dominated by 2+ year old fish (Figure 29).

**Corner Inlet**

**Commercial fishery**

**Fishing method**

In 2008/09, 86% of the King George whiting catch taken in Corner Inlet was by haul seines and 14% was taken by mesh nets.

**Trends in catch, effort and catch rates**

**Catch**

Since the late 1970s King George whiting catches from Corner Inlet have fluctuated; the highest annual catch for haul seines was 105 tonnes taken in 1996/97 and the lowest was 9 tonnes taken in 1979/80 (Figure 3). For mesh nets, a high of 21 tonnes was taken in 1989/90 and a low of 0.8 tonnes was taken in 2001/02 (Figure 3).

Synchronised fluctuations in commercial catches for hauls seines and mesh nets suggest variable recruitment of King George whiting to the Corner Inlet fishery.

**Effort**

From 1978/79 to 2008/09, total commercial haul seine fishing effort targeting King George whiting and other species in Corner Inlet fluctuated, with a long-term increasing trend observed from 1978/79 to 1999/00, and a decreasing trend observed from 1999/00 to 2008/09. A peak in haul seine effort of 3,991 shots was observed in 1999/00 and a low of 926 shots was observed in 1978/79 (Figure 3). Total commercial mesh net fishing effort fluctuated, with a long-term decreasing trend; a high of 1,486 km-lifts was observed in 1979/80 and a low of 390 km-lifts was observed in 2002/03 (Figure 3).

**Catch rates**

Haul seine catch rates of King George whiting from 1978/79 to 2008/09 fluctuated; a high of 42 kg/shot was observed in 1987/88 and a low of 7.5 kg/shot was observed in 1979/80 (Figure 3). Catch rates for mesh nets since 1978/79 have also been variable; a high of 32 kg/km-lift was observed in 1989/90 and a low of 1.8 kg/km-lift was observed in 2001/02 (Figure 3).


Peaks in catch rates of King George whiting from Corner Inlet show a markedly different pattern to those observed for Port Phillip Bay and Western Port (Figure 4). Catch rates of whiting from Corner Inlet tend to peak 2 to 3 years prior to those of Port Phillip Bay and Western Port.

**Size/age composition**

Length frequency distributions of King George whiting taken by haul seines ranged from 20 to 42 cm FL (Figure 18). The length frequency distributions of King George whiting taken by mesh nets ranged from 24 to 39 cm FL (Figure 19). A higher proportion of large fish (>35 cm FL) were taken by haul seines compared to mesh nets (Figure 18 and 19). The proportion of large fish (>35 cm FL) in mesh net catches has increased in recent years (Figure 19).

Age frequency distributions of whiting sampled by haul seines and mesh nets show that the Corner Inlet commercial fishery is based on fish that are 1+ to 4+ years of age; most of the catches are made up of 2+ and 3+ year old fish (Figure 20 and 21).

**Victorian Coastal Waters West of Wilson’s Promontory**

**Recreational fishery**

**Catch Rates**

From 1998/99 to 2006/07, mean annual catch rates reported by angler diarists targeting King George whiting in coastal waters of Victoria west of Wilson’s Promontory fluctuated; a high of 3.6 fish/angler hour was observed in 1998/99 and a low of 0.8 fish/angler hour was observed in 2004/05 (Figure 7). From 2001/02 to 2006/07, catch rates declined to <2.0 fish/angler hour. A
similar trend to this was observed for both Port Phillip Bay and Western Port (excluding the 2005/06 peak observed for Western Port).

**Size/age composition**

Length frequency distributions of King George whiting caught by angler diarists in the coastal waters of Victoria west of Wilson’s Promontory between 1997/98 and 2004/05 ranged between 24 and 50 cm TL (Figure 30).

**Fishery-independent survey**

Inter-annual variation in the average abundance of King George whiting post-larvae in Port Phillip Bay is shown in Figure 9. Peaks in post-larval catch rates were observed in 1997, 2001 and 2005. The abundance of post-larval King George whiting from 2006 to 2009 has been relatively low. This suggests that fishery catches are likely to remain consistently average for at least the next year or two.

The fishery-independent surveys of post-larvae in Port Phillip Bay have successfully identified some stronger year classes several years prior to them appearing in the fisheries as an increase in fishery catch rates. In 2007/08, commercial haul seine, recreational onsite survey and angler diarist average annual catch rates peaked along with fishery independent catch rates (2005 catch rate with a 2 year lag) (Figure 10). The fishery-independent surveys of post-larvae in Port Phillip Bay have also successfully identified some stronger year classes several years prior to them appearing in the Western Port fisheries as an increase in fishery catch rates; however, the relationship is not as strong as that observed for Port Phillip Bay (Figure 11). For both Port Phillip Bay and Western Port, the variation in commercial and recreational catch rates that is not predicted by the pre-recruit surveys suggests that there are factors affecting post-larval/juvenile King George whiting before they enter the fishery that are yet to be determined. Despite this unexplained variation, the pre-recruit surveys do provide an indication of future fishery catch rates.
Management implications

This section describes the findings regarding fishery trends and the status of Victorian King George whiting stocks, and provides advice to management in relation to current management objectives.

The following were highlighted at the April 2010 King George whiting stock assessment:

- The majority of the commercial state-wide catch is from Port Phillip Bay (57%) and Corner Inlet (38%)
  - The Port Phillip Bay and Corner Inlet commercial fisheries are based on 2+ and 3+ year old fish
  - Western Port was closed to commercial haul seine and mesh net fishing in December 2007
- The majority of the recreational state-wide catch is taken from Port Phillip Bay, Western Port, and to a lesser extent Victorian coastal waters west of Wilson’s Promontory
  - Recreational catches of whiting from Victorian bays and inlets are dominated by 2+ year old fish
  - It is estimated that ~155 tonnes of King George whiting are harvested from Victorian waters by recreational fishers annually
  - There was a marked increase in the use of Western Port by recreational fishers between 2000/01 and 2006/07
- Catch rates of King George whiting peaked in the late 2000s
  - Commercial catch rates have exhibited a long-term increasing trend from a low of 2.5 kg/day taken in 1984/85 to 23 kg/day taken in 2007/08 (all Victorian waters, all gear types combined)
  - There was a peak in recreational catch rates of King George whiting in Port Phillip Bay in 2007/08 (4.1 fish/angler hour); this peak was also observed in commercial haul seine and mesh net catches in Port Phillip Bay
  - A peak in recreational catch rates of King George whiting in Western Port was observed in 2008/09 (2.9 fish/angler hour)
- Fishery predictions based on:
  - Commercial catch rates showing an eight to ten year cyclic trend, with peaks observed in 1989/90, 1997/98 and 2007/08 (all Victorian waters, all gear types combined) suggest that the next peak season for King George whiting may occur between 2015/16 and 2017/18
  - The abundance of post-larval King George whiting from 2006 to 2009 has been relatively low suggesting that fishery catches are likely to remain consistently average for at least the next year or two.
- Zonal westerly winds influence production of King George whiting in three to four years time. This correlation is based on a 60 year-long time series. There is potential for this relationship to be used to forecast future production trends, and as an indicator to make decision rules that reduce exploitation during prolonged periods of poor environmental conditions.

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Research needs and priorities

The following issues were raised during the 2010 King George whiting stock assessment, and previous assessment workshops, as key research and assessment needs for King George whiting in Victorian bays and inlets.

Research

• Determine where the spawning areas are that supply Victoria’s whiting fishery. The spawning location of Victorian whiting stocks has implications for the short-term dynamics of King George fisheries. It is not known whether Victorian King George whiting are coming from South Australian spawning stocks, and how important the contribution of Victorian fish is to these spawning stocks
• Estimate the post-release mortality of King George whiting
• Examine the diet of juvenile whiting (<2 years old)
• Estimate mortality rates of pre-recruits
• Investigate the potential effects of climate change on whiting spawning, and the delivery of larvae to Victorian bays and inlets
• Investigate factors causing seagrass loss and possible methods of restoration
• Investigate factors influencing variability in growth among locations and seasons
• Investigate the relationship between climatic/environmental variables and variation in commercial and recreational catch rates. For example, explore if, and how, changes in seagrass abundance affect King George whiting production.
• Investigate patterns of movement of immature whiting between Victorian bays and inlets and whether juvenile migration is the source of recruitment to Corner Inlet
• Determine the impact of fishing in Victorian bay/inlet and coastal waters on the sustainability and replenishment of adult populations in coastal waters

• Examine the relationships between climate change and whiting fishery production, particularly recruitment to Victorian bays and inlets

Assessment

• Assess the selectivity of haul seines and mesh nets for King George whiting
• Develop a method to validate the size and age composition taken by recreational research anglers. This would allow for comparisons to be made between research angler indicators and fishery independent pre-recruit and commercial fishery indicators
• Develop appropriate performance measures and reference points to track the status of the whiting fishery. Also identify trigger points for each performance indicator
• There is a need to establish a decision making framework for King George whiting stocks involving:
  o Scientific evaluation and consultation with stakeholders to identify appropriate performance indicators, reference and trigger points
  o Stakeholder agreement to performance indicators, reference and trigger points, and management responses to be used, and incorporation of these decision rules in fishery management plans
  o Evaluation of alternative management measures to identify the most cost-effective response if and when a trigger point is reached
• Evaluate the potential for adapting the stock assessment model developed for King George whiting in South Australia to the Victorian fishery

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variability in recruitment of a temperate, seagrass-associated fish is largely determined by physical processes in the pre- and post-settlement phases. *Marine Ecology-Progress Series* **148**, 23-35.


Appendix I – Industry perspectives 2006

This section documents the perspectives of the commercial and recreational fishing sectors from a King George whiting workshop conducted in June 2006.

2006 King George whiting stock assessment

Commercial perspectives

- Fish numbers in Port Phillip Bay over the last 12 months were reported to have increased; with more 20 to 25 cm fish being taken.
- Fish that are 20 to 25 cm appeared to disappear around December/January in Port Phillip Bay.
- Lots of large fish (~30 to 40 cm) were reportedly being taken from Port Phillip Bay.
- Large numbers of northern Pacific sea star (Asterias amurensis) were reportedly present in Port Phillip Bay from Grassy Point to Swan Bay. Clearing the sea star from nets was suggested to have significantly slowed fishing in these areas.
- The prevalence of large jelly fish in Port Phillip Bay was reportedly hampering fishing.
- Increased numbers of seals in Port Phillip Bay were suggested to be causing some operators to abandon or shift their fishing away from preferred locations.
- More large fish (>30 cm) were reported to be present in Port Phillip Bay, Western Port and Corner Inlet.
- King George whiting catches in Corner Inlet were reported to have been low for the past few years. However, 2005/06 had been one of the best years for whiting ~35 cm.
- Whiting of ~25 to 30 cm in size were being taken in November in Corner Inlet; however, in the past, fish of this size were generally taken in May.
- Losses of seagrass in parts of Corner Inlet was one of the factors reported to be causing some commercial operators to switch to targeting other species such as rock flathead and garfish.

Recreational perspectives

- The number of anglers and effort was reported to have increased significantly in Port Phillip Bay. Localized increases in the number of anglers, for example, between St. Kilda and Mordialloc had been observed.
- The Port Phillip Bay recreational fishery for whiting was suggested to have become a year round fishery, rather than from November to May, as it had been in the past.
- Catches of whiting in Port Phillip Bay were reported as being very good from January to April, compared with other years.
- Fishing for whiting was reportedly poor around Point Cook and Campbell’s Cove, Port Phillip Bay.
- Anglers reported that bag limits were rarely reached.
- King George whiting that were being caught in Port Phillip Bay were reportedly larger than has been in the past.
- An angler reported that fishing in February and March resulted in an average of 25 whiting/boat trip. From 1991 to 1997, an average of 29 whiting/boat trip were being taken. From 2000 to 2006, an average of 20 whiting/boat trip were being taken.
- Fishing in Western Port was reportedly better than it had been in recent years. However, in some areas, like east of Hastings/Varneet, catches were the lowest that had been observed in three years.
- Large whiting (>40 cm) were commonly being caught in Western Port and that there were few fish <35 cm being taken.
- The number of boats and anglers in Western Port was reported to be increasing.
- Few whiting were reportedly taken this season in Western Port until October, whereas the fishing season for whiting usually begins in September.
- Poor fishing for whiting was reported in the northern regions of Western Port.
• An abundance of small snapper in Western Port was reportedly hindering the ability to catch whiting.

• Fishers reported that they rarely reached the bag limit in Western Port, instead taking ~6 to 8 whiting.

• Snapper was being targeted instead of whiting in Western Port. Off Cowes and Rhyll, fishers were bagging out snapper in half an hour.

• Soft plastics were being used more often to target whiting.

Environmental perspectives

• Observations of seagrass declines were reported for Port Phillip Bay, Western Port and Corner Inlet. Some areas were suggested to be recovering, while others were not.

• An abundance of brown algae had been observed in Port Phillip Bay over the past few months.

• Water quality had reportedly improved in eastern Port Phillip Bay, and new seagrass beds were re-establishing since the end of scallop fishing.

• Large numbers of dead northern Pacific sea star were reported at Edwards Point in Port Phillip Bay in May 2006.

• The northern Pacific sea star was reportedly present in high abundances from Grassy Point to Swan Bay in Port Phillip Bay; causing a significant impact on commercial fishing practices.

• An increase in the number of seals feeding in Port Phillip Bay was reportedly negatively affecting commercial catches.

• Seasonal environmental conditions were reported as being ‘unusual’ recently with higher water temperatures and salinities than usual.

• The presence of dense brown algae smothering the seabed in certain areas was reported as being common to all embayments.

• Severe seagrass declines were reported for areas north of Hastings in Western Port.

• Turbidity had been high in the northern parts of Western Port, but water clarity was good in southern regions of the bay. Sediments from sand extraction by local quarries were suggested to have contributed to the deterioration of water quality in Western Port.

• An increase in shoreline mangrove habitats in Western Port in recent times was reported to have helped stabilise shoreline sediments.

• Water quality in Corner Inlet was reported as being very good with no reports of algal blooms.
Appendix II – Data and methods

This section further describes relevant research and monitoring used to provide information for the 2010 King George whiting stock assessment.

Commercial fishery
Recording of commercial catches from bay and inlet fisheries commenced in 1914. Catch information was recorded in this manner by calendar year up to 1963. Fishers provided more detailed monthly catch data to the Victorian Department of Fisheries and Game between 1964/65 and 1972/73. This catch information was forwarded to the Commonwealth Bureau of Census and Statistics for processing and reporting. Throughout this period, fishing effort data were not detailed and have not been summarised. Between 1973/74 and 1977/78, the same type of data were recorded and collected but were processed and summarised by the Victorian Fisheries and Wildlife Division.

More detailed daily records of fishing method, area, catch and effort (and therefore catch rate) have been collected and entered into databases since 1978/79.

These data have been checked for major errors by a series of range tests and other validation routines that are part of the normal data entry procedures of the Catch and Effort Unit at the Department of Primary Industries, Queenscliff. A review of logbook data quality has indicated that more than 95% of monthly catch/effort returns have been submitted. There is potential for some errors in catch rate due to unrecorded effort and/or errors in coding effort data.

No attempt has been made to independently verify the accuracy of catch weight, fishing location or effort values supplied by fishers. Effort values are not standardised as no attempt has been made to make any adjustment for changes in fishing power over the period for which catch/effort statistics have been collected.

Recreational fishery
There have been two large-scale, telephone-diary surveys of recreational fishing in Victoria aimed at estimating total recreational catch. The National Recreational Fishing Survey in 2000/01 provided state-wide and regional estimates of both retained and discarded catches of key target species by recreational fishers (Henry and Lyle 2003). Diarists were identified and recruited for the survey using a state-wide telephone screening method.

State-wide and regional recreational catches of key Victorian marine and estuarine species were estimated again in 2006/07 using a telephone diary survey (Ryan et al. 2009). The 2006/07 survey used the Recreational Fishing Licence database as a sampling frame to identify and recruit diarists.

Data from onsite access point surveys provides a time series of information on species targeted and caught by anglers, discard rates, catch rates and size/age composition of the retained catch of key target species. A variable number of interviews occur on any sample day and data outputs are reported in calendar years. Avid anglers are anglers who recalled fishing at least five days in the previous 12 months. Calculating mean catch rates from these anglers increases consistency in the sampling effort and reliability of the analyses.

The access point angler survey covers a large number of anglers with random sampling by day type (weekday and weekend). Discard rates are potentially subject to recall bias. The precision of the annual and seasonal catch rate estimates is influenced by sampling intensity. Fork length measurements from the shore-based survey are made by trained interviewers.

Volunteer angler diarists have been operating in Victorian waters since 1997. General angler diarists have provided data on target preferences, catch effort and gear from their everyday fishing activities. Research anglers have provided more detailed data on catch rate and size/age composition of particular target species using prescribed gear. These angler diary data are not representative of all anglers, but are collected in a consistent manner and are therefore comparable from year to year.

Average recreational catch rates were calculated using the mean-of-ratios estimator (Jones et al. 1995). This estimator allows for the fact that information obtained from interviews with shore-based recreational fishers represents incomplete trips. Confidence limits were estimated using bootstrapping methods (Hoyle and Cameron 2003). Statistical procedures are
constantly being refined to improve output quality.

**Age/length monitoring**

Research fishing surveys and limited on-board monitoring have improved the quality of length data, which was prone to bias from sorting of fish by size prior to sale. There is also potential selectivity associated with different gear types, net length, distance from shore and depth. No correction of age/length data has been made for potential post-mortem shrinkage. The index of average percent error (IAPE) was used to quantify intra-reader variability (Beamish and Fournier 1981). Age estimates were consistent between the primary and secondary readings. Intra-reader variability was calculated every year and was <5% in all years, indicating the structure of the otolith was consistently interpreted.
Appendix III – Data Figures and Tables
Figure 1: Commercial catch, effort and catch rate of King George whiting for (i) all Victorian waters, all gear types (ii) Port Phillip Bay haul seine and (iii) Port Phillip Bay mesh nets from 1978/79 to 2008/09, presented by financial year.
Figure 2: Commercial catch, effort and catch rate of King George whiting for Western Port (i) haul seine, and (ii) mesh nets from 1978/79 to 2008/09, presented by financial year.
Figure 3: Commercial catch, effort and catch rate of King George whiting for Corner Inlet (i) haul seine, and (ii) mesh nets from 1978/79 to 2008/09, presented by financial year.
Figure 4: Catch rates of King George whiting from Corner Inlet, Port Phillip Bay and Western Port for commercial haul seines from 1978/79 to 2008/09, presented by financial year.
Figure 5: Commercial catch, effort and catch rate of King George whiting for (i) Victorian coastal waters haul seine, (ii) Victorian coastal waters mesh nets, and (iii) Victorian coastal waters inshore trawl from 1978/79–2008/09, presented by financial year.
Figure 6: Average annual recreational catch rates by avid anglers, targeting King George whiting in Port Phillip Bay in summer/autumn from 1995/96 to 2009/10 from onsite surveys. No data available from 1997/98 to 2001/02. Sample days: n = 488; Interviews: 3745.

Figure 7: Average annual recreational catch rates of King George whiting targeted by angler diarists that are caught and kept during summer/autumn in Port Phillip Bay, Western Port and Victorian coastal waters west of Wilson’s Promontory from 1998/99 to 2008/09. No data available for Victorian coastal waters west of Wilson’s Promontory from 2007/08 to 2008/09.
Figure 8: Average annual recreational catch rates by avid anglers, targeting King George whiting in Western Port in summer/autumn from 1998/99 to 2009/10 from onsite surveys. No data available from 1995/96 to 1997/98. Sample days: n = 430; Interviews = 4686.

Figure 9: Fisheries independent survey average annual abundance of King George whiting post larvae in Port Phillip Bay from 1996 to 2009.
Figure 10: Catch rates of King George whiting from Port Phillip Bay for commercial haul seines, fishery-independent surveys (FIS), and recreational angler onsite access point surveys and angler diary surveys from 1995/96 to 2001/011, presented by financial year.

Figure 11: Catch rates of King George whiting from Western Port for commercial haul seines, fishery-independent surveys (FIS), and recreational angler onsite access point surveys and angler diary surveys from 1995/96 to 2001/011, presented by financial year.
Figure 12: Length frequency distributions of King George whiting caught by haul seine in Port Phillip Bay from 1994/95 to 2008/09, presented by financial year.
Figure 13: Length frequency distributions of King George whiting caught by mesh nets in Port Phillip Bay from 1994/95 to 2008/09, presented by financial year. No data available for 2001/02 and 2004/05.
Figure 14: Estimated age composition of King George whiting caught by haul seine in Port Phillip Bay from 1994/95 to 2008/09. No data available from 2004/05 to 2007/08.
Figure 15: Estimated age composition of King George whiting caught by mesh nets in Port Phillip Bay from 1994/95 to 2008/09. No data available for 2001/02 and 2004/05 to 2007/08.
Figure 16: Length frequency distributions of King George whiting caught by mesh nets in Western Port from 1997/98 to 2004/05, presented by financial year. No data available from 2005/06 to present.
Figure 17: Estimated age composition of King George whiting caught by mesh nets in Western Port bay from 1997/98 to 2004/05.
Figure 18: Length frequency distributions of King George whiting caught by haul seine in Corner Inlet from 1994/95 to 2008/09, presented by financial year.
Figure 19: Length frequency distributions of King George whiting caught by mesh nets in Corner Inlet from 1994/95 to 2008/09, presented by financial year. No data available from 1999/00 to 2006/07.
Figure 20: Estimated age composition of King George whiting caught by haul seine in Corner Inlet from 1994/95 to 2008/09. No data available from 1995/96 to 1997/98 and from 2005/06 to 2007/08.
Figure 21: Estimated age composition of King George whiting caught by mesh nets in Corner Inlet in 1994/95, 1998/99 and 2008/09.
Figure 22: Length frequency distributions for King George whiting caught and retained by boat and shore-based anglers in Port Phillip Bay from 1996/97 to 2009/10, presented by financial year. The % of fish that were below the legal minimum length is shown in red. No data available from 1997/98 to 2001/02.
Figure 23: Length frequency distributions of King George whiting caught by angler diarists in Port Phillip Bay from 1997/98 to 2008/09, presented by financial year. The % of fish that were below the legal minimum length is shown in red.
Figure 24: Estimated age composition of King George whiting caught by boat- and shore-based anglers in Port Phillip Bay from 1996/97 to 2008/09, presented by financial year. No data available from 1997/98 to 2001/02 and 2004/05 to 2007/08.
Figure 25: Estimated age composition of King George whiting caught by angler diarists in Port Phillip Bay from 1997/98 to 2008/09, presented by financial year. No data available from 2004/05 to 2007/08.
Figure 26: Length frequency distributions for King George whiting caught and retained by boat and shore-based anglers in Western Port from 1998/99 to 2009/10, presented by financial year. The % of fish that were below the legal minimum length is shown in red.
Figure 27: Length frequency distributions of King George whiting caught by angler diarists in Western Port from 1998/99 to 2008/09, presented by financial year. The % of fish that were below the legal minimum length is shown in red.
Figure 28: Estimated age composition of King George whiting caught by boat- and shore-based anglers in Western Port from 1998/99 to 2008/09, presented by financial year. No data available from 2005/06 to 2007/08.
Figure 29: Estimated age composition of King George whiting caught by angler diarists in Western Port from 1998/99 to 2008/09, presented by financial year. No data available from 2005/06 to 2007/08.
Figure 30: Length frequency distributions of King George whiting caught by angler diarists in the coastal waters of Victoria west of Wilson’s Promontory from 1997/98 to 2004/05, presented by financial year. The % of fish that were below the legal minimum length is shown in red. No data available from 2005/06 to present.
Appendix IV – Industry perspectives 2010

This section documents the perspectives of the commercial and recreational fishing sectors from the King George whiting workshop held in April 2010.

2010 King George whiting stock assessment

Commercial perspectives

No commercial perspectives were provided.

Recreational perspectives

- Large whiting were reportedly feeding on yabbies at high tide in shallow waters, and anglers are often not fishing these shallow waters.
- Lots of juveniles were reported on shallow banks in Western Port.
- A recreational angler reported that last year, on 15 trips between December and July to a location near Tortoise Head in Western Port, 179 whiting were taken. Of the six trips taken in July, only 14 whiting were taken. This year on 22 trips taken between December and April, 550 whiting were taken.
- Anglers were been using number 6 shiner hooks and pipis and mussels as bait to catch whiting.
- The number of whiting in Western Port was reported to have been lower for the past two years compared with years prior.
- Changes to snapper possession limit regulations (no more than three fish may be equal to or exceed 40 cm TL; whereas previously it had been 50 cm TL) were reportedly resulting in more King George whiting being taken due to smaller snapper on the banks where whiting are.
- An abundance of 10 to 20 cm whiting off Ricketts Point was reported.
- Large numbers of boats in certain areas were suggested to be leading to local depletions, e.g. off Beaumaris in Port Phillip Bay.
- Good catches of whiting up to 45 cm at dusk were reported off Clifton Springs, Port Phillip Bay.
- Large whiting were being taken after dark on the sand banks of Safety Beach and Dromana, Port Phillip Bay.
- Circle hooks were being used more often to target whiting.
- There was more targeted effort for whiting reported off Torquay and Lorne. Large whiting (~60 cm) had been taken off Airey’s Inlet in autumn/winter.
- Catches of whiting in autumn in Port Phillip Bay were reported as being low, whereas in other years catches in autumn had been good.
- Fishing for whiting was reportedly good off Warrnambool. Fish were up to ~50 cm and generally 15 fish were being taken/trip.
- Since January, there were few whiting reportedly near Point Leo in Western Port whereas in other years whiting were often taken in this location. However, further north there were good sized fish.
- Anglers were catching different species in Western Port compared to other seasons e.g. Cowanyoung.
- Low numbers of whiting were reported for Corner Inlet.

Environmental perspectives

- Declines in seagrass in Port Phillip Bay were restricted to certain areas. Prolonged drought was thought to be contributing to the declines, along with sediment movement/transport.
- Water temperatures in Western Port were suggested to be warmer than other years.
- Continued declines in seagrass at the top end of Corner Inlet were reported.