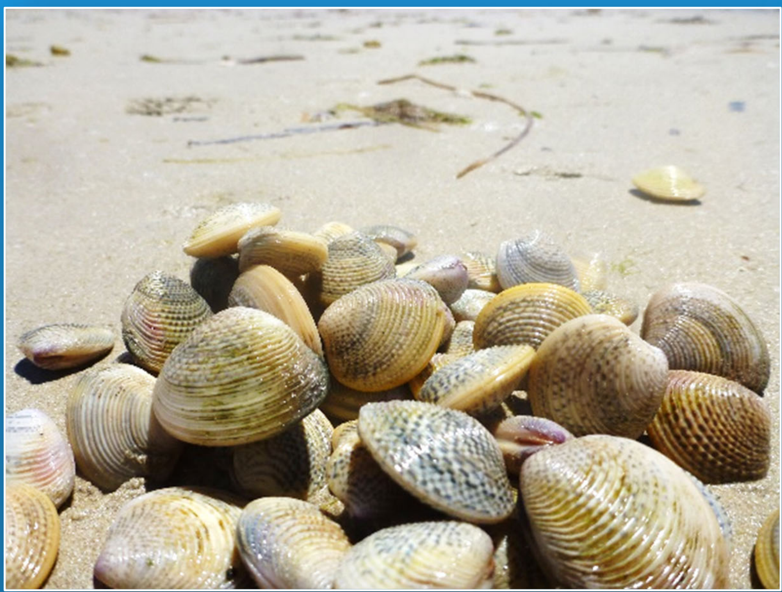
Fisheries

Harvestable biomass in the South Australian Vongole Fishery (*Katelysia* spp.)



G. Ferguson, K. Heldt, B. Stobart and S. Mayfield

SARDI Publication No. F2014/000191-3
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SARDI Aquatics Sciences
PO Box 120 Henley Beach SA 5022

May 2022

Report to PIRSA Fisheries and Aquaculture

Government of South Australia
Department of Primary Industries and Regions

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

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EXECUTIVE SUMMARY

This report provides estimates of harvestable biomass for Vongole (*Katelysia scalarina*, “greys”; *K. rhytiphora,* “yellows”; *K. peronii,* “whites”) to inform setting of the annual total allowable commercial catch (TACC) for the South Australian Vongole Fishery under the harvest strategy in the Management Plan (PIRSA 2013). Stock status was determined using a weight-of-evidence analysis and adopting the terminology of the National Fishery Status Reporting Framework (NFSRF; Piddock *et al.* 2021).

Coffin Bay Fishing Zone

Coffin Bay was fully sampled in 2015, 2020 and 2021; given their robustness, this report focuses on these three estimates of density and biomass (Foster 2022).

Estimated harvestable biomass in 2021 was 1095.0 t (80% confidence limit). As the TACC in 2021/22 was 40.8 t, this equates to a harvest fraction of 3.7% (see table below).

Using consistent transects, total harvestable biomass halved from 2015 to 2020, then more than doubled between 2020 and 2021. This mainly reflected an increase in the biomass of yellows. The increase in total biomass from 2020 to 2021 reflected increases in the densities of legal-sized yellows and greys. The presence of sublegal-sized individuals in length-frequency distributions in 2020 and 2021 suggests recent recruitment.

The Coffin Bay Vongole fishery was classified as ‘depleting’ in 2018/19 and 2020/21 (Heldt and Mayfield 2020; Heldt 2021). Between 2020 and 2021, there is evidence that the status of the Coffin Bay Fishing Zone (CBFZ) stock improved based on data that were sampled consistently across space and time: (1) harvestable biomass for yellows and greys increased; (2) densities of legal and sublegal yellows and greys increased; and (3) sublegal individuals were common in length-frequency distributions. The Coffin Bay Vongole Fishery in 2021/22 is classified as ‘**sustainable**’, reflecting a change from ‘depleting’.

West Coast Fishing Zone

The whole West Coast fishery was surveyed in 2021. This was different to the sequential sampling that occurred between 2015 and 2021: Streaky Bay in 2016; Smoky Bay in 2017; and Venus Bay in 2018.

The estimated harvestable biomass in 2021 was 630.8 t (393.6 t in Streaky Bay; 97.3 t in Smoky Bay; and 139.9 t in Venus Bay). As the TACC in 2021/22 was 16.0 t, this equates to a harvest fraction of 2.3% (see table below).

The status of the West Coast Vongole fishery was 'undefined' in 2018/19. The 2021 survey has demonstrated a high biomass, low harvest fraction and evidence of recent recruitment. Therefore, the West Coast Vongole Fishery in 2021/22 is classified as '**sustainable**', reflecting a change from 'undefined'.

Port River Fishing Zone

The Port River Vongole Fishing Zone has been closed since 2011/12 due to low levels of stock biomass, and therefore maintains the classification of '**depleted**'.

Key performance indicators and metrics for the South Australian Vongole Fishery are as follows:

Coffin Bay				
Year	**TACC (t)**	**Stock Status**	**Biomass (t)**	**Harvest Fraction (%)**
2015/16	50.0	Sustainable[1]	867.7	5.8
2016/17	50.0	Sustainable[1]	730.4	6.8
2017/18	50.0	Sustainable[1]	791.8	6.3
2018/19	50.0	Depleting[2]	538.5	9.3
2019/20	50.0	Depleting[2]	-	-
2020/21	50.0	Depleting[2]	543.9 t	9.2
2021/22	40.8	Sustainable[1]	1095.0 t	3.7

West Coast				
Year	**TACC (t)**	**Status**	**Biomass (t)**	**Harvest Fraction (%)**
2015/16	16.0	Sustainable[1]	478.1 (all bays)	3.3
2016/17	16.0	Sustainable[1]	236.4 (Streaky Bay)	N/A
2017/18	16.0	Sustainable[1]	109.1 (Smoky Bay)	N/A
2018/19	16.0	Undefined[3]	75.6 (Venus Bay)	N/A
2019/20	16.0	Undefined[3]	-	-
2020/21	16.0	Undefined[3]	-	-
2021/22	16.0	Sustainable[1]	630.8 (all bays)	2.3

[1] Biomass (or proxy) is at a level sufficient to ensure that, on average, future levels of recruitment are adequate (recruitment is not impaired) and for which fishing mortality (or proxy) is adequately controlled to avoid the stock becoming recruitment impaired (overfishing is not occurring) (Piddock *et al.* 2021)

[2] Biomass (or proxy) is not yet depleted and recruitment is not yet impaired, but fishing mortality (or proxy) is too high (overfishing is occurring) and moving the stock in the direction of becoming recruitment impaired (Piddock *et al.* 2021)

[3] Not enough information exists to confidently determine stock status (Piddock *et al.* 2021)

Keywords: mollusc; bivalve; Vongole; *Katelysia* spp.; fishery; stock assessment; stock status; harvestable biomass; harvest strategy.

1 INTRODUCTION

1.1 Overview

The genus *Katelysia* (Family Veneridae), commonly known as mud cockles or Vongole, is a group of commercially important bivalves that comprise a major faunal component of shallow estuarine and marine embayments (Roberts 1984). In Australia, the genus is represented by three species — *Katelysia scalarina* known as "greys", *K. rhytiphora* known as "yellows", and *K. peronii* known as "whites" — all of which are broadly distributed around the temperate coastline from Augusta, Western Australia to Port Jackson, New South Wales (Roberts 1984).

Vongole have been harvested in South Australia since the early 1960s, with management arrangements changing over that period (Table 1-1). Prior to 1985, most catches were obtained from the Port River and Kangaroo Island for use as bait. Despite increasing demand for human consumption, the fishery remained lightly exploited until 1995/96, when the state-wide annual catch first exceeded 50 t. From 1996/97, catches increased rapidly to a peak of 375 t in 2005/06. Most of the catch during this period was obtained from the Port River and Coffin Bay. Given the large number of licenses (>600) with access to the resource and the rapid increases in catch, sustainability concerns led to implementation of a quota management system across the three Vongole Fishing Zones (Port River, Coffin Bay and West Coast; Figure 1-1) in October 2008.

The combined total allowable commercial catch (TACC) for all zones in 2008/09 was 195 t. In 2009/10, a fishery-independent sampling program was established to estimate harvestable biomass in each of the fishing zones, following advice from fishers (West Coast and Coffin Bay) and survey results (Port River fishing zone) that raised sustainability concerns. Following the first assessment of harvestable biomass (Gorman *et al.* 2010), TACCs for 2010/11 were reduced to 11.3 t for the Port River, 48.1 t for Coffin Bay and 21.0 t for the West Coast (total 80.4 t).

In response to further sustainability concerns, the Port River Vongole Fishing Zone was closed from 1 July 2011, and the TACC for the West Coast was reduced for the 2011/12 season (Table 2). The Port River Vongole Fishing Zone remains closed and is classified as 'depleted' (Piddocke 2021).

The maximum exploitation rate specified in the Management Plan is 7.5% of the estimated harvestable biomass at the 80% confidence level (PIRSA 2013). Exploitation rates among similar bivalve fisheries are highly variable (e.g., 2.5% for the OHV Dutch Hand-Raked Cockle Fishery, Cappell 2019; 33% for the Thames Estuary Cockle Fishery, Hough and Andrews 2019). The Tasmanian Vongole Fishery in Anson Bay (*K. scalarina*), that uses similar methods to those described in this report to obtain estimates of harvestable biomass, sets its TACC at 10% of the most recent biomass estimate, and has a biomass limit reference point of 40 t (Tarbath and Gardner 2015).

This report provides estimates of harvestable biomass in the Coffin Bay Fishing Zone (CBFZ) and West Coast Fishing Zone (WCFZ), following established methods (Gorman *et al.* 2010; Dent *et al.* 2012, 2014, 2016; Heldt and Mayfield 2020). Stock status was determined using a weight-of-evidence assessment, with terminology adopted from the National Fishery Status Reporting Framework (NFSRF; Piddock *et al.* 2021), because the current Management Plan (PIRSA 2013) does not provide a definition of stock status. The key data sources used to determine status were: (1) changes in biomass relative to 2015, 2016-2018 (for WCFZ only) and 2020; (2) densities of legal-size Vongole; (3) frequency of legal-size Vongole; and (4) evidence of recruitment.

Table 1-1. Management milestones in the South Australian Vongole Fishery.

Date	Milestone
1960	Fishery started; Minimum legal length (MLL) set at 30 mm shell length (SL) Statewide
1990	MLL at Coffin Bay increased to 38 mm SL for all three *Katelysia* species
2005	Statewide catches peaked at 375 t
2008	TACCs introduced; TACCs: Coffin Bay (70 t); West Coast (25 t); Port River (100 t)
2009	TACCs: Coffin Bay (56 t); West Coast (15 t); Port River (22.6 t)
2010	• MLL at Coffin Bay reduced to 33 mm SL for all three species by ministerial exemption (ME) • TACCs: Coffin Bay (48.1 t); West Coast (21 t); Port River (11.3 t) • Trial to harvest Vongole at Coffin Bay at the natural ratio (yellow to grey Vongole 2:1)
2011	• Port River Vongole Fishing Zone closed due to concerns over sustainability • TACCs: Coffin Bay (48.1 t); West Coast (18 t)
2012	• TACCs increased to 50.0 t Coffin Bay and 18.5 t West Coast • MLL for greys at Coffin Bay reduced to 30 mm SL by ME • MLLs for yellows and whites at Coffin Bay returned to legislated 38 mm SL • TACCs: Coffin Bay (50 t); West Coast (18.5 t)
2013	• New Management Plan for SA commercial Marine Scalefish fishery (PIRSA 2013) • TACCs: Coffin Bay (50 t); West Coast (18.5 t)
2014	TACCs: Coffin Bay (46 t); West Coast (16 t)
2015	• TACCs: Coffin Bay (50 t); West Coast (16 t) • MLL for yellows and whites at Coffin Bay amended to 35 mm SL by ME
2016	TACCs: Coffin Bay (50 t); West Coast (16 t)
2017	TACCs: Coffin Bay (50 t); West Coast (16 t)
2018	TACCs: Coffin Bay (50 t); West Coast (16 t)
2019	TACCs: Coffin Bay (50 t); West Coast (16 t)
2020	TACCs: Coffin Bay (50 t); West Coast (16 t)
2021	TACCs: Coffin Bay (40.8 t); West Coast (16 t)

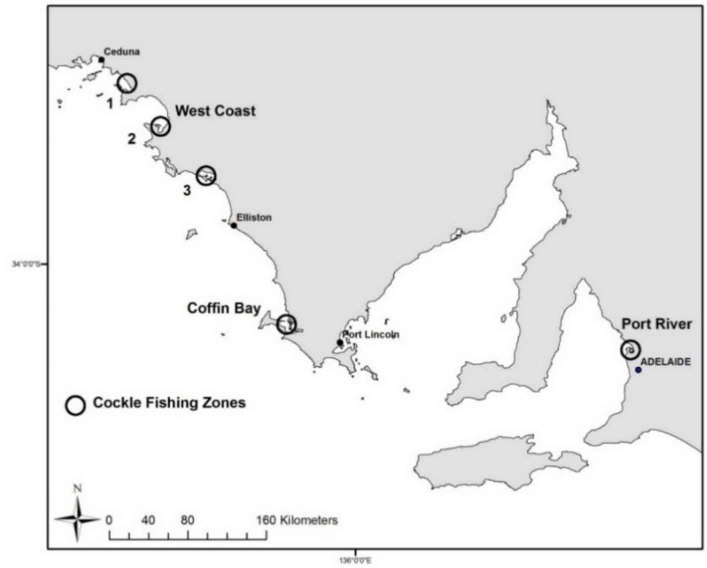

Figure 1-1. Map with locations of commercial Vongole Fishing Zones in South Australia: Port River, Coffin Bay and the West Coast. Coffin Bay contains four main fishing areas (Point Longnose, Long Beach, Little Douglas, and Oyster Farms), and the West Coast zone comprises Smoky Bay (1), Streaky Bay (2) and Venus Bay (3).

2 METHODS

2.1 Fishery-dependent information

Catch and effort data have been provided by the fishers to the South Australian Research and Development Institute (SARDI) on a monthly basis, since July 1984. Catch (weight in kg) and effort days and fisher days are reported against Marine Fishing Areas (MFAs). The first measure of effort (days) was the number of days fished. The second measure (fisher days) was the total number of individuals engaged in fishing, each day, multiplied by the number of days fished. Additionally, since 2003 catch/effort data have been reported by Marine Scalefish Fishery (MSF) licence holders on a daily basis. Catch, effort and catch-per-unit effort (CPUE) data are presented by financial year from 1984/85 to 2020/21. In cases where aggregated data included fewer than 5 licence holders, each statistic has been presented as a proportion of a nominal amount. Catch locations were inferred from the MFAs reported in the catch/effort log (Table 2-1).

Table 2-1. Locations of commercial Vongole catches by Marine Fishing Areas.

Location	Marine Fishing Areas
West Coast Fishing Zone	
Smoky Bay	8, 9
Streaky Bay	10
Venus Bay	15, 17
Coffin Bay Fishing Zone	27
Port Adelaide	36
Other	16, 20, 23, 28, 29, 30, 33, 34, 35, 40, 41, 42, 45

To evaluate the utility of CPUE as an index of relative abundance, annual CPUE was estimated from each of two effort units (days, fisher days; Appendix A).

2.2 Fishery-independent survey (FIS)

Survey design

The overall survey design integrated principles of fishery-independent research with knowledge obtained from commercial fishers (Mayfield *et al.* 2008; 2009). Within each Vongole Fishing Zone, fishers identified areas of high and low productivity in the fishing grounds on large-scale aerial photographs, which were digitised using a Geographic Information System package (ArcGIS V10.3.1) and used to identify areas of high and low-density strata. Maps depicting areas of different Vongole density were generated and returned to fishers for confirmation. To improve survey precision, transects were then distributed systematically within the high and low-density strata (Ault *et al.* 1999) with greater sampling intensity in areas with expected high densities of Vongole (high density strata, transects separated by 30-100 m) than those of expected low densities of Vongole (low density strata, transects separated by 250-360 m).

Since 2015, the Coffin Bay survey comprised 12 strata, while the West Coast survey comprised 28 strata: 9 in Smoky Bay, 3 in Streaky Bay and 16 in Venus Bay. The strata areas from which the transects were sampled remained consistent from 2015–2018. In 2020, new strata areas were sampled in Coffin Bay (i.e. 19 transects in a new strata at Oyster Farms and 4 transects in a new strata at Point Longnose South) and there was increased sampling intensity in existing strata (i.e. 14 new transects in Oyster Farms), based on information from fishers. Although Vongole were present in small numbers in Point Longnose South, this area was not surveyed, and this area is not included in biomass estimates or further discussed. For 2021, a further 41 transects were included in the eastern, southern and western Oyster Farms fishing ground.

For each year, from 2016 to 2018, surveys were based on a triennial method, comprising: (1) complete sampling of all established transects in at least one Coffin Bay primary fishing grounds; (2) subsampling of transects in the remaining Coffin Bay fishing grounds (Table 2-2); and (3) sampling of one West Coast bay (i.e. Streaky Bay in 2016, Smoky Bay in 2017, and Venus Bay in 2018; Table 2-3). Triennial sampling differed from the biennial method described in previous assessments (i.e. complete sampling of all fishing grounds; Gorman *et al*. 2010; 2011; Dent *et al*. 2012; 2014, 2016) where surveys were conducted every second year. Comparison of historical estimates of harvestable biomass was confounded by differences in the survey method among years for the Coffin Bay Fishing Zone and also prevented estimation of the total harvestable biomass or harvest fractions for the West Coast Fishing Zone. Hence, in 2020, there was a return to biennial sampling for Coffin Bay (i.e. sampling in 2020 and 2021) with all bays in the West Coast being sampled every three years (i.e. sampling in 2021).

The fishery-independent surveys were conducted by survey teams, including a SARDI observer and a commercial fisher. Sampling was completed at established sampling sites with fixed transects located using coordinates (latitude, longitude) stored in handheld global positioning system (GPS) units. At each sampling site, a commercial fisher used a Vongole rake of known size (range 32 to 45 cm in width by ~20 cm in height) with a mesh bag insert (2 cm stretched diagonal mesh size) to collect Vongole along a transect of 200 cm (i.e. ~0.8 m^2) length. Samples were sieved through 7 mm square mesh in the base of a plastic crate to remove sand. Live and dead Vongole were bagged, labelled and frozen for subsequent processing in the laboratory. Surveys results are reported in financial years (e.g. 2015 denotes 2015/16).

Table 2-2 The number of established transects in each of the primary fishing grounds in Coffin Bay (i.e. 2015 biennial sampling), in the triennial sampling program from 2016 to 2018, and in the 2020 and 2021 sampling years. Note bold font denotes entire fishing ground sampled, * denotes subsampling, where approximately every second established transect from the 2015 survey design was sampled and ** denotes addition of new transects.

	Number of transects sampled			
	Point Longnose	Oyster Farms	Little Douglas	Long Beach
2015	**91**	**38**	**33**	**61**
2016	**91**	26*	13*	19*
2017	33*	**37**	**33**	21*
2018	33*	26*	13*	**61**
2020	**91**	**71****	**33**	**61**
2021	**91**	**111****	**33**	**61**

Table 2-3 The number of established transects in each of the primary fishing grounds in the West Coast Fishing Zone (i.e. 2015 biennial sampling), in the triennial sampling program from 2016 to 2018 and 2021 sampling years. ** denotes addition of new transects.

	Number of transects sampled		
	Streaky Bay	Smoky Bay	Venus Bay
2015	42	53	98
2016	42		
2017		53	
2018			98
2020			
2021	42	53	109**

In the laboratory, each sample was sorted to remove dead shells and to identify Vongole to species (Cantin 2010). Legal and sub-legal Vongole were sorted, weighed, and counted. In the CBFZ, the MLL was 30 mm shell length (SL) for greys and 35 mm SL for yellows and whites resulting in the following classifications: (1) greys <30 mm SL, sublegal-sized (hereafter referred to as "sublegal"; (2) greys ≥30 mm, legal-sized, hereafter referred to as "legal", (3) yellows and whites <35 mm SL, sublegal-sized; and (4) yellows and whites ≥35 mm SL, legal-sized. For the WCFZ where the MLL was 30 mm for all species, individuals <30 mm SL were classified as sublegal-sized and those ≥30 were classified as legal-sized.

Methods for determining total weights and counts for sublegal and legal Vongole have varied among years. Prior to 2015 and in 2016, for each sample, Vongole were separated into legal and sublegal components, and size categories were counted and weighed to the nearest gram. In 2017 and 2018, each individual was measured using digital callipers to the nearest 0.1 mm along the longest axis (SL) and weighed to the nearest gram (Gorman *et al*. 2010; Dent *et al*. 2012; 2014) except for samples that exceeded 300 individuals (see Heldt and Mayfield 2020). In 2021, all Vongole were measured unless abundance for a transect was >100, in which case a subsample of ~100 individuals of each species was randomly chosen and individuals were measured and weighed; the remaining Vongole were grouped into size classes and weighed. A total weight was recorded for all samples. For each laboratory subsample, the proportion of the sample comprised each of the three species and the proportion by weight and number in sublegal and legal size-classes were determined, then scaled up to the whole weight to provide a total estimated weight and count for legal and sublegal Vongole for each species in each sample. Analyses were completed using R statistical software v3.5.0 (R Core Team, 2018).

The total number of Vongole collected in 2021 from Coffin Bay was 45,333 (n = 296 transects, sampling area = 6.4 km^2). For comparison among years, estimated harvestable biomass, densities and length frequency distributions were obtained from consistent transect locations (n = 223, sampling area = 6.2 km^2).

A total of 20,365 Vongole were collected from the West Coast Fishing Zone in 2021, with 2,846 individuals obtained at Streaky Bay (n=42 transects, sampling area = 1.6 km^2), 10,044 at Smoky Bay (n=53, 1.2 km^2) and 7,475 obtained at Venus Bay (n=108, 1.8 km^2). For Venus Bay in 2021, 108 transect locations were surveyed that included 10 additional locations north and south of Germein Island and on the Venus Peninsula. For comparison across 2015, 2018 and 2021, estimates were based on 98 consistent transect locations (1.6 km^2).

Temporal change in density and length-frequency distribution

To evaluate changes in density, biomass and length frequency distributions among years in Coffin Bay and the West Coast, methods described in Heldt and Mayfield (2020) were followed, using consistent transects and current size limits from 2015, 2020 and 2021 (Coffin Bay: 223 transects; West Coast: 42 transects in Streaky Bay, 53 transects in Smoky Bay, and 98 transects in Venus Bay). For Coffin Bay, these three years were selected because they represent ‘full’ surveys and were not confounded by the relatively limited, triennial sampling program (Foster 2022). For the West Coast, the years included were the years in which each bay were surveyed. A time-series of total densities (all sizes) for transects in large or high-density strata in Coffin Bay from 2013 to 2021 are provided in Appendix B-2.

Estimates of harvestable biomass

In 2020 and 2021, the estimates of harvestable biomass for the Coffin Bay Fishing Zone were obtained using 256 and 296 transects, respectively (Table 2-2). The additional transects in 2021 provided increased spatial intensity of transect locations at Oyster Farms. The harvestable biomass estimate for each bay in the WCFZ was calculated using all transects from 2015 (Table 2-2). For Venus Bay, 11 additional transect locations were included in 2021.

Harvestable biomass for each of Coffin Bay, Streaky Bay, Smoky Bay and Venus Bay was estimated by: (1) calculating weighted-means, by using the mean biomass per transect area (i.e. g/~0.8 m^2) for each stratum multiplied by its respective stratum area (m^2); and then (2) summing the weighted-means:

$$\text{Harvestable biomass (G)} = \sum_{k=1}^{n} N_h\,\bar{x}_h, \text{where } N_h = \text{stratum area and } \bar{x}_h = \text{ mean biomass}$$

A non-parametric bootstrap method (after McGarvey *et al.* 2008) was used to determine quantiles of the estimates of legal-sized biomass for each species, in each fishing ground, using R statistical software v3.5.0 (R Core Team, 2018). All strata and survey areas within each fishing ground were included in the analysis. The bootstrap procedure accounted for the random variation among the primary sample units (i.e. the transect sample locations). The 20,000 bootstrap iterations of estimated biomass were ranked and the 10–90% quantile confidence intervals extracted, and a table for each fishing ground was generated based on the nine quantile levels of lower-bound, survey-estimated biomass (Mayfield *et al.* 2008; Gorman *et al.* 2011). Each value specifies the cumulative confidence probability that the actual harvestable Vongole biomass is greater than or equal to the estimated biomass values. Values in the tables were considered conservative since the assumption that the sampling gear was 100% efficient was unlikely to be true. These tables provide a risk assessment framework for TACC determination. The sum of harvestable biomass values for each species at the 80% quantile was used to determine the harvest fraction for the Coffin Bay and West Coast Fishing Zones.

3 RESULTS

3.1 Fishery-dependent data

3.1.1 State-wide catches

From 1983/84 to 1994/95, State-wide catches of Vongole were below 50 t.y^{-1} (Figure 3-1). From 1995/96, total annual catches increased to a peak historical value of 384 t in 2005/06. From then, annual catches remained above 300 t.y^{-1} until 2007/08 before declining to steeply to 171 t in 2008/09. This was lower than the first annual State-wide TACC of 195 t. In 2009/10, the TACC of 93.6 t constrained the State-wide annual catch. Although the TACC of 107 t in 2010/11 failed to constrain the catch of 85 t, catches were constrained each year thereafter.

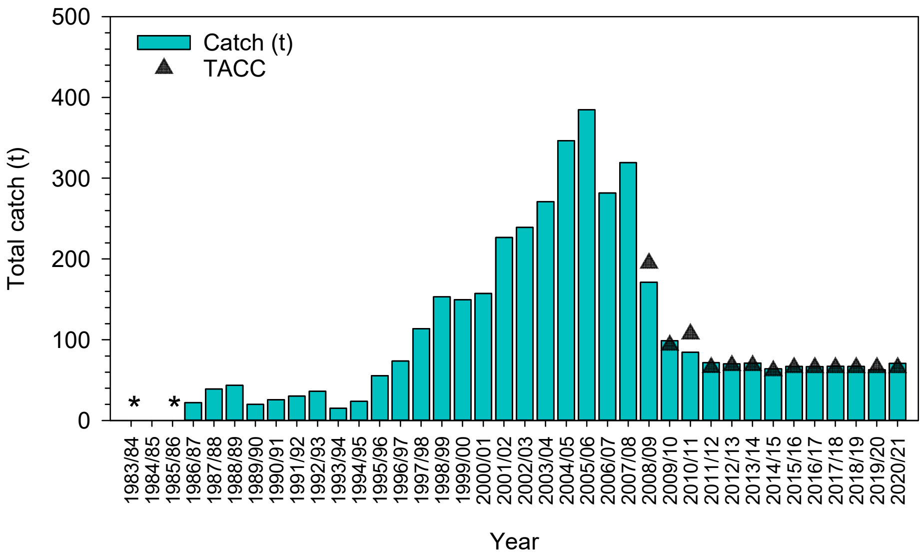

Figure 3-1. South Australian catches of Vongole from 1984/85 to 2020/21: (A) total annual catches (bars) and total allowable commercial catch (triangles). *removed for confidentiality (<5 licences).

3.1.2 Catches from West Coast and Coffin Bay Fishing Zones

Catches from Coffin Bay made a significant contribution to the State-wide catch in most years from 1984/85 with this location the major contributor to the State-wide catches from 2004/05, with the remainder (~25%) from the West Coast Fishing Zone (WCFZ; Figure 3-2). The WCFZ catches were harvested from Streaky, Smoky and Venus Bays from 2002/03 onwards (Figure 3-2). Catches from Port Adelaide were the dominant contributor to the State-wide catch from 1994/95 to 2008/09, followed by a rapid decline to low levels from 2009/10 until the fishery was closed in 2011.

While the contribution to the State-wide catch from the west coast has been relatively consistent among years since TACCs were introduced in 2008, the contribution from Streaky Bay has declined since 2010/11 (from ~14% to 4%), while that from Venus Bay has increased (from 5% to 15%; Figure 3-2).

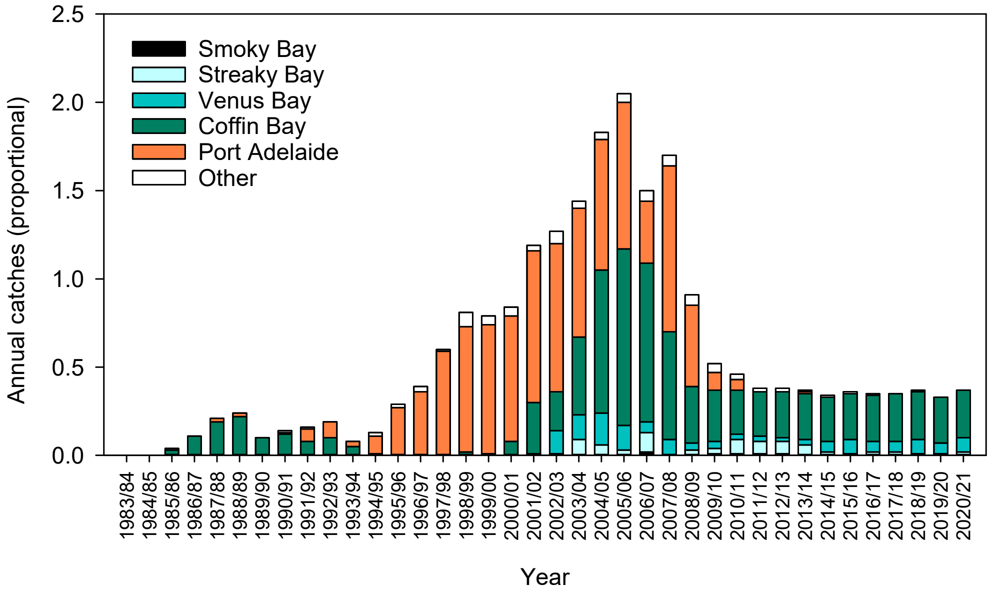

Figure 3-2. Location of South Australian catches of Vongole from 1984/85 to 2020/21. Catches are expressed as proportions to protect licence holder confidentiality (<5 licences).

3.2 Fishery-independent surveys

Coffin Bay Fishing Zone

In 2021, yellows were the dominant species by number contributing 72% of the total while greys contributed the remaining 28%. The estimate of harvestable biomass at the 80% CI for Coffin Bay was 1095.0 t. The overall contribution to harvestable biomass was higher for yellows than greys, with whites not contributing to the biomass (Table 3-1).

Estimated harvestable biomass, based on consistent transects in 2015, 2020 and 2021, decreased by 50% from 867.7 t in 2015 to 437.4 t in 2020 (Figure 3-3; Dent *et al*. 2016; Heldt 2021). From 2020 to 2021, the estimated harvestable biomass more than doubled to 1,199.1 t (**Error! Reference source not found.**).

During 2015–2020, the average density of legal-size yellows and greys followed the trend observed for harvestable biomass (Figure 3-4). The average densities of sublegal yellows and greys increased by a factor of three times. From 2020 to 2021, the density of sublegal-sized yellows increased further and was approximately double that from the previous year with a similar but smaller increase observed for greys.

Table 3-1. Estimated total harvestable biomass (t) for the Coffin Bay Fishing Zone for 10-90% quantiles in 2021 for greys; yellows and whites. Surveys were completed in September and October 2021 (n = 296 transects). Minimum legal lengths vary among species: greys (30 mm); yellows (35 mm); and whites (35 mm). Total harvestable biomass estimates for each quantile in bold.

Coffin Bay 2021

Species	**Probability (%) of legal biomass estimate (t)**								
	90%	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**
Greys (*K. scalarina*)	166.5	179.4	189.3	197.9	206.5	215.3	225.1	236.8	253.7
Yellows (*K. rhytiphora*)	862.3	915.6	953.5	987.1	1020.6	1054.5	1090.4	1134.2	1193.5
Whites (*K. peronii*)	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.9	0.9
Total	**1028.8**	**1095.0**	**1142.8**	**1185.5**	**1227.6**	**1270.3**	**1316.0**	**1371.9**	**1448.1**

In 2015, the length frequency distribution for greys was bimodal with a dominant mode (31 mm) slightly above the MLL of 30 mm and a smaller mode (21 mm) representing potential future recruits to the harvestable biomass (Figure 3-5). In 2020 and 2021, the length frequency distributions for this species were unimodal with modes at 21 mm and 23 mm, respectively. Length-frequency distributions for yellows were multi-modal for each year surveyed with a dominant mode (41 mm) above the MLL in 2015, and a smaller secondary mode (25 mm; Figure 3-5). In 2020, the length frequency distribution for yellows was characterised by a dominant mode at 25 mm, a secondary mode at 31 mm and a smaller mode above the MLL at 45 mm. In 2021, the distribution for this species was bimodal with the dominant mode at 27 mm and secondary mode at 45 mm. The persistence of modes of sublegal sized Vongole from 2015 to 2021 for greys and yellows suggests that recruitment remains strong.

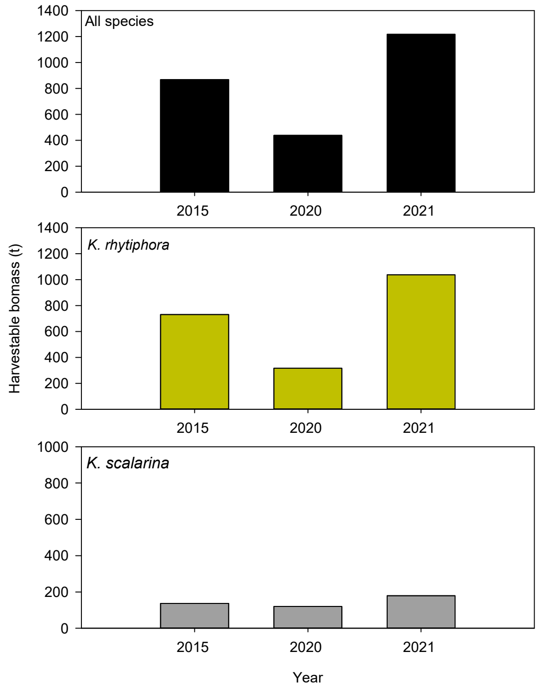

Figure 3-3. Estimates of harvestable biomass from Coffin Bay in 2015, 2020 and 2021 using consistent transect locations (n=223). Scales on y-axes vary between species.

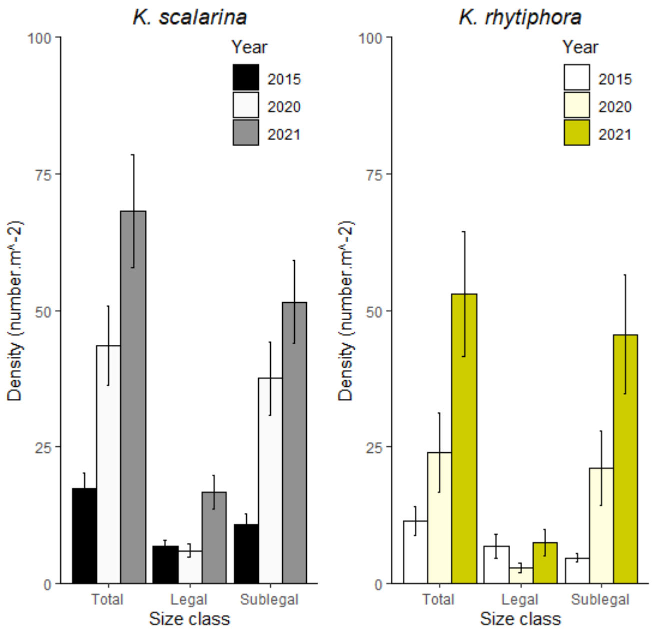

Figure 3-4. Mean average legal density (Vongole.m^{-2}) of greys (grey) and yellows (yellow) from Coffin Bay in 2015, 2020 and 2021 using consistent transect locations (n = 223 transects). Scales on y-axes vary between species.

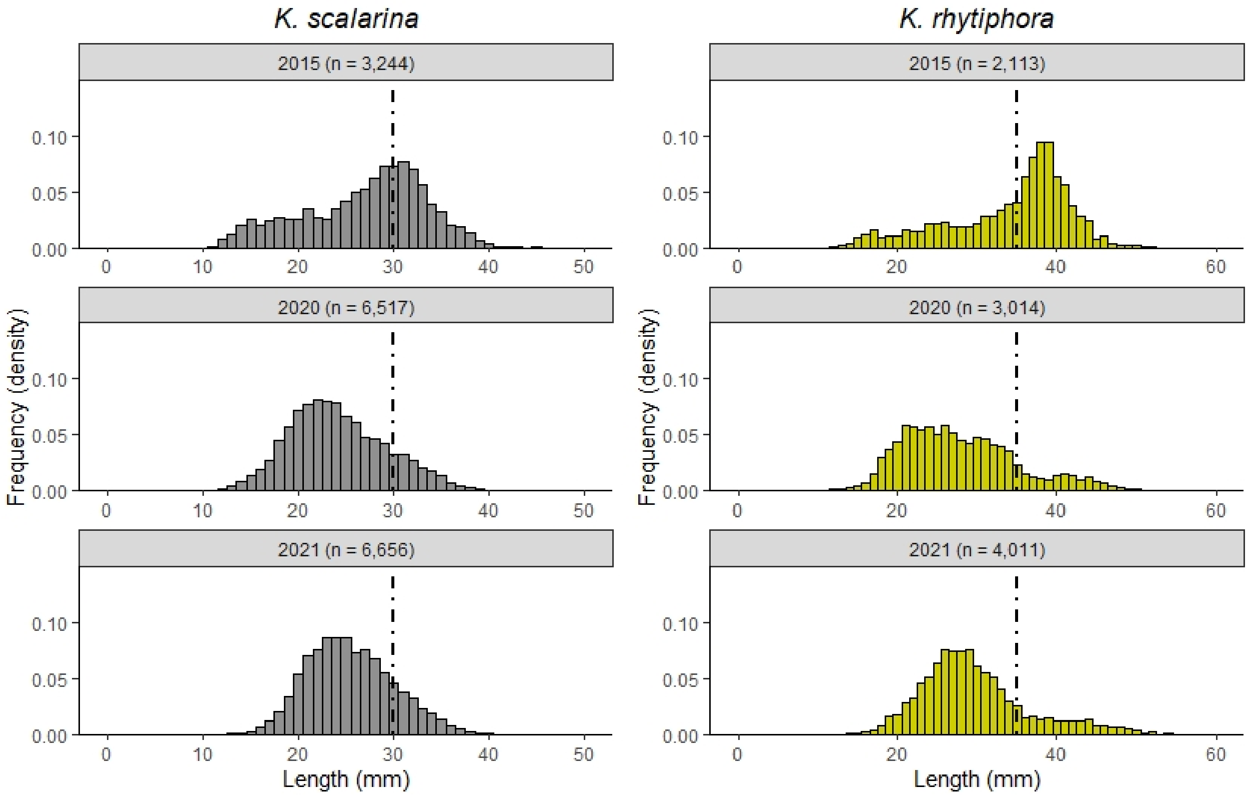

Figure 3-5. Length-frequency distributions of greys (grey, left) and yellows (yellow, right) from Coffin Bay in 2015, 2020 and 2021 using consistent transect locations (n = 223 transects). Scales on y-axes vary between species but not among years, vertical dashed line indicates the current MLLs.

West Coast Fishing Zone

For Streaky Bay, Smoky Bay and Venus Bay the dominant species, by number, at was greys, which comprised 81%, 90% and 77% of the total numbers, respectively. The total harvestable biomass (80% CI) for the WCFZ was 630.8 t (Table 3-2).

Table 3-2. Estimated total harvestable biomass for the West Coast Fishing Zone (t) for 10–90% quantiles in 2021 for greys; yellows and whites. Surveys were completed during August–October 2021. (Transects: Smoky Bay, n=53; Streaky Bay, n=42; Venus Bay, n=108). Minimum legal length was 30 mm for all species. Total harvestable biomass estimates for each quantile in bold.

Streaky Bay 2021

Species	**Probability (%) of legal biomass estimate (t)**								
	90%	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**
Greys *(K. scalarina)*	196.8	227.0	249.9	270.1	288.9	309.4	331.2	357.5	394.4
Yellows *(K. rhytiphora)*	141.9	166.7	184.8	200.5	215.7	230.6	246.8	266.4	291.5
Whites *(K. peronii)*	0.0	0.0	0.0	0.7	0.7	0.7	0.7	1.4	1.4
Total	**338.7**	**393.6**	**434.7**	**471.3**	**505.3**	**540.7**	**578.7**	**625.3**	**687.2**

Smoky Bay 2021

Species	**Probability (%) of legal biomass estimate (t)**								
	90%	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**
Greys *(K. scalarina)*	63.9	74.1	81.7	88.5	95.0	101.5	108.9	118.1	130.9
Yellows *(K. rhytiphora)*	16.4	23.2	67.2	71.3	74.3	77.5	82.6	125.8	132.2
Whites *(K. peronii)*	0.0	0.0	0.0	0.5	0.5	0.5	0.5	1.0	1.0
Total	**80.3**	**97.3**	**148.9**	**160.2**	**169.8**	**179.5**	**192.0**	**244.9**	**264.1**

Venus Bay 2021

Species	**Probability (%) of legal biomass estimate (t)**								
	90%	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**
Greys *(K. scalarina)*	75.3	82.4	88.1	92.9	97.6	102.2	107.6	113.7	122.8
Yellows *(K. rhytiphora)*	49.6	56.7	62.1	66.7	71.1	75.7	80.5	86.3	94.7
Whites *(K. peronii)*	0.4	0.8	1.1	1.4	1.5	1.7	2.1	2.3	2.6
Total	**125.3**	**139.9**	**151.3**	**161.0**	**170.2**	**179.6**	**190.1**	**202.4**	**220.1**

Streaky Bay

In 2021, the harvestable biomass at the 80% CI for Streaky Bay was 393.6 t (Table 3-2). Estimated total harvestable biomass was similar in 2015 and 2016 but increased by 66% to 2021 (Figure 3-6). This increase mostly reflected an increase in yellows, combined and a small increase for greys. The increase for yellows related to increases in the density of legal and sublegal individuals (Figure 3-7). For greys, the total density increased from 2016 to 2021, mostly reflecting higher densities of sublegal individuals, while the density of legal individuals remained stable during this period.

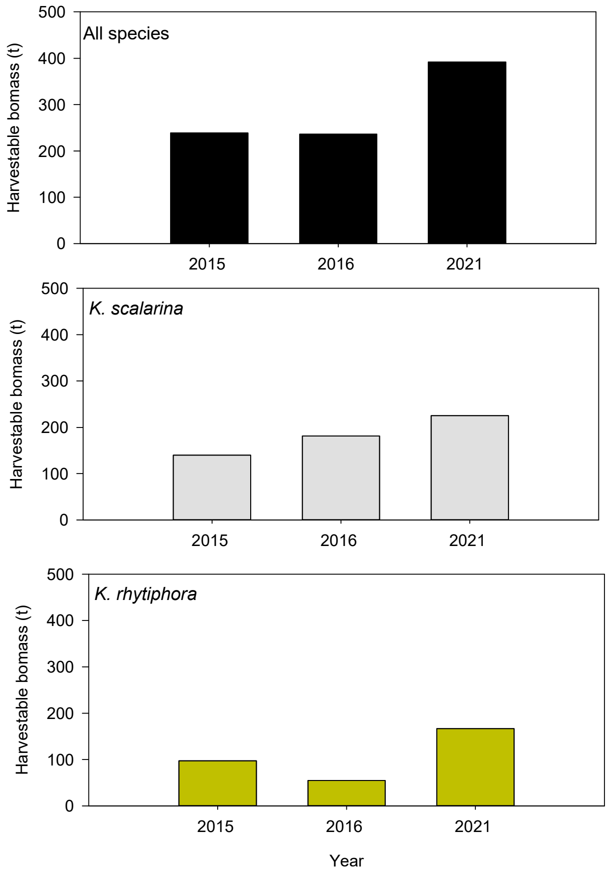

Figure 3-6. Estimates of harvestable biomass for (A) all species (black bars), greys (grey bars), and yellows (yellow bars) using consistent transect locations (n=42) at Streaky Bay in 2015, 2020 and 2021.

In 2015 and 2016, length frequency distributions of yellows had dominant modes of legal individuals (~37 mm; Figure 3-8). In 2021, the dominant mode was at ~32 mm with a secondary mode of sublegal yellows (~20 mm) that indicated potential recruitment to the fishery.

Distributions of greys were multimodal with 1–2 modes of sublegal individuals and few legal individuals greater than 40 mm.

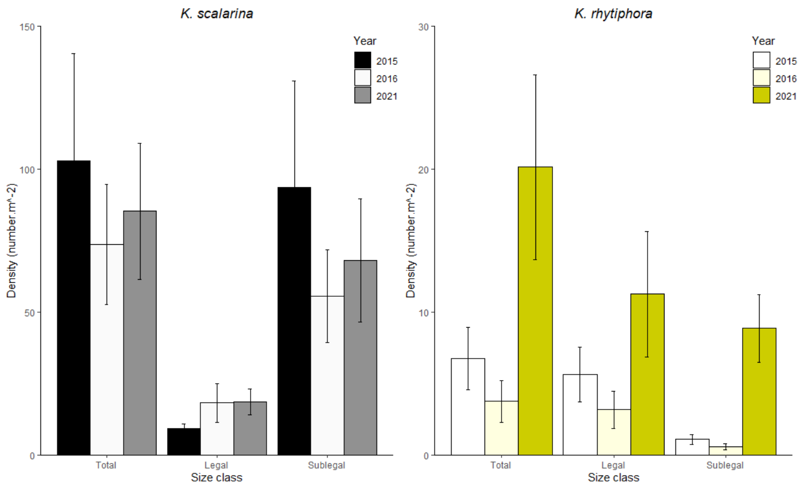

Figure 3-7. Estimated density of a greys (*K. scalarina*), and yellows (*K. rhytiphora*) using consistent transect locations (n=42) at Streaky Bay in 2015, 2016 and 2021.

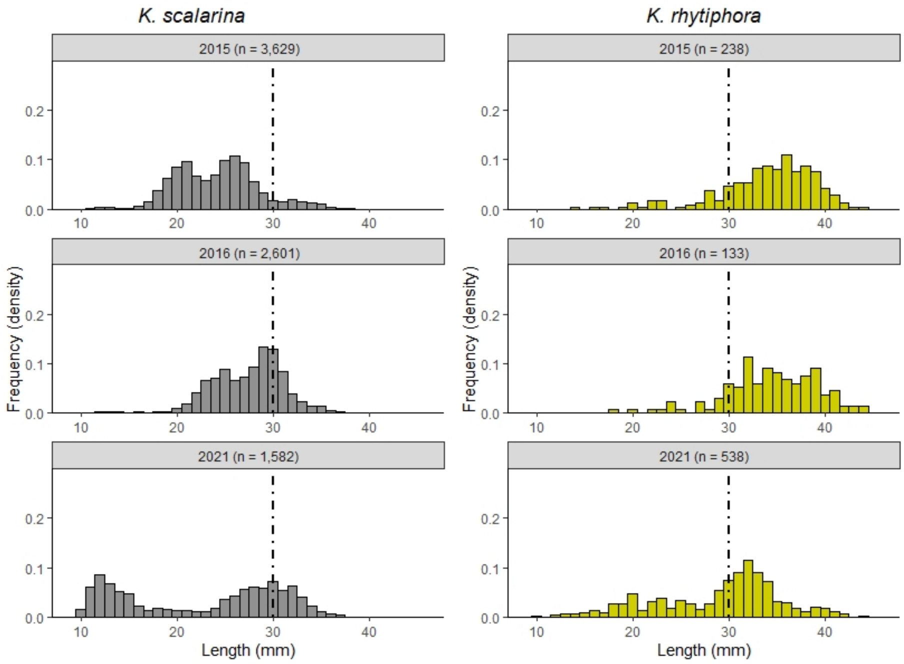

Figure 3-8. Length-frequency distributions for greys (grey bars) and yellows (yellow bars) from Streaky Bay in 2015, 2016 and 2021 (n=42 transects). Vertical dashed line indicates the MLL of 30 mm SL. Scales on y-axes vary between species.

Smoky Bay

In 2021, the total harvestable biomass at the 80% CI in Smoky Bay was 97.3 t (Table 3-2). Overall, total harvestable biomass was consistent across 2015 to 2021 (~95–110 t). Harvestable biomass of greys was consistent between 2015 and 2017, then increased (31%) over 4 years to 2021 (Figure 3-9). For yellows, harvestable biomass (62%) from 2015 to 2017, then decreased (50%) over 4 years to 2021. The density of legal greys was similar during 2015–2017, then increased in 2021 (Figure 3-10). The density of legal yellows increased from 2015–2017, then remained stable in 2021. During 2015–2021, the densities of sublegal individuals increased for both yellows and greys.

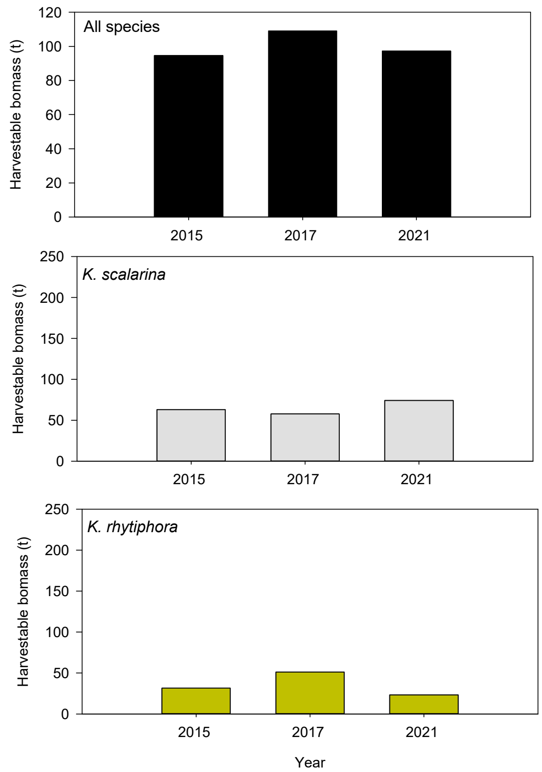

Figure 3-9. Estimates of harvestable biomass for (A) all species (black bars), greys (grey bars), and yellows (yellow bars) using consistent transect locations at Smoky Bay (n=53) in 2015, 2017 and 2021. Scales on y-axes vary between species.

In 2015, the length frequency distribution for greys was dominated by a mode of small individuals (~18 mm) which appeared to persist to 2021 at a modal size (~28 mm) which was close to the MLL. This suggested potential for recruitment to the fishery (Figure 3-11). In 2015, the distribution for yellows was dominated by a mode of larger individuals (~34 mm). In 2017 and 2021, the distributions for yellows were dominated by modes of smaller individuals also suggesting potential for recruitment to the fishery.

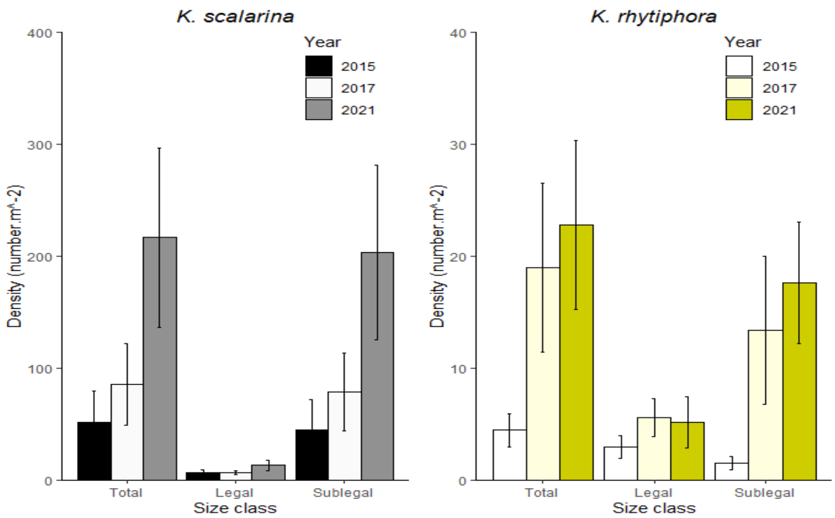

Figure 3-10. Estimated density of a greys (*K. scalarina*), and yellows (*K. rhytiphora*) for comparable transect locations (n=53) at Smoky Bay in 2015, 2017 and 2021. Scales on y-axes vary between species.

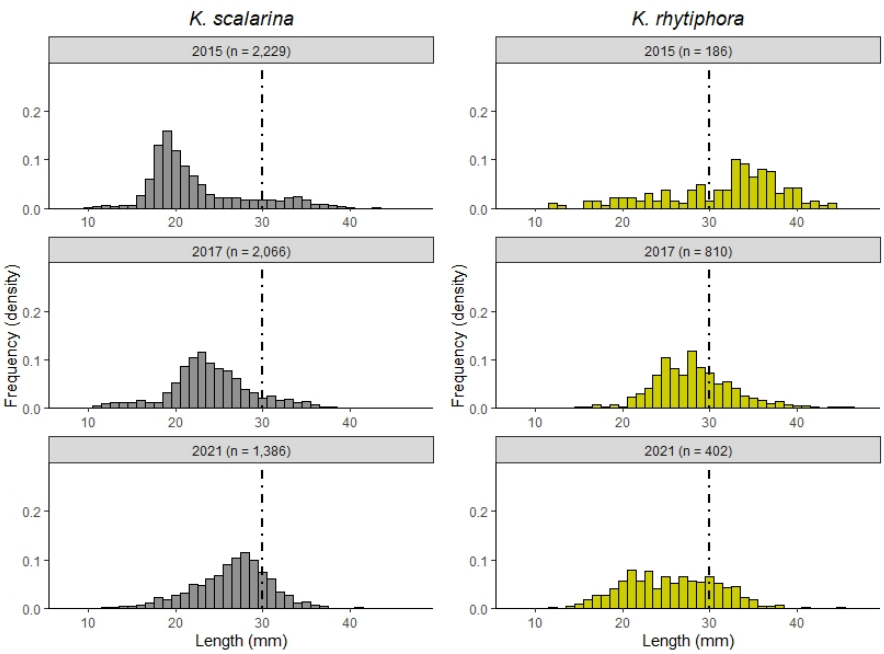

Figure 3-11. Length-frequency distributions for greys (grey bars) and yellows (yellow bars) from Smoky Bay in 2015, 2017 and 2021 from comparable transect locations (n=53). Vertical dashed line indicates the MLL of 30 mm SL. Scales on y-axes vary between species.

Venus Bay

In 2021, the total harvestable biomass at the 80% CI for Venus Bay was 139.9 t (Table 3-2). The harvestable biomass decreased from 2015 to 2018 before increasing (16%) to 2021. This reflected the temporal trend for greys, which contributed 77% of the harvestable biomass (Figure 3-12). Yellows made smaller contributions to the total harvestable biomass (20%) and showed a slightly increasing temporal trend from 2015–2021. The whites observed in total harvestable biomass estimates and size structures in 2015 and 2018 were not observed in 2021.

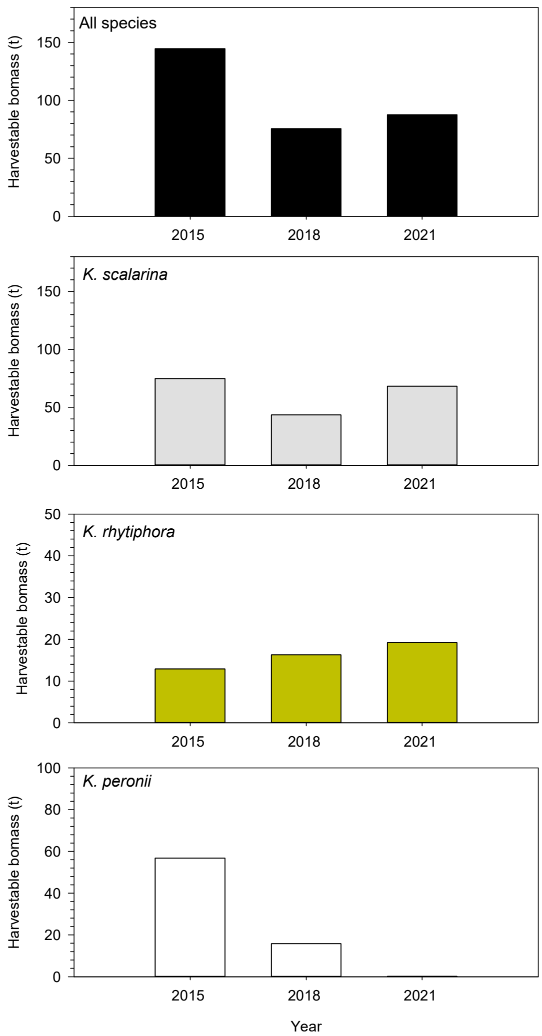

Figure 3-12. Estimates of harvestable biomass for all species (black bars), greys (grey bars), yellows (yellow bars) and whites (white bars) using consistent transect locations (n=98) at Venus Bay in 2015, 2018 and 2021. Scales on the y-axes vary among species.

The increase in harvestable biomass of yellows reflected increases in the density of legal and sublegal-sized individuals (Figure 3-13). For greys, the total density was stable during 2015–2018 then increased to 2021. This reflected increased densities of sublegal individuals, while the density of legal individuals was stable during this period.

In 2015, the length frequency distribution of yellows comprised a single mode (~33 mm) of legal individuals but was bimodal in 2018 with a mode close to the MLL (~30mm) and a secondary mode of legal individuals (~36 mm) (Figure 3-14). The dominant mode (~28 mm) in 2021 suggested potential recruitment to the fishery. The temporal trend in length frequency distributions was similar for greys, except for the presence of multiple modes of sublegal individuals present in 2021 which suggested several (~12 mm, ~22 mm) year classes with potential to recruit to the harvestable biomass.

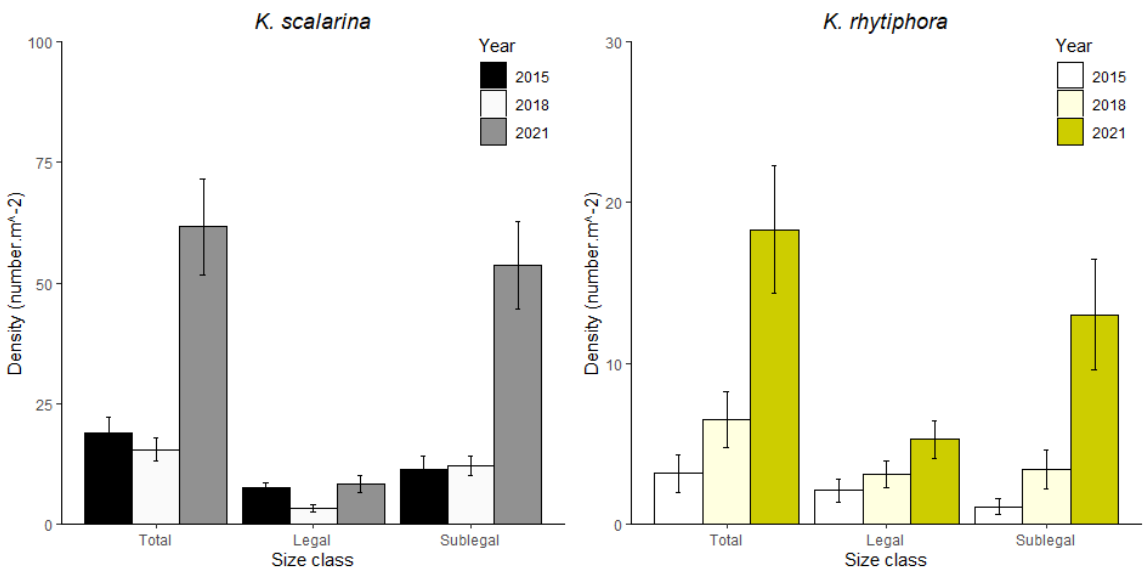

Figure 3-13. Estimated density of a greys (*K. scalarina*), and yellows (*K. rhytiphora*) using consistent transect locations (n=98) at Venus Bay in 2015, 2018 and 2021.

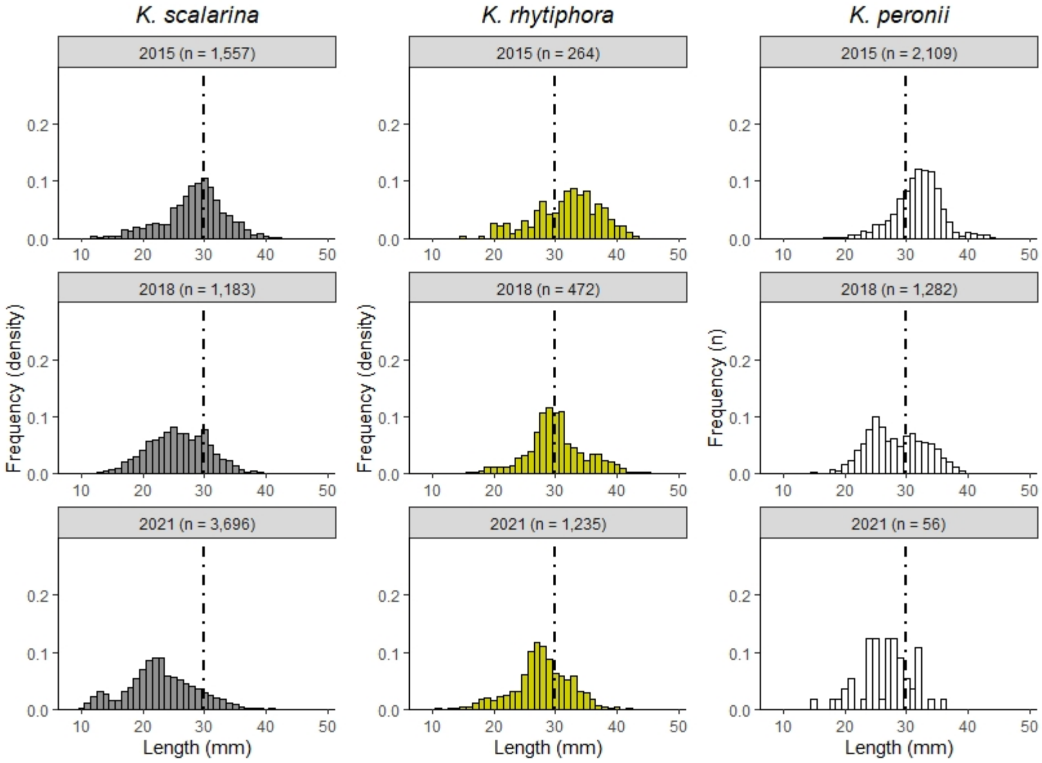

Figure 3-14. Length-frequency distributions for greys (grey bars), yellows (yellow bars) and whites (white bars) from Venus Bay in 2015, 2018 and 2021 using consistent transect locations (n=98). Vertical dashed line indicates the MLL of 30 mm SL. Scales on y-axes vary between species.

4 DISCUSSION

4.1 Information sources used for the assessment

Fishery-dependent information

Catch, effort and two types of CPUE data for Vongole were available from 1984/85 to 2020/21 for the Coffin Bay and West Coast Fishing Zones. There is uncertainty around the use of fishery-dependent CPUE as an index of relative abundance, partly due to changes in targeting for different markets (Maunder *et al*. 2006; Gorman *et al*. 2010; Ferguson *et al*. 2015). This is supported by different temporal trends for CPUE based on catch per day, compared to that based on catch per fisher day, that suggest fishing practices may have changed over time. This means CPUE is unlikely to be a reliable indicator of changes in Vongole abundance.

Fishery-independent information

Uncertainty around CPUE as an index of abundance for Vongole led to the development of the use of fishery-independent surveys (FIS) of biomass as a stock assessment tool (Gorman *et al*. 2010). The survey design, and methods used for the fishery-independent surveys, were reviewed in 2022 (Foster 2022). Key outcomes from the review were that: (1) the area surveyed should be consistent among years to support historical comparisons of biomass; (2) the temporal frequency of surveys should be consistent, and ongoing, with an interval of two years an appropriate compromise; and (3) all individual Vongole should be measured, rather than using bin counts, to future-proof the historical data against changes in the MLL (this adjustment was made in 2016). Overall, the review concluded that the sampling program, and associated analyses, were fit for purpose (Foster 2022).

Uncertainty around the assessment of stock status of the South Australian Vongole Fishery has been significantly reduced in 2021 by: (1) returning to biennial, complete sampling of Coffin Bay; (2) sampling all three West Coast bays within a single year; and (3) increasing survey sampling in Coffin Bay to include an area identified by fishers in 2021 as having high Vongole densities (Foster 2022).

Estimates of biomass are available from 2009 to 2021 for Coffin Bay, Streaky Bay, Smoky Bay and Venus Bay, although estimates are not available for all locations in all years. Size frequency data are available at the same temporal and spatial scales as the biomass estimates. For Coffin Bay, this report focused on the three most recent complete surveys (2015, 2020, 2021), which provided the most robust comparable estimates of harvestable biomass across 6 years (Dent *et al.* 2016; Foster 2022). For the West Coast Fishing Zone (WCFZ), the three most recent complete surveys were: Streaky Bay (2015, 2016, 2021), Smoky Bay (2015, 2017, 2021) and Venus Bay (2015, 2018, 2021). Again, this approach is considered to provide the most robust and reliable information (Foster 2022).

4.2 Current status

Coffin Bay Fishing Zone

The estimated harvestable biomass in 2021 (80% confidence interval) was 1095.0 t. As the TACC was 40.8 t, this equates to a harvest fraction of 3.7%. This is a substantial increase to the biomass estimate, and a large reduction to the harvest fraction, when compared with 2020. However, catches by species were unlikely to be harvested in proportion to the available biomass, because catches were dominated by yellows.

Notably, the estimate of harvestable biomass, based on consistent transects, decreased by 50% between 2015 and 2020. However, a large increase in Vongole density and harvestable biomass was observed between 2020 and 2021, primarily driven by an increase in biomass of yellows which contributed most of the biomass. This increase was consistent with increases in the density of sublegal yellows from 2015 to 2020 and from 2020 to 2021, as well as a mode of smaller sublegal individuals present in the length-frequency distribution in 2020 that appear to have entered the harvestable biomass in 2021. This potential recruitment was noted in Heldt (2021).

For bivalves, such as Vongole, abundance may vary widely among years due to high inter-annual variability in recruitment (Cantin 2010, Dent *et al*. 2016, Heldt and Mayfield 2020). For Coffin Bay, the presence of modes of smaller sublegal individuals in length frequency distributions for yellows (2020, 2021) and greys (2015, 2018, 2021) suggest recent progression to the harvestable biomass between the 2020 and 2021 surveys. For yellows, a mode of sublegal (~30 mm) individuals in length frequencies in 2020 appear to have entered the harvestable biomass by 2021. These patterns in length-frequency distributions are supported by observations of localised recruitment in Coffin Bay (individuals <5 mm SL attached to shells by byssal thread) by fishers and SARDI staff during October–November in 2020.

Fishery-independent surveys in 2021 provided several positive indicators of stock status of Vongole in Coffin Bay: (1) a greater than 200% increase in harvestable biomass when compared to 2020; due to (2) increases in harvestable biomass of both yellows and greys; reflecting (3) increases in densities of legal-sized yellows and greys; and (4) clear evidence of recent recruitment through increases in the densities of sublegal-sized Vongole. This evidence indicates that biomass is at a level sufficient to ensure adequate levels of recruitment and that mortality is adequately controlled to avoid the stock becoming recruitment impaired. On the basis of this evidence, the Coffin Bay Vongole Fishery in 2021/22 is classified under the NFSRF as '**sustainable**'. This is a change from the previous classification of 'depleting' in 2020 (Heldt 2021).

West Coast Fishing Zone

Estimates of total harvestable biomass in 2021 were highest in Streaky Bay (393.6 t at 80% CI), lowest in Smoky Bay (97.3 t at 80% CI), and intermediate in Venus Bay (139.9 t at 80%CI). The cumulative estimate across all three bays was 630.8 t. This is 4.5% higher than the last full-survey estimate of 603.5 t in 2015, and reflects increases in Streaky Bay and Venus Bay, and a stable harvestable biomass for Smoky Bay. As the TACC in 2021/22 was 16.0 t, this represents a harvest fraction of 2.3%. However, catches are not harvested from these three bays in proportion to the available biomass. For example, based on catches from 2020/21 and the 2021 estimated harvestable biomass, the harvest fractions for each West Coast bay in 2020/21 were 0% for Smoky Bay, 1% for Streaky Bay and 10% for Venus Bay.

Fishery-independent surveys provide several postive indicators of stock status for the three bays in the WCFZ: (1) increased biomass from the last full survey; reflecting (2) increases in harvestable biomass at Streaky Bay and Venus Bay; based on (3) higher densities of legal-sized yellows at Streaky Bay and Venus Bay in 2021 than in 2016 or 2018 respectively; (4) higher densities of legal-sized greys at Smoky Bay and Venus Bay in 2021 than in 2017 and 2018 respectively; and (5) widespread evidence of recent recruitment through increases in densities of sublegal Vongole. The evidence above indicates that biomass is at a level sufficient to ensure adequate levels of recruitment and that mortality is adequately controlled to avoid the stock becoming recruitment impaired. On the basis of this evidence, the West Coast Vongole Fishery in 2021/22 is classified under the NFSRF as '**sustainable**'. This is a change from the previous classification of 'undefined' in 2018 (Heldt and Mayfield 2020).

4.3 Future Research Needs

The first Management Plan that is specific to the South Australian Vongole Fishery is currently being developed, and the Harvest Strategy (HS) is under review. In reviewing the HS, consideration should be given to (1) establishing performance indicators and/or the limit reference point for identifying when the stock is 'depleting' or 'depleted'; (2) species-specific TACCs for Coffin Bay because catches focus on yellows, yet greys comprise a substantial part (16%) of the harvestable biomass, resulting in disproportionate harvest fractions; (3) bay-specific TACCs for the West Coast because each bay in the WCFZ likely comprises a separate Vongole population;

and (4) if the Harvest Strategy is based on fishery-independent surveys, the optimal survey design (i.e. frequency and sampling intensity; Foster 2022). For the latter, the comprehensive dataset from 2021 can be used to evaluate the impact of less-intensive sampling on biomass estimates, including their uncertainty.

There are areas of Coffin Bay with high Vongole densities, which are thought to impede growth rates. Industry have suggested that translocation/thinning of stocks may increase growth rates, yield and the spatial extent of stocks. Testing this hypotheses is a high research priority.

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APPENDIX A – COMMERCIAL CATCH, EFFORT AND CPUE

Coffin Bay Fishing Zone

Annual catches from Coffin Bay were historically low from 1985/86 to 1999/00, then increased steeply (>600%) from 2000/01 to the historical peak in 2005/06 (**Error! Reference source not found.**). From 2006/07 to 2007/08, annual catches declined to 2008/09, then remained stable at a an historically moderate level until 2020/21. The temporal trend in annual effort$_d$ and effort$_{fd}$ generally followed that of annual catches. However, from 2008/09, values of effort$_{fd}$ were higher than those for effort$_d$ with this divergence reflecting increased numbers of fishers per licence per day. The temporal trend in effort$_d$ was variable among years until 2000/01, then increased to an historical peak in 2006/07, before declining to 2007/08. From 2008/09, annual CPUE$_{fd}$ was lower than corresponding values CPUE$_d$, with this divergence also likely reflecting increased numbers of fishers per licence per day.

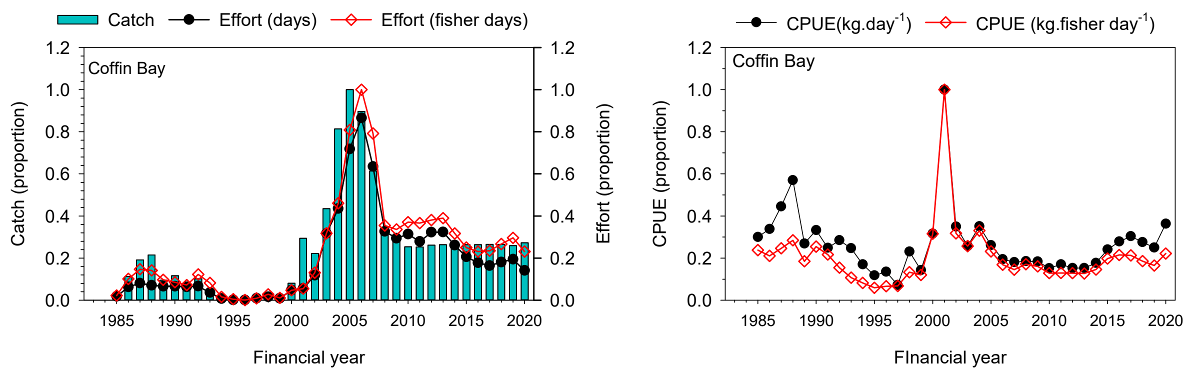

Figure A1. Annual catch, two measures of effort and catch per unit effort based on each of the effort measures for Coffin Bay. NB Data shown as proportional to protect licence holder confidentiality (<5 licences).

CPUE, as an index of relative abundance should be interpreted with caution. The relationship between effort (day, fisher days) and catch has changed over time. For example, linear relationships between effort (days) and catch for the periods 1983/84 to 2005/06 (LR: y=1.4714x + 0.2575; r^2=0.93) and 2006/07 to 2020/21 (LR: y=0.8795x + 0.0578, r^2=0.89) had different slopes and intercepts. The same occurred for the relationship between effort (fisher days) and catch: 1982/84 to 2005/06 (LR: y = 0.0863x + 0.0174, r^2=0.93); 2006/07 to 2020/21 (LR: y=0.0675x + 0.0298, r^2=0.91). The calculation, and utility, of CPUE using fishing hours rather than days or fisher days should be explored.

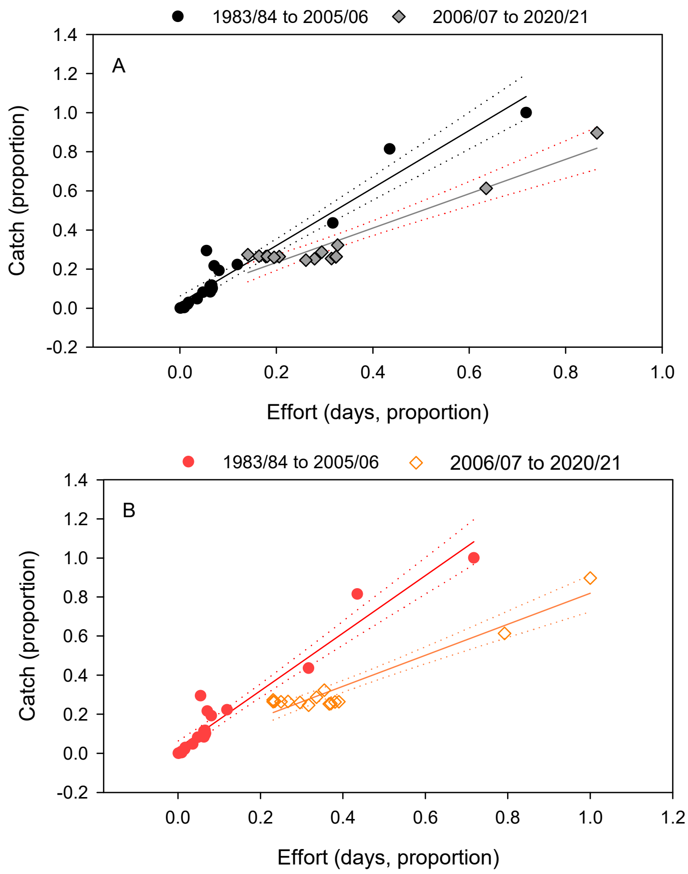

Figure A-2. For Coffin Bay, the relationship between catch and effort (days, A) and effort (fisher days, B) and for two periods: 1983/84 to 2005/06 and 2006/07 to 2020/21.

West Coast Fishing Zone

Intermittent harvests of Vongole were taken from Smoky Bay during 8 years from 1989/90 onwards. The highest catch was in 2006/07, with smaller catches from 2009/10 to 2014/15. There was no clear trend in CPUE.

Vongole have been harvested from Streaky Bay since 1999/00, with historical peaks in 2003/04 and 2006/07. Following the high catches during 2003/04–2006/07, a second period of higher catches occurred during 2010/11–2014/15. From 2015/16, catches were <25% of those during 2010/11–2014/15. While the temporal trend in annual effort generally followed that of annual catches, $effort_{fd}$ (effort in fisher days) increased after 2005, compared to $effort_{d}$ (effort in days). Temporal trends in the CPUE estimated using the two available measures of effort were similar from 1999/00–2007/08. From 2007/08, the two measures of CPUE diverged with $CPUE_d$ generally increasing after 2014/15 and $CPUE_{fd}$ remaining stable.

For Venus Bay, annual catches were historically high for several years during 2002/03–2005/06. In contrast to the trend in annual catches observed in Streaky Bay, annual catches in Venus Bay were relatively low from 2006/07–2013/14, then increased during 2015/16–2020/21. Catches from Venus Bay during 2015/16–2020/21 were <50% of those during 2002/03–2005/06. The temporal trend in $effort_d$ generally followed that of catches, however $effort_{fd}$ increased from 2014/15. The temporal trend in CPUE estimated from two measures of effort was similar from 2019/20 to 2012/13, then diverged with $CPUE_d$ generally increasing to 2018/19, and $CPUE_{fd}$ generally stable.

For all three bays, the calculation, and utility, of CPUE using fishing hours rather than days or fisher days should be explored.

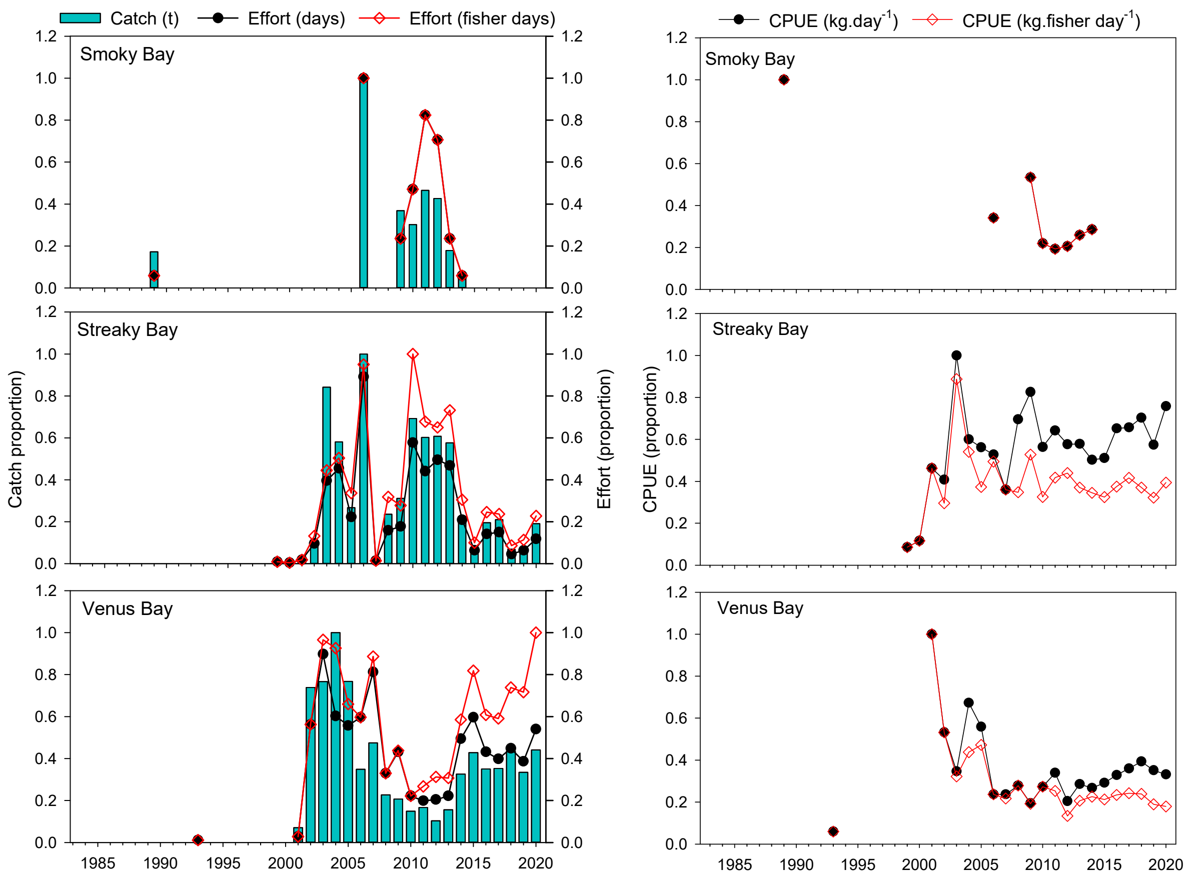

Figure A-3. Annual catch, two measures of effort and catch per unit effort based on each of the effort measures for Smoky, Streaky and Venus Bays on the west coast of South Australia. Data shown as proportional to protect licence holder confidentiality (<5 licences).

APPENDIX B – TIME-SERIES OF TOTAL DENSITY FOR TRANSECTS IN COFFIN BAY

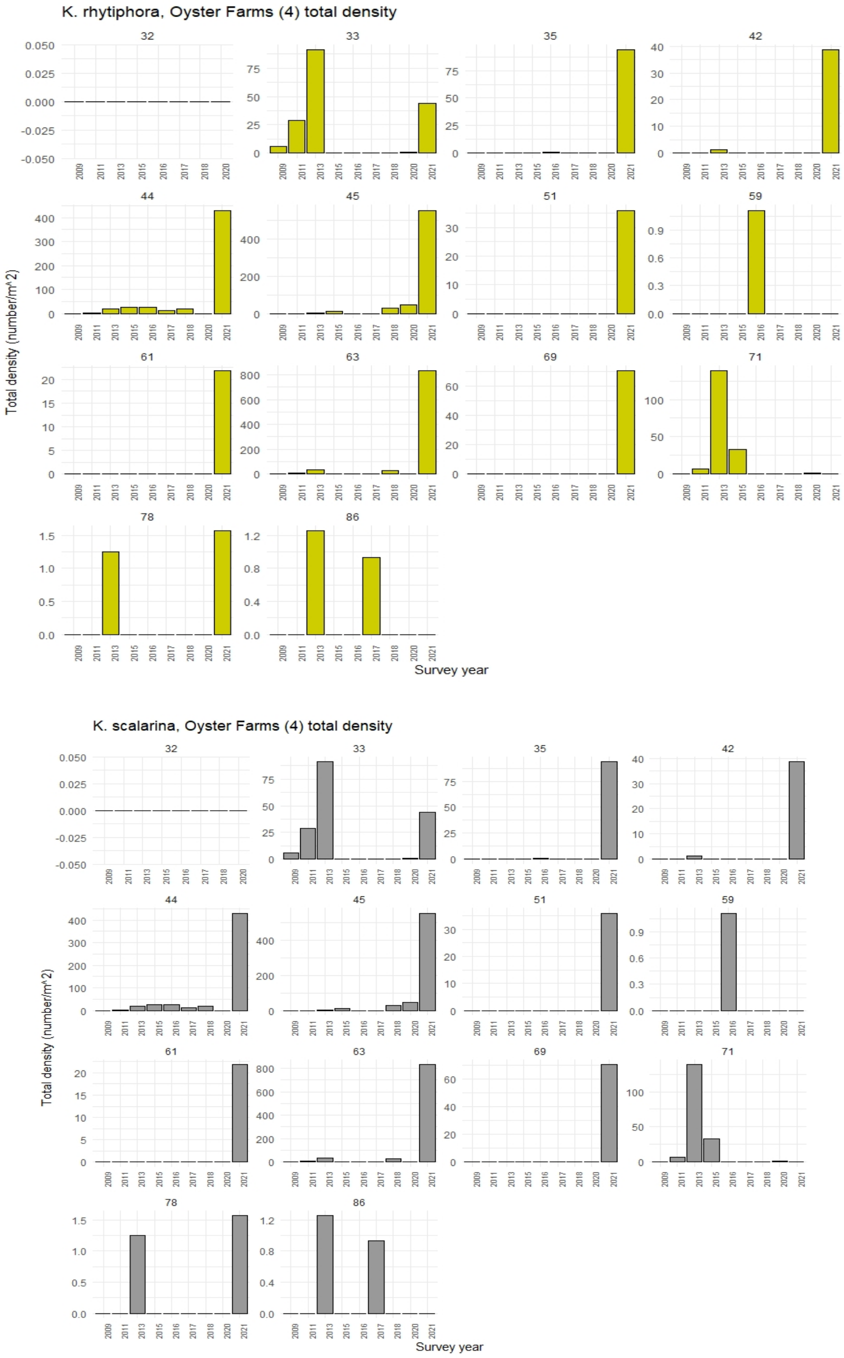

Figure B-1. Total densities (all sizes) of yellows (*K. rhytiphora,* top panel) and greys (*K. scalarina*, bottom panel) from individual transects in high density strata at Oyster farms from 2013 to 2021.

Figure B-2. Total densities (all sizes) of yellows (*K. rhytiphora,* top panel) and greys (*K. scalarina*, bottom panel) from individual transects in high density strata at Point Longnose from 2013 to 2021.

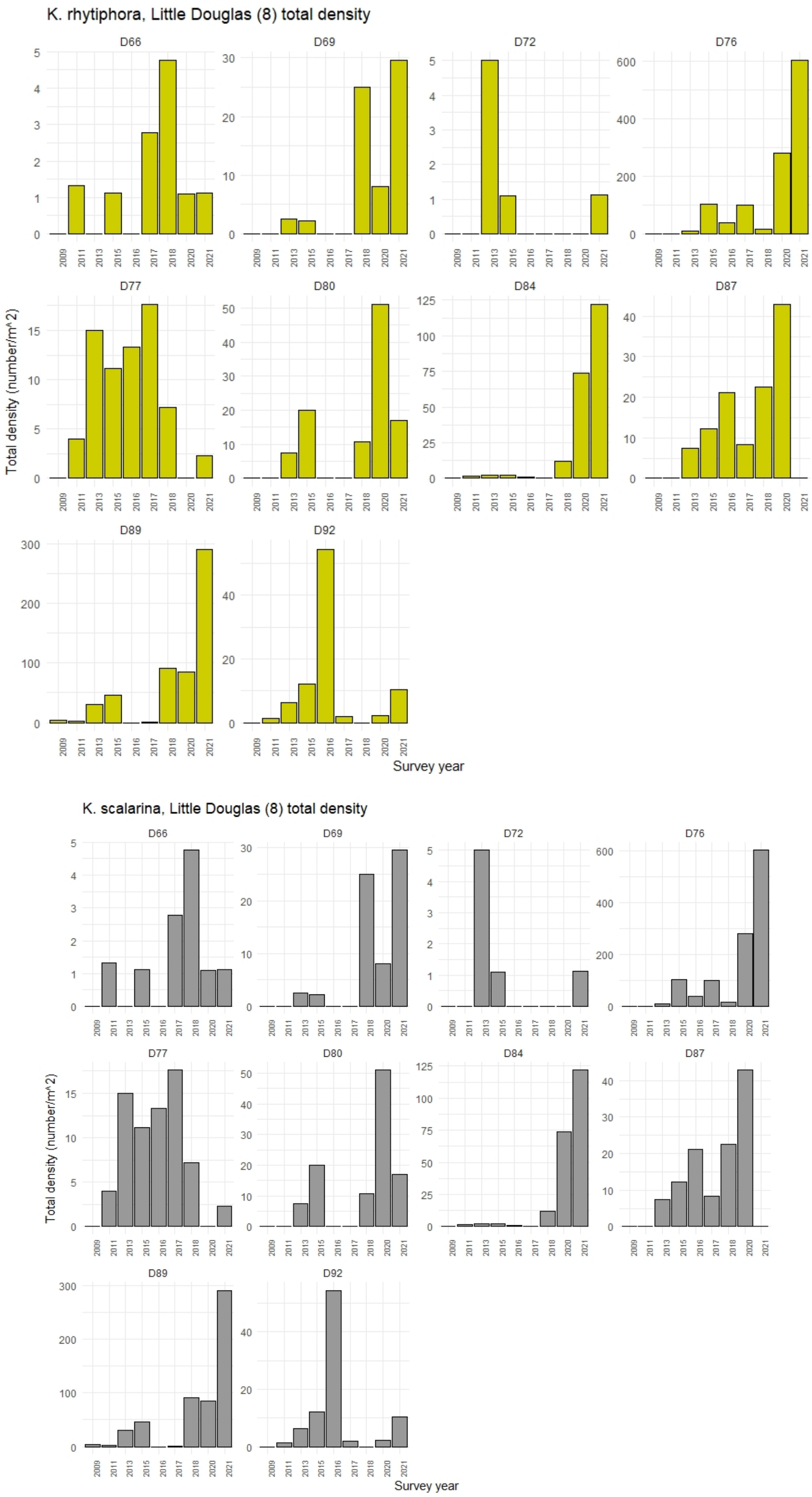

Figure B-3. Total densities (all sizes) of yellows (*K. rhytiphora,* top panel) and greys (*K. scalarina*, bottom panel) from individual transects in high density strata at Little Douglas from 2013 to 2021.

Figure B-4. Total densities (all sizes) of yellows (*K. rhytiphora,* top panel) and greys (*K. scalarina*, bottom panel) from individual transects in high density strata at Long Beach from 2013 to 2021.