TASMANIAN SCALLOP FISHERY ASSESSMENT 2020

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December 2021

This assessment of the Tasmanian Scallop Fishery is produced by the Institute for Marine and Antarctic Studies (IMAS).

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Contents

Executive Summary

STOCK STATUS	RECOVERING
The Tasmanian Scallop Fishery (TSF) is managed with a harvest strategy where surveys are undertaken to estimate abundance and decision rules are used to open areas to fishing with total allowable catches (TACs) based on the estimated abundance. Biomass in the Tasmanian Scallop Fishery (TSF) is historically overfished (Caton and McLoughlin, 2004), with recruitment and production levels now affected. In 2013, 2014 and 2015, surveys generally found low scallop densities and limited evidence of successful recent recruitment but did identify two beds (one on the north-west coast and the other on the east coast) containing commercial quantities (Ewing *et al.*, 2016). Surveys in 2016 and again in 2017 generally only found very low levels of scallop abundance and limited evidence of successful recruitment, with no area considered to contain commercially viable quantities in either year (Ewing *et al.*, 2017; Semmens *et al.*, 2018). This includes the east and north-west coast beds fished in 2013-2015, which appeared to have been fished down to a commercially unviable density, with no subsequent recruitment evident. Given the results of the 2016 and 2017 surveys, there was a low expectation that conducting pre-season surveys in 2018 and 2019 would yield the presence of commercially viable scallop beds, and as such, pre-season surveys were not conducted. In 2020, a pre-season survey was conducted, consisting of 635 survey dredge tows and around 1300 commercial tows across all areas of the fishery. Although the survey results were dominated by low to moderate densities of legal sized scallops, several areas demonstrated signs of recruitment that suggest the possibility of supporting a tightly managed commercial fishery in the near- to medium-term. Fishing mortality is managed with the aim of restricting catches to beds of mature scallops near the end of their lifespan. The combination of the harvest strategy and depleted biomass has led to a history of closures due to low abundance. In recent times, the fishery was closed between 2000-2002 and again between 2009 and 2010. Areas with commercial density of scallops towards the end of their lifespan were opened to fishing each year between 2013 and 2015. The fishery was closed between 2016 and 2020. On the basis that biomass is depleted, and large-scale recruitment is impaired, but that current restrictions are effectively limiting fishing mortality, and there is evidence of recovery of recruitment, the TSF is classified as recovering.	
STOCK	Tasmanian Scallop Fishery
INDICATORS	Size structure, catch, effort and CPUE trends

The TSF targets the commercial scallop (*Pecten fumatus*), one of 3 species naturally occurring in Tasmania. The SE Australian commercial scallop fishery began in Tasmania in the early 20th century and has exhibited a classic boom/bust trajectory with a combination of high recruitment variability and repeated overfishing and serial depletion leading to periods of very high effort and catches followed by extended closures for stock recovery. The TSF extends to 200 nm from the Tasmanian coast, with the exception of Bass Strait, where its jurisdiction covers 3-20 nautical miles offshore (DPIPWE, 2005). The fishery is managed by an individual transferable quota (ITQ) program and several input controls.

In comparison with historical levels, Tasmanian commercial scallop stocks are severely depleted and since 2003, the TSF has been regulated under a spatial management approach, referred to as a “paddock” fishery, whereby all areas are closed to fishing, except that certain areas can be opened after a stock assessment is completed. This approach is intended to promote stock re-building whilst allowing continuity of employment and supply for a small fishing fleet.

Sampling for the pre-season stock assessment has been conducted by selected scallop fishing vessels (issued with survey authorisations), and scallop stocks are assessed against criteria including:

- Population structure – particularly size where >80% of scallops landed must be greater than the minimum legal size (90 mm shell length (SL); animals of this size are approximately 3+ years of age and have had at least two major spawnings)
- Commercial viability – including catch rates, market suitability, estimated costs of fishing and meat recovery (<85 scallop meats per kg).

The Scallop Fishery Advisory Committee (ScFAC) considers the pre-season-stock assessment and then provides advice to the ministry on which, if any, "paddocks" should be open for fishing. Members of ScFAC include representatives from the scallop fishing and processing industry, the research community, the relevant federal and state fisheries management agencies, and the marine conservation sector; and reflect the co-management framework for the management of the Tasmanian scallop fishery.

Sampling for the 2016 and 2017 pre-season stock assessments (Ewing *et al.*, 2017; Semmens *et al.*, 2018) on the east, north east and northwest coasts of Tasmania indicated low densities of scallops in all regions. Further, these surveys found limited evidence of successful recruitment. These findings were also supported by an IMAS fishery-independent video survey on the east coast in 2017. Based on these previous pre-season surveys, ScFAC advised the minister not to open the Tasmanian commercial scallop fishery in both 2018 and 2019 and stock status of the TSF remained classified as depleted. However, the pre-season dredge survey conducted in May-June 2020 (Ewing and Semmens 2020) offered evidence of recruitment across several areas of the fishery. While this has raised the possibility of stock recovery in these areas, based on the overall low to moderate densities of legal sized scallops in the dredge survey and the results of an IMAS fishery-independent video survey conducted in Great Oyster Bay (Semmens *et al.*, 2020), ScFAC advised the minister not to open the Tasmanian commercial scallop fishery in 2020, but to further monitor recovery prior to the 2021 season.

1. Introduction

History of the TSF

The Tasmanian scallop fishery began as a recreational fishery in the Derwent Estuary in the early 1900s. A commercial fishery developed in 1919 and in the ensuing 5 years expanded rapidly and moved to target beds in the D'Entrecasteaux Channel. At the time the loss of stocks in the Derwent were attributed to flooding and predation by crabs and starfish, however, over-fishing, industrial pollution and siltation from land-use practises are likely to have played a role in subsequent declines.

The northern beds in the D'Entrecasteaux Channel were closed amid concerns of over-fishing in 1925, then were re-opened, then were closed again in 1930, and again re-opened. Sharp declines in catches in the Channel in the 1940s were attributed to over-fishing and poor recruitment, and the fishery began exploiting east coast stocks (Figure 1). By the 1970s east coast stocks were severely depleted and effort shifted to large scallop beds off the Furneaux Island Group in Bass Strait by the late 1970s (Figure 1). Landings and numbers of vessels increased rapidly (Figures 1 & 2), with 12,000 t (live weight) taken in Bass Strait in 1983 by 231 vessels. By the late 1980s these beds were also severely depleted; in fact there were virtually no productive scallop grounds left in southern Australian (Caton and McLoughlin, 2004) (Figures 1 & 2).

Stricter management arrangements commenced in the 1980s including catch history for access, allocation of fishing units, limits on vessel numbers, and fishery closures. The fishery was totally closed for 8 years from the end of 1987 until 1995 (Figure 2) to promote the rebuilding of the scallop stock. Partial recovery of the stock in some areas led the fishery to be opened for short seasons in 1995, 1996, 1998 and 1999, although the fishery again closed between 2000 and 2002 (Figure 2).

Following the introduction of 'bag' quotas in the 1990s, transferable units were introduced in 2000 to encourage restructuring in the fishery. A total of 10,730 scallop units were issued to operators and these remain in place as a fundamental component of the fishery. To limit the level of catch increasing as a result of activating effort from latent units and licences, the quota unit value was reduced effectively reducing the 'bag' quota unit value based on volume (equating to around 950 kg) to a weight-based value "kilogram scallop unit" of 500 kg. These measures reduced the total potential catch from 10400 t (if all units were activated and used) to a more conservative level of 5,350 t.

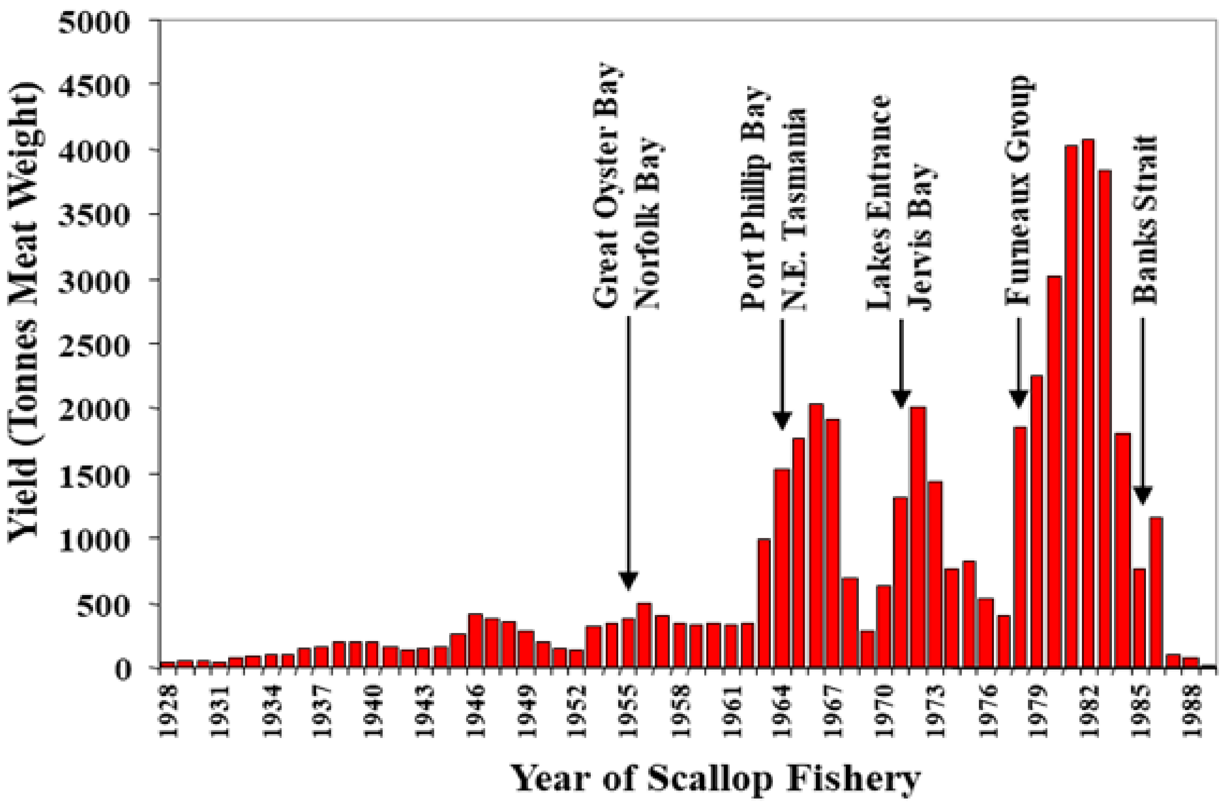

Figure 1. Commercial catches, as total meat weights, of *P. fumatus* from Bass Strait and Tasmanian and Victorian waters from 1928 to 1989. The years when new beds were first exploited are indicated by arrows (Young *et al.*, 1988).

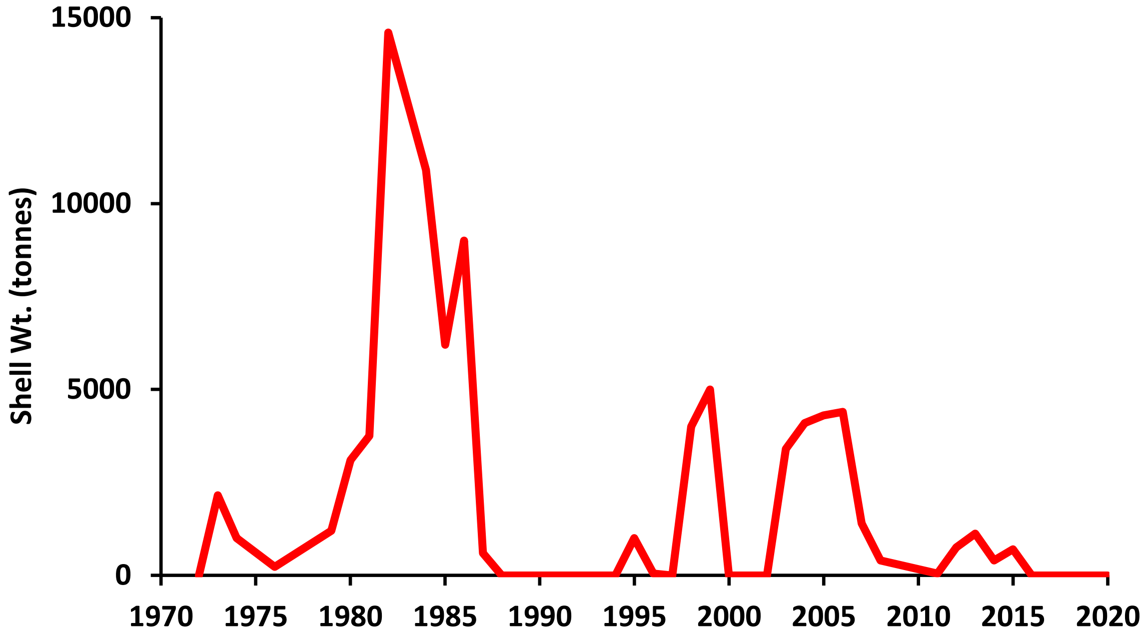

Figure 2. Commercial scallop catch (shell wt.) within the Tasmanian scallop fishery.

In 2002 extensive areas of scallops were identified off Flinders Island (Furneaux Island group), however, the fishery remained closed as most of these scallops were undersize. Regardless, this generated a high level of interest in the fishery indicating that it was highly probable that most scallop licences would be activated, and most scallop units would be seasonally transferred. This created the potential for catch to exceed 4200 t and the trigger point relating to capacity of active licences being reached. DPIPWE took a proactive approach, and the scallop unit value was reduced from 500 kg to 400 kg prior to the commencement of the fishery opening in June 2003. The change reduced the maximum potential catch from 5,350 t to 4,280 t. While the industry accepted that there were no guarantees that they would catch their quota each season, DPIPWE considered it created an expectation for the opening of all areas that fulfilled the discard criteria in the immediate season.

After the fishery experienced considerable difficulties in re-establishing markets after being a long period of total fishery closure (1999 to June 2003), a spatial management strategy was refined to focus on providing for continuity of fishing seasons. This continues to be a primary aim of the management of the fishery. The intention was to develop harvesting plans for potential open areas, ranking the order in which areas could be opened including, where feasible, reserve areas to ensure fishing seasons 2-3 years into the future.

In 2003, three areas were opened under the spatial management strategy, east of Flinders Island, Banks Strait (stretch of water between north-eastern Tasmanian and the Furneaux Island group) and Eddystone Point (east coast), with the 30 participating operators catching 3324.5 t of the 4146.4 t TAC (10366 units at 400kg per unit). Similarly, in 2004, three areas were opened, St Helens Point to Schouten Island (east coast), then Eddystone Point and Marion Bay (east coast), with all the 4146.4 t TAC caught by the 24 participating operators (see Table 1). For both seasons, period and trip limits were used to limit catch.

In 2005, a new management plan was introduced which allowed the Minister to set and alter the quota unit value by public notice. The alteration in unit value effectively sets the TAC for any particular year and is based on the best available stock information at that time. DPIPWE intended to use this management tool in combination with the harvesting plans discussed above to maximise the likelihood of continuous fishing years. In addition, industry restructuring resulted in a reduction of the number of licences to 92 by 2005. In 2005, the Tasmanian Aquaculture and Fisheries Institute (TAFI) advised that surveys had not indicated signs of significant recruitment of scallops and that the amount of known harvestable scallop stocks was likely to be less than the cumulative TAC over the next few years. To assist in meeting the objective of continuous fishing years, and to continue stock rebuilding, DPIPWE adopted a precautionary approach and reduced the TAC to 3628.1 t (by altering the unit value to 350 kg, with 10366 units) for the 2005 season.

Four areas were opened in 2005, Eddystone Point, Marion Bay, Paddy's Head to Schouten Island (east coast), and east of Flinders Island. Surveys conducted before fishing demonstrated that the scallop abundance east of Flinders Island was declining rapidly through natural mortality. In response, DPIPWE allocated an additional 50kg to the unit values, taking it back up to 400kg per unit, with operators also able to apply for an extra 50kg/unit to be caught off Flinders Island. A temporary legal minimum size of 80 mm shell length was also set for the east coast of Flinders Island. These measures were intended to ensure that fishers could maximise the east Flinders Island beds before they were completely lost though natural mortality. For all areas combined, 4329.0 t was caught in 2005, by 25 operators.

In 2006, White Rock (east coast) was initially opened, then Cape Lodi to Wardlaws Point (east coast). The 24 participating operators caught all the 4146.4 t TAC. Figures 3 to 6 below show the catch and effort for 2006 compared to more recent seasons (2011-2015), as 2006 was the first year that White Rock was fished since the reopening of the fishery in 2003. White Rock has been the most consistent site of the fishery in recent years (2011-2015) (Figure 3) but has produced significantly smaller catches than those in 2006. In 2007, initially a small area around Eddystone Point was open, with a larger area in Banks Strait subsequently opened. Only 1390.9 t of the 4253.2 t TAC was caught, marking the beginning of the first downturn in catches, corresponding to declining stocks, since the fishery re-opened in 2003. In 2008, the stocks declined further, and there was no significant recruitment. However, two areas where opened, one-off Bicheno (east coast) and another in Marion Bay. Pre-season scallop surveys found the two open areas contained low densities of large scallops in good condition. The two open areas had been fished several times since 2003 and the scallops available for harvest were residual scallops from previous seasons with no evidence of recruitment to these beds. Despite this, the fishery was opened with a TAC of 4253.2 TAC, but a ministerial warning was issued that it was highly unlikely the TAC would be taken. This warning proved correct, with only 489.8 t caught by the 15 participating operators.

The Tasmanian fishery was closed to fishing in 2009–10 due to low abundance and small average sizes (below the minimum size).

The fishery opened again in 2011 (see Figures 3-6) after a survey in White Rock indicated some stock recovery in this region of the fishery. The TAC was set at 2552 t, however, after opening the fishery, it was found that the beds had suffered a large die-off and very little fishing took place in the White Rock region (Figure 3). Only 103 t catch was taken in 2011 and this came from a state-wide survey that failed to identify significant new scallop beds.

In 2012 Marion Bay was initially opened with a TAC of 525 t. The White Rock area was opened later, and the TAC increased to 1163 t, however, the season was abandoned due to a toxic algal bloom on the east coast, with a total of 790 t of scallops landed for the season by the 13 participating operators.

In 2013, 2014 and 2015 (see Figures 3-6) industry surveys found low scallop densities and limited evidence of successful recent recruitment other than two beds with commercial quantities. One was in the Circular Head region on the north-west coast and the other in the White Rock region. These areas were subsequently opened to fishing each year between 2013 and 2015 (Figure 3). A lower minimum size limit (85 mm SL) was applied to the north-west bed given the historically slow growth rates in this region and the fact that most scallops of this size are still 3+ years old (Martin *et al.*, 1988).

A voluntary industry closure was implemented in July 2013 for a portion of the east coast bed when a large aggregation of sub-legal scallops was discovered in the northern section of the fishing area. The 2013 season was originally opened with a TAC of 638 t, which was later was increased to 1063 t, and then to 1489 t, following in-season surveys, with 1226 t harvested by the 14 operators participating. Similarly, a TAC of 620 t was set in 2014, but later increased to 1240 t. However, only 489 t was caught, with 6 operators participating. Most of the catch (404 t) came from the Circular

Head region, which had average scallop densities of almost twice those of the White Rock region when surveyed. Again in 2015, the initial TAC (620 t) was increased during the season, with only 781 t of the final 1033 t TAC taken, with 11 operators participating. Seven hundred and seventeen t came from the White Rock region, which had average scallop densities of almost twice those of the north-west bed when surveyed. However, it should be noted that two different vessels returned different scallop densities and size frequency distributions for the same area of the White Rock region surveyed in 2015, with the second survey showing a lower density and greater percentage of sub-legal scallops (greater than the 20% allowed under the decision rules).

Through 2014–17 market supply was maintained from the Commonwealth Bass Strait central zone scallop fishery (BSCZSF) which had significantly greater stocks than those for the Tasmanian fishery at this time. Most licensees in the Tasmanian fishery also operate in the Commonwealth fishery. As such, some of the uncaught TAC in the Tasmanian fishery during this period may have been caused by a shift in effort to Commonwealth waters, where scallops were more abundant. Given the more abundant resource in the BSCZSF, industry state-wide surveys were only conducted within known scallop beds on the state's east coast in 2016 (White Rock and Marion Bay regions), with no knowledge of the status of beds elsewhere in the state. In 2017, the White Rock and Marion Bay regions were again surveyed, along with Circular Head and the Flinders Island regions. For both years, the surveys generally only found very low levels of scallop abundance and limited evidence of successful recruitment, with no area considered to contain commercially viable quantities. This included the White Rock and Circular Head beds fished between 2013 and 2015, which appeared to have been fished down to commercially unviable densities, with no subsequent recruitment evident.
Based on these previous pre-season surveys, ScFAC advised the minister not to open the Tasmanian commercial scallop fishery in both 2018 and 2019 and stock status of the TSF remained classified as depleted. However, the pre-season dredge survey conducted in May-June 2020 (Ewing and Semmens 2020) offered evidence of recruitment across several areas of the fishery, including White Rock, the east coast of Tasmania and the Flinders Island region.

The 2020 dredge survey covered all six state-wide survey areas (see Figure 7). Overall, low densities, suggested that Area 1 could not support a commercial dredge fishery at the time of the survey and that the area had not yet recovered to levels prior to it being fished between 2013 and 2015 (Circular Head Region). Note that during these fishery years, the size limit was set at 85 mm, not 90 mm. However, there are potential good signs for the future, with clear evidence of new recruits (sub-areas 1A and B), although survey densities of these recruits are low, particularly in sub-area 1B. The size frequency histograms show the presence of juvenile scallops as small as 34 mm, which may be underrepresented due to small scallops not being maintained in the dredge in large numbers.

Densities in Area 2, the western region of Area 3, Area 5 and sub-area 6C yielded uniformly very low densities of legal-size scallops, with very few scallops encountered across all dredge tows.

A relatively small (~ 3 x 3 km) higher density bed was encountered in Area 3 just north of Babel Island and was characterised by a low discard rate of 3.7% at 90mm. This bed was likely contiguous with medium density beds in the northern part of Area 4 (see below). There were potential good signs for the future in Area 3, with clear evidence of new recruits, although survey densities of these recruits were very low. The size frequency histograms showed the presence of juvenile scallops as small as 40 mm, which may be underrepresented due to small scallops not being maintained in the dredge in large numbers.

The average density of scallops in Area 4 was moderate, with a high discard rate at 90mm of 32%. Even though a few small beds of higher density were encountered inshore off Ansons Bay and the Gardens (Figure 14), the eastern side of Flinders Island (Babel Island and Pot Boil) yielded more consistent beds of a moderate density. While Area 4 yielded a much higher density of legal-sized scallops than when it was last sampled in the 2017 pre-season survey, the 2020 distribution of scallops was patchy with a strong representation of undersize classes. All regions sampled in Area 4 yielded discard rates above 20% at 90 mm and discard rates were particularly high in areas of high legal-sized densities. This evidence of new recruits across Area 4 was a potential good sign for the future of the fishery.

White Rock (sub-area 6A) survey tows yielded an average density of 21 kg/1000m^2, with a discard rate of 7.5%. Densities in the Marion Bay (6B) sub-area were lower than White Rock (6A), with an average density of 8.3 kg/1000m^2. The discard rate of 15.6% in sub-area 6B was twice that of 6A. The improved density of scallops encountered in 6A and 6B in the 2020 survey, compared with the last two pre-season surveys, is likely to be due to four years of stock-rebuilding from the closure of the fishery since the 2015 season. However, despite the increase in density since the 2017 survey, the moderate (6A) and low (6B) density areas were highly spatially restricted, i.e., patchy, as was likely the limited recruitment in these areas.

The density patterns in 6A and 6B are very similar to those seen in the 2015 pre-season survey. Like the 2020 survey, the 2015 survey was also preceded by seasons of low overall densities and displayed a patchy distribution of scallops in low to moderate densities. The ensuing 2015 commercial season located in the White Rock (6A) sub-region left very low densities of scallops in this area and may have contributed to the current extended fishery closure in this region. Although the higher densities are only present in discreet patches, this is still a positive sign that settlement has occurred despite very low densities preceding and during the current fishery closure. There is, however, limited evidence of recent recruits (small scallops <60 mm) in these two sub-areas.

Along with the dredge survey, a towed underwater video camera was used to assess scallop densities and size frequency in survey sub-area 6A (White Rock) in May and June 2020 (Semmens *et al.* 2020). Forty-nine video tows were randomly allocated within the area of interest and video was scored to determine the abundance of the scallops encountered, the size structure of the scallop population and the density and biomass of scallops across the survey area.

Higher density sites were highly spatially restricted, i.e., patchy. Size structure from video transects showed strong representation of sub-legal scallops (58.9% at the 90 mm legal-size) and a mean size <90 mm. Along with the discreet patches of higher densities, the high proportion of sub-legal scallops throughout the survey area, clearly demonstrated that there has been recruitment during the closure of survey sub-area 6A (and the entire TSF) since the 2015 fishing season. Furthermore, there are potential good signs for the future, with clear evidence of new recruits.

Biomass across the nearly 200 km^2 survey area was estimated at approximately 7691 t for the total biomass and 3161 t for the legal-sized biomass, further highlighting the large biomass of sub-legal scallops that may be available to the fishery in subsequent years.

The sites sampled for the video survey generally aligned with the sites sampled in the pre-season dredge survey, allowing for some comparison of the results between the two methods. In the dredge survey, tows in survey sub-area 6A yielded a mean and median density of legal-sized (≥ 90 mm) scallops of 21 and 16.6 kg/1000m^2, respectively, with a sub-legal proportion (discard rate) of 7.5%. In the video survey, a very similar mean density (21.9 kg/1000m^2) to that of the dredge survey was found for legal-sized scallops. However, the median density from the video survey was significantly lower (8.5 kg/1000 m^2) than that of the dredge survey with a much higher sub-legal proportion (58.9%), reflecting the difference in size selectivity of the two methods as well as the sampling of several sites with low legal sized densities in the video survey. For both surveys, median density was substantially lower than mean density due to the influence of a small number of high-density sites on the overall mean density, whereas the lower median value reflected the predominantly patchy nature of most sites, which suggests that caution must be taken when extrapolating mean density values across the whole fishery.

Most of the scallops observed in the video survey transects were below the 90 mm minimum legal-size, leading to a sub-legal proportion of 58.9%, which was an approximate 8-fold increase over that of the dredge survey. This difference in the size frequency between the two methods is not unexpected, as a scallop dredge is designed to be size selective for legal-sized scallops and allow smaller scallops to pass through. Similar disparities have been previously reported in other fisheries when camera and dredge surveys were compared.

While the 2020 surveys raised the possibility of stock recovery around the state, based on the overall low to moderate densities of legal sized scallops in the dredge survey and the results of the IMAS fishery-independent video survey conducted in Great Oyster Bay, ScFAC advised the minister not to open the Tasmanian commercial scallop fishery in 2020. It should be noted that since 2014 (including 2020) market supply has been maintained by the Commonwealth Bass Strait central zone scallop fishery (BSCZSF), which has held significantly greater stocks than those for the Tasmanian fishery during this time period. The Victorian Ocean Scallop Fishery is also open in 2020.

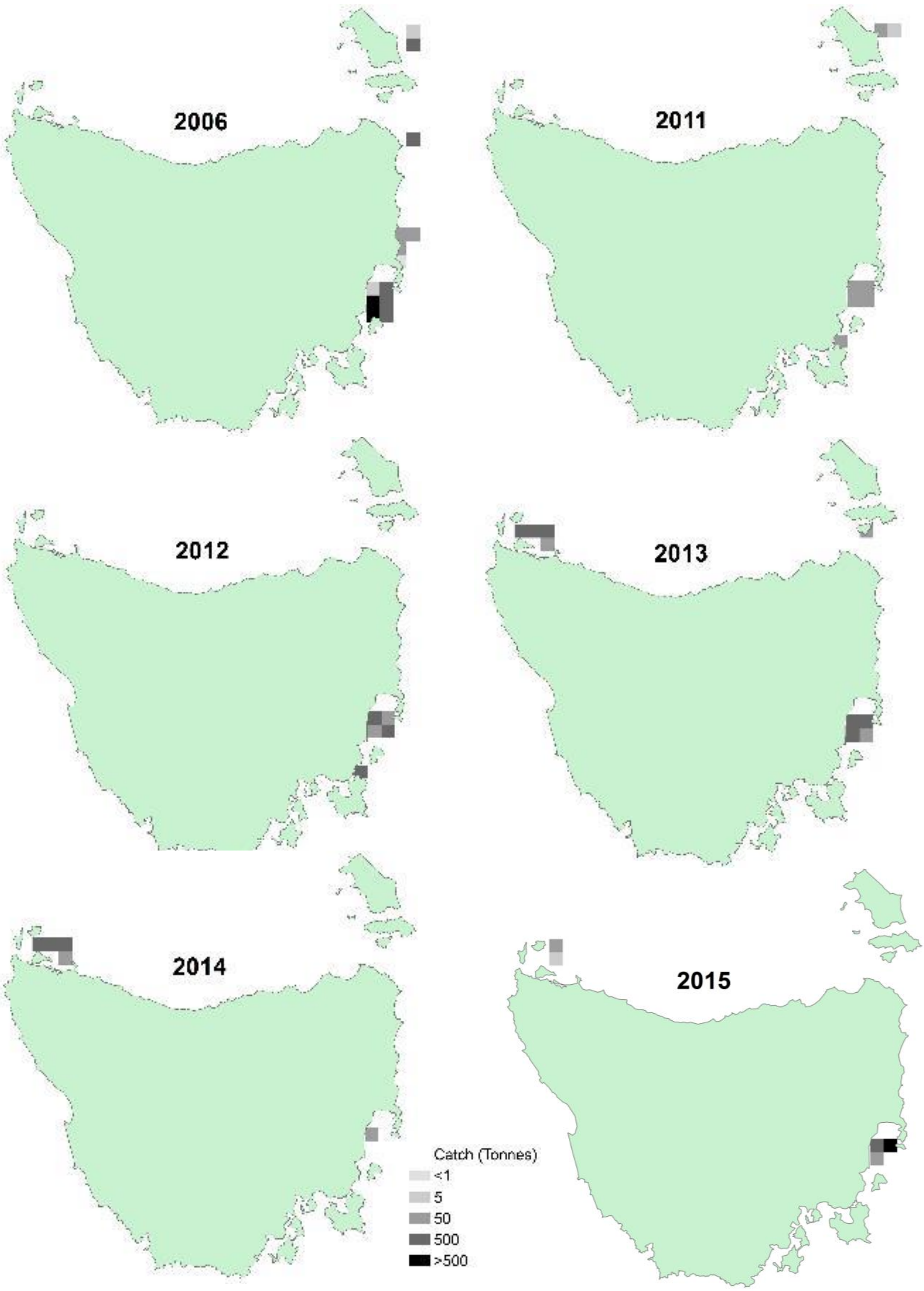

Figure 3. Distribution of catch (tonnes) for 2006 and for the last five open seasons by block.

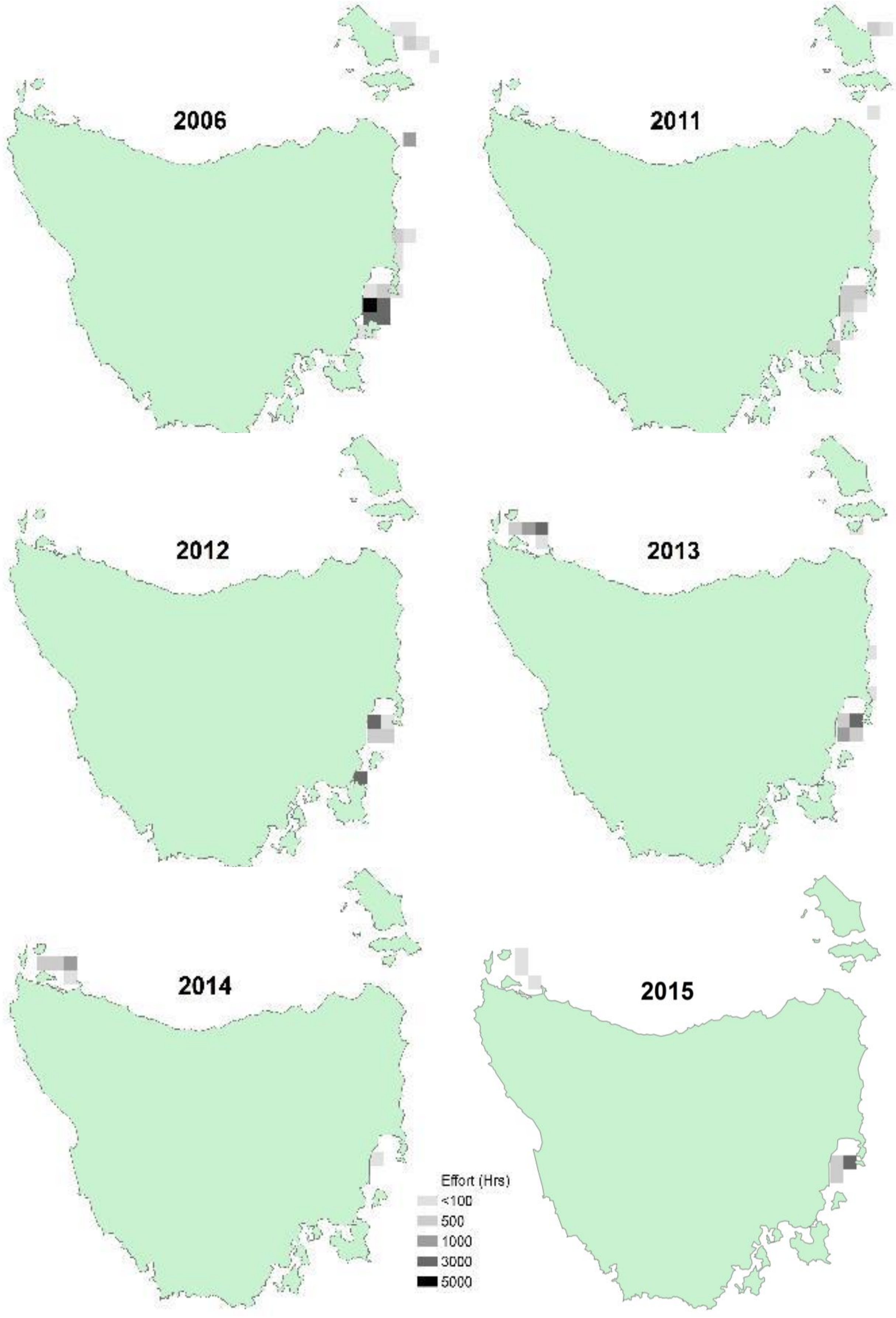

Figure 4. Distribution of effort (hours) for 2006 and for the last five open seasons by block.

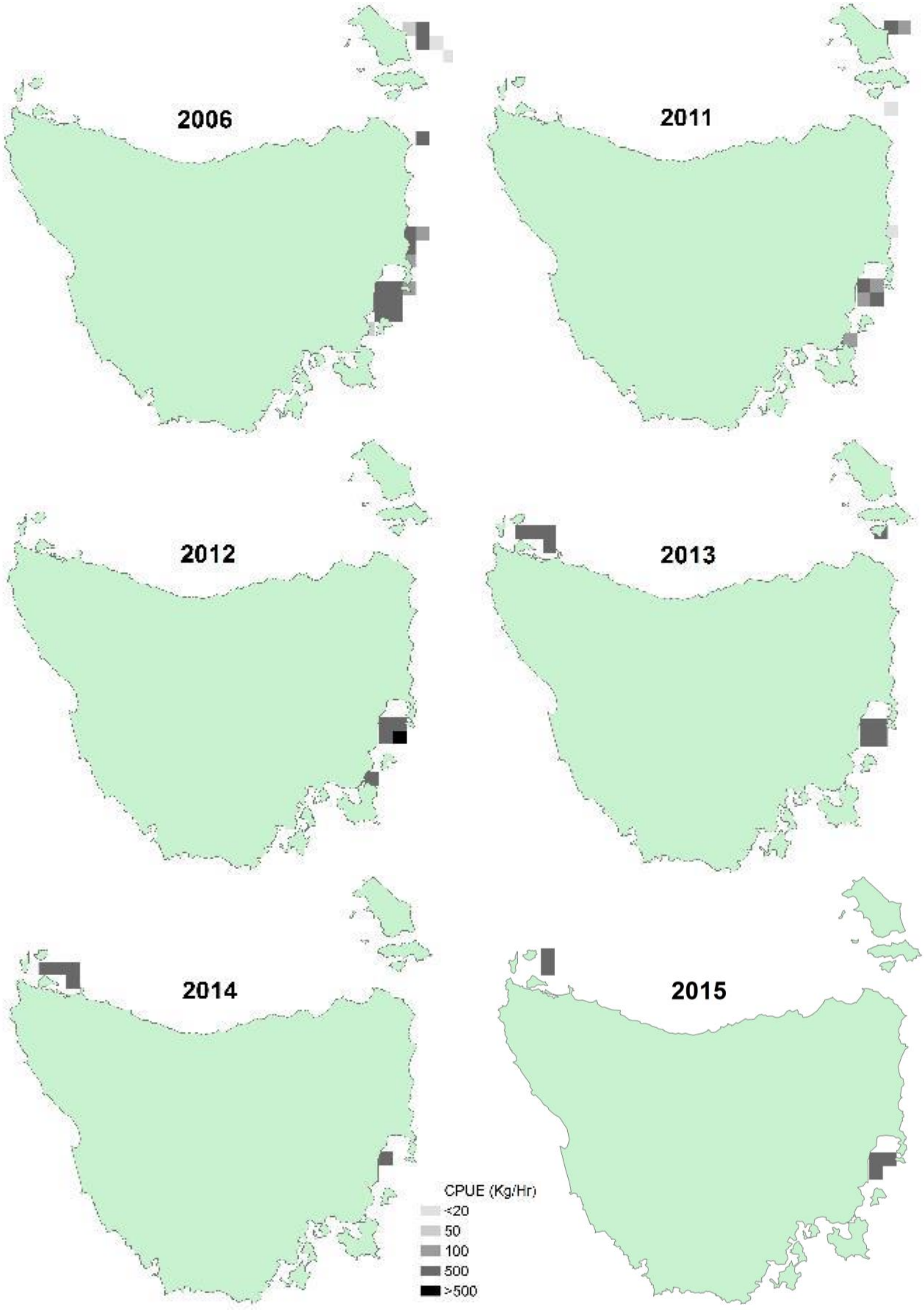

Figure 5. Regional CPUE (kg/hr) for 2006 and for the last five open seasons by block.

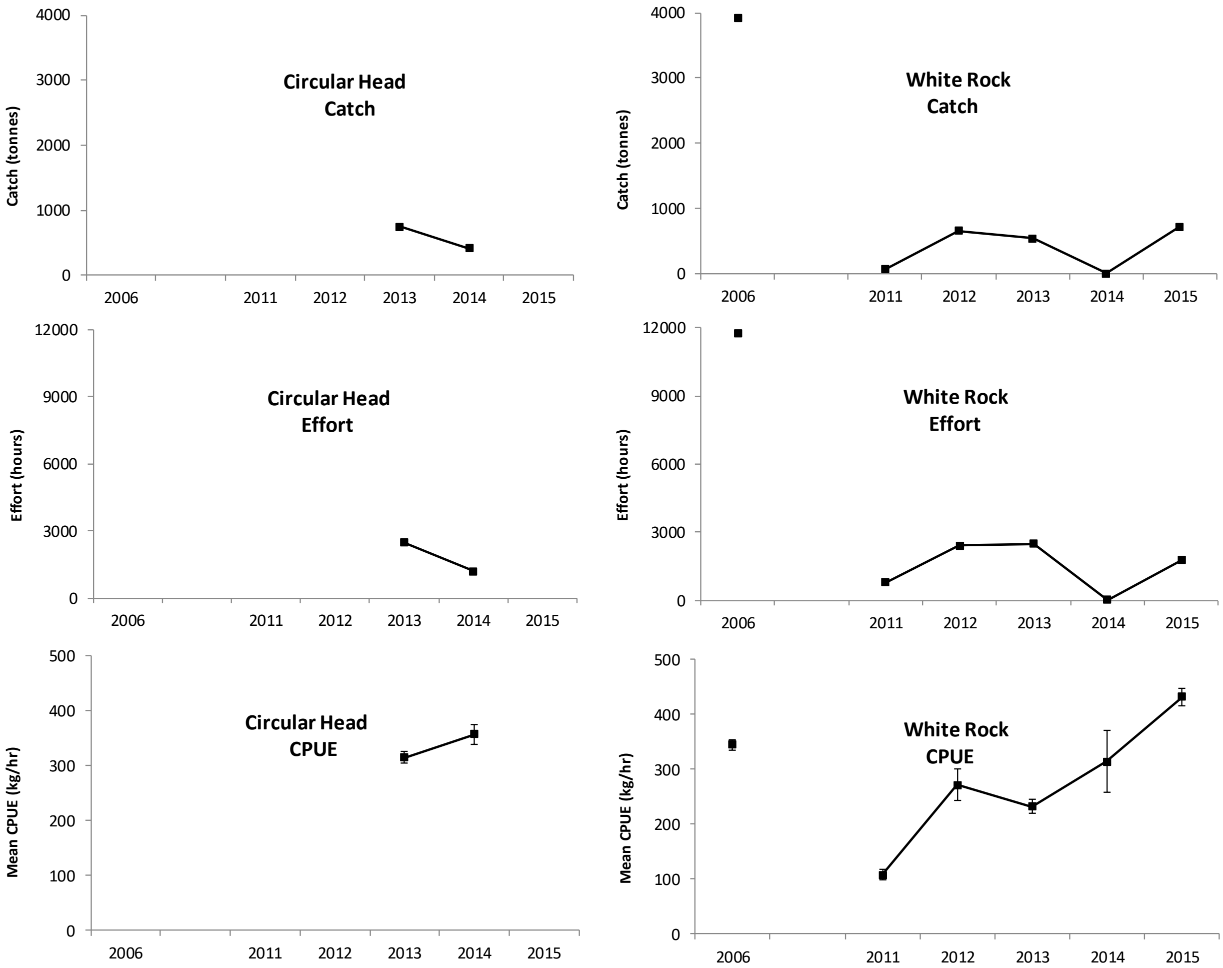

Figure 6. Catch (tonnes), Effort (hours), and mean CPUE (kg/hr) for 2006 and for the last 5 open seasons. CPUE error bars are standard error.

Table 1: Summary of the Tasmanian scallop fishery 2003-2015. *Denotes that operators were also able to apply for an extra 50kg/unit to be caught off Flinders Island in 2005.

Year	TAC	Operators	Days fished	Catch tonnes
2003	4146.4	30	1010	3324.5
2004	4146.4	24	1402	4159.5
2005	4146.4*	25	1642	4329.0
2006	4146.4	24	1386	4359.3
2007	4253.2	20	634	1390.9
2008	4253.2	15	480	489.8
2011	2552.0	10	102	103.3
2012	1163.0	13	373	790.2
2013	1489.0	14	552	1226.0
2014	1240.0	6	196	489.0
2015	1033.0	11	261	781.2

Recent research

In recent years, several research projects have been undertaken by IMAS to facilitate management of the TSF.

FRDC 2012/027: Determining when and where to fish: Linking scallop spawning, settlement, size and condition to collaborative spatial harvest and industry in-season management strategies.

This project defined timing of scallop spawning based on gonad condition, and hence potential settlement of recruits across the different populations/beds of the fishery and determine any differences in spawning potential among scallop beds/locations. Additionally, this project defined differences in spawning potential between scallops ranging from 80 to 90 mm SL and assessed the size limits used to define a bed as commercially viable across the three southeast Australian jurisdictions. Furthering our understanding of growth rate in several fishing locations across all three jurisdictions allowed better management of individual beds and use of scallop condition in setting season openings and closings (Semmens *et al.*, 2019).

Changes in muscle weight, gonad weight and meat recovery weight (combined meat and gonad weight) varied through the season and the gametogenic cycle, but this relationship is affected by year. There was no common trend in changes in muscle, gonad and combined weight across areas, instead the changes are area-specific and year-specific and can vary considerably. The differences were of such a magnitude that each area requires research prior to harvesting. This is particularly relevant in the TSF, when only relatively small areas of the fishery are opened at any one time and the remainder of the fishery is closed, although the adaptive in-season management model in this fishery (i.e., open area boundaries can be changed during the season) can overcome this issue in some circumstances. In the BSCZSF and OSF, given only relatively small areas of the fishery are closed during the fishing season or the entire fishery is opened, respectively, there may be a greater opportunity for scallop fishers to find beds with higher muscle, gonad and combined weights, although this of course relies on fisher behaviour and is dependent on the number of different beds available, with limited to no scallop beds available for harvest in the OSF for over two decades. Furthermore, without adaptive in-season management, which is the case in the BSCZSF (i.e., spatial closures are not adjusted during the fishing season), there is the potential for the best quality scallops to be 'locked-up' in spatial closures for the entire season.

Maturity stages identified macroscopically did not consistently match the maturity stages identified by histological sampling. Apart from macroscopic stage 2, which comprised scallops with predominantly gonads in the developing stage, the other macroscopic stages showed a mixture of reproductive stages. Therefore, while the macroscopic staging scheme is useful to derive a general indication of gonad condition, it does not accurately reflect the maturity stage in the ovary.

Based on microscopic observations compared to macroscopic examination of gonads, three visual stages are described based on the morphological appearance of the gonad to the naked eye: Developing or spent; maturing or atretic (reabsorbing eggs as spawning is delayed); and partially spawned. Fishing in the Commonwealth predominately takes place in the beds or regions surveyed before the season commences. Similarly, the TSF only opens to fishing surveyed areas that meet the management plan. While the OSF does not use surveys to determine open areas, as it is not a spatially managed fishery, fishing generally occurs in traditional areas, which will have variable gonad development and spawning timings within and between them. As such, the simple three stage visual classification system developed in this project is useful to both scallop resource managers and industry, as part of in-season management strategies, to define the overall reproductive stage of scallops and predict timing of spawning, thus assisting in the best condition scallop beds being fished sequentially throughout the season.

Collection of data on scallop condition, reproductive stages and settlement rates collectively can help inform best timing for season opening and closing dates in each location. The information available from this study and previous studies, suggest that the Lakes Entrance region, which comprises the majority of the OSF, would profit from an early start during winter. However, note that the OSF is currently considered depleted and has not had significant catches in over two decades. This in part may be attributable to the fact that the fishery has historically been open continuously throughout the year, including the settlement period. At White Rock in the TSF, starting the fishery in September would appear more beneficial in terms of harvesting the best product, although this may not fit best with protecting newly settled scallops, and may in part explain why this area has not supported a fishery in recent years and is now classified as depleted. At the Bass Strait site in the eastern section of the BSCZSF, the best time to fish appears to be spring and summer/autumn. Fishing up to the closing date of December 31 may not fit best with protecting newly settled scallops, with the major settlement period occurring in spring, and again may in part explain why this area has not been viable in recent years. At King Island, in the BSCZSF, the best time to fish appears to be spring and summer, however, settlement occurs from approximately November to January.

Fecundity increased exponentially with SL and modelling predicted that a scallop measuring 90 mm in shell length would be 13 and 25% more fecund than an 85 and 80 mm scallop, respectively. Furthermore, an 80 mm scallop would be 44% more fecund that a scallop measuring 70 mm in SL. Scallops measuring 100 mm in SL would produce 32% more eggs than a scallop measuring 90 mm. These differences are less dramatic than previous findings where 3+ years old scallops measuring ~90 mm SL shed (3.5 million eggs on average) compared to 2 million eggs shed by scallop measuring ~ 83 mm SL (a 57% difference compared to 19% estimated in this study). This result of the current study showing a much smaller difference in fecundity in scallops of various sizes compared to previous findings, is a very important finding in relation to the decision rules around scallop harvest, particularly the under-sized discard rate rule and the two spawnings criteria which states that scallops should be allowed a minimum of two major spawning events before being harvested. Scallops that are 85-95 mm SL are 3+years old and have had two major spawning and thus contributed significantly to potential recruitment. However, given the relationship between fecundity and SL demonstrated in this study, which shows a 3-fold decline in the difference between fecundity of an 83 and 90 mm SL scallop compared to the previous research, the size limits are very conservative. As such, the use of 85 mm SL still allows the scallops to have produced two major spawnings before harvest, with relatively little difference between the fecundity of 85 and 90 mm SL scallops (13%). However, it should be noted that in regions that have very low biomass or are recovering from being depleted (e.g., TSF), this additional 13% could be significant, and a highly conservative approach may be warranted. Furthermore, it should be noted that the 80 mm SL size limit used for the decision rules in the OSF is likely not appropriate, as it is outside of the size range for the two major spawnings criteria and should be revisited, with this low size limit perhaps contributing to the long history of limited biomass and recruitment in the fishery.

Differences in shell morphology were evident among regions, with significant differences between the standardised height for a standard scallop measuring 90 mm SL. However, differences in morphology were more evident among locations when comparing shell widths for standard scallops measuring 90 mm SL. Northwest Tasmania (TSF) and Great Bay (TRSF) had comparatively thinner individuals, followed by King Island (BSCZSF), Banks Strait (TSF), Marion Bay (TSF) and White Rock (TSF). Scallops from Babel Island (TSF and BSCZSF) showed no significant differences in shell width with Eddystone (TSF) or the Bass Strait (BSCZSF) site. Scallops located in Victoria (OSF) had the thickest scallops. For fisheries management purposes it is interesting to determine if scallops with greater SW also have greater muscle and/or gonad weights. Indeed, the Victorian (OSF) site had the thickest (deepest) scallops, and these scallops generally had the heaviest muscles, gonads and combined weights in winter of all the regions. Additionally, other thick scallop regions, Isthmus Bay (TRSF) and Eddystone Point (TSF), also had heavy muscles, gonads and combined weights in winter. Furthermore, the relatively thick scallops from the Bass Strait (BSCZSF) site had heavy muscles, gonads and combined weights in autumn. Fishing these areas (when opened) in the seasons noted could increase commercial yields.

Scallops at different sites showed variable mean growth increments depending on initial mean size of cohorts. There was no obvious growth pattern on the latitudinal gradient. For instance, sites at the extreme north (North Flinders and King Island, both in the BSCZSF) and south (Great Bay, TRSF) of Tasmania showed average mean growth increments. Low and high values of growth were observed in sites that are close to each other in the BSCZSF (1.9 and 9.20 mm/year for King Island Middle and King Island 2 respectively). Therefore, growth variations seem to be associated with local factors rather than factors linked with large spatial scale change, which has also been observed for other species of scallop. This growth analysis has shown that there is great variation in growth rates of commercial scallop across the traditional fishing areas within the southeast of Australia, with great variation even prevalent between beds in the same area, e.g., King Island (BSCZSF) and East Flinders Island (TSF).

Importantly, however, this analysis has shown that the fishing areas examined can be generally grouped into three general groups: rapid growers; moderate growers; and slow growers. Rapid growers will be younger than their shell length indicates, so those scallops may not be 3+ at 85-95 mm SL and may not have had three major spawnings. As such, despite the relationship between size and fecundity showing that the 90 mm size limit is very conservative, it may not be for these rapidly growing scallops, and perhaps a more conservative approach is needed, particularly as the size limit used in the BSCZSF, where the two North Flinders fishing areas are located, is 85 mm SL. Alternatively, if a validated aging technique can be developed for commercial scallops, this should be adopted to ensure scallops are only fished from the 3+ age class onwards. It is interesting to note that three rapid growing areas are North and Northwest Flinders (BSCZSF) and White Rock (TSF), all areas that have shown large reductions in biomass, with little or no recruitment in recent years. The TSF had plans to use an 85 mm SL size limit from 2020 onwards, however, based on this research, the 90 mm SL size limit was maintained.

Note that as previously mentioned, there is great variability with areas, with Flinders Island 1 (BSCZSF), which like North and Northwest Flinders is also situated north of Flinders Island, showing slow growth. Two other slow growing areas are at King Island (KI 2 and KI New, BSCZSF), with King Island Mid (BSCZSF) showing moderate growth. The slow growing scallops will be older than their shell length indicates, and as such 90 mm SL minimum size is likely to be very conservative. The King Island sites are in the BSCZSF, and as such currently managed under an 85 mm SL size limit, which would appear very appropriate, but likely to be highly conservative. This may be a key factor in the fact that this region has been maintaining very high biomasses despite the fishery operating in the region since 2014 and ~12500 t coming out of the area (west of 147 degrees east) in that time. Although note that the Northwest region in Tasmania is fished with an 85 mm SL size limit rule, as fishers nominated this area as a slow growing scallop area, however it has undergone a large decline in biomass, following no recruitment in recent seasons.

In those areas with slow growing scallops, closing beds based on the 20% discard rule may mean that some beds that have 80% or greater of the scallops within it having reached 3+ and having had at least two major spawnings may be inadvertently closed, and as such this rule will be very conservative in these areas. Conversely, the opposite will apply in fast growing areas, with beds that have less than 80% of the scallops within it having reached 3+ and having had at least two major spawnings being inadvertently opened, and as such this rule is not met in these, which could have an impact on the sustainability of fisheries in these areas. As such, defined use of the minimum size limit and 20% discard rule is not appropriate, and instead they should be used in conjunction with the known attributes of the beds within region to be fished and applied in an informed and sensible manner such that recruitment potential is not impacted. If a validated aging method can be developed for commercial scallops, the 20% discard rule will be able to be applied with greater confidence.

FRDC 2008/022: Establishing fine-scale industry based spatial management and harvest strategies for the commercial scallop fishery in South East Australia

FRDC 2008/022 examined scallop stock structure, spawning biomass density/recruitment relationships, and the impacts of intensive fine spatial scale fishing on scallop communities with the aim of refining detailed spatial management/industry fine-scale management harvest strategies, such that they promote recruitment and minimise impacts on the broader environment (Semmens *et al.*, 2015).

This project demonstrated that the south east Australian commercial scallop population is largely a genetically homogeneous single population. However, there was some evidence of population structure within Bass Strait, which has implications for management of apparently genetically linked populations in separate management jurisdictions (Tasmania, Victoria, and Commonwealth). Evidence from this study suggested that these differences may be due the effect of ocean gyres that exist in the Bass Strait and may force self-recruitment of certain beds and genetic separation from the general population of the scallops in the Strait. It is important to note that these differences may be due to genetic drift rather than spatial barriers to cross bed recruitment. This project also demonstrated that overall genetic exchange appears to be limited when distances exceed 300km and the finest scale at which genetic subdivision was found was approximately 100km. Importantly, this study demonstrates that appropriate scales of management should consider both long established patterns of dispersal and recruitment as indicated by population genetic structure, as well as short term patterns due to demographic heterogeneity. The genetic evidence indicates that stock structuring can occur within 100 km implying that yearly stock- recruitment dynamics are likely to exist on even smaller spatial scales. In other words, recovery of depleted scallop beds in the short term will be heavily influenced by recruitment from adjacent scallop beds rather than from distant beds. This study reinforces existing knowledge based on the modelling of currents in Bass Strait (Hammond *et al.*, 1994) indicating that cross seeding of scallop beds is rare. The scale of the current spatial management harvest strategies employed in both the Commonwealth and Tasmania would seem appropriate given the genetic evidence presented here. However, the harvest strategy employed in the Commonwealth, where a proportion of known beds cannot be fished, should perhaps be considered in Tasmania, given that localised recruitment appears to be the driving process.

In accordance with research in other benthic molluscs, this project found a strong indication that the density of recruits is related to the density of adults in the previous year. In the areas studied, recruit density increased by between 2 and 10 times for every single unit of adult density prior to spawning. The density of adult spawners also has an impact on the level of synchronicity between spawning adults. This study showed a difference in spawning intensity and synchronisation between sites of high and low densities and suggests that maintaining dense areas of adult scallops may increase the probability of recruitment, through increased spawning intensity. To this end, the protection of dense scallop beds has been incorporated into the Commonwealth Harvest Strategy, with at least part of a high-density bed(s) found during surveys closed to fishing during the season. Again, this may well be a strategy worth adopting in Tasmania to promote recruitment.

Analysis of data from the Before-After-Control-Impact (BACI) study component of this project, which aimed to determine the impacts of commercial dredge fishing effort on the benthic communities found within scallop habitat, showed no significant effect on abundance or species composition of fishing, the level of fishing effort, the sampling year or the region sampled. This suggests that intensive fine spatial scale fishing associated with spatial management has no obvious short- to medium-term detrimental effects on scallop communities within the fishing grounds of the Commonwealth Bass Strait Central Zone Scallop Fishery (BSCZSF). As such, allowing for beds to potentially be rotationally fished after relatively short temporal closures, if they meet the harvest strategy decision rules, may have relatively little impact on the scallop communities.

However, it is important to note that the BSCZSF has been fished since the 1970s, and the small differences in species assemblages selective to dredge fishing between fished and non-fished sites found in this study may be due to ‘historical impacts’ the dredge fishery may have had on the benthic community. Repeated dredging over many years may have shifted the entire community to one which is more resilient and which can withstand dredge fishing pressure as has been found in other studies (Bradshaw *et al.*, 2001). Those species that are most effected by dredging may now be too rare to be effectively sampled using dredge surveys.

Furthermore, previous studies have also shown that changes in community structure following seasonal weather events can be more significant than those changes associated with fishing (Currie and Parry, 1996). Communities within the BSCZSF are more exposed to environmental variability than other regions where commercial scallops are or have been fished, perhaps further explaining why changes in species abundance were not observed in this study, but were observed for commercial scallops in inshore waters (see Currie and Parry, 1996). Despite this, heavily fished inshore regions also show resilience to fishing, with species abundances similar to those prior to dredging within six to nine months after fishing in the Port Phillip Bay Scallop fishery (Currie and Parry, 1996), which was fished close to continually for around 30 years.

FRDC 2005/027: Facilitating industry self-management for spatially managed stocks: a scallop case study

FRDC 2005/027 established the capacity for industry to organise and implement surveys at both the scale of the fishery, and the scale of individual scallop beds (Harrington *et al.*, 2008). These surveys are independent of direct research and management involvement. The population structure and abundance data that industry obtains during such surveys can be used by management to meet decision rules allowing the successful implementation of detailed spatial management strategies within the fishery. Furthermore, the development and use of electronic measuring and recording devices both simplifies and adds a level of credibility to the process of data collection, storage and analysis. The inclusion of industry in the data collection process of management also creates a sense of Industry ownership. In general, this improves the relationship and communications between all stakeholders in the fishery (industry, managers and research), and creates both an acceptance and level of understanding of the biological and economic benefits of detailed spatial management. This belief in the benefits of spatial management has directly led to industry empowerment, with much greater roles and responsibilities in the management of their fishery.

FRDC 2003/017: Juvenile scallop trashing rates and bed dynamics: testing the management rules for scallops in Bass Strait

FRDC 2003/017 concluded that spatial closures in the management of commercial scallop stocks, where the majority of the fishery is closed to fishing and only small discrete regions of the fishery are opened to harvesting, offers a real prospect for providing continuity and sustainability for the fishery (Haddon *et al.*, 2006), especially when compared to conventional management. It also identified the very extensive data/stock information requirements of closed area spatial management (Haddon *et al.*, 2006; Harrington *et al.*, 2007). Without credible up-to-date stock information, scallop beds cannot be opened to harvesting, within season contingency plans cannot be formulated, and longer-term harvest strategies cannot be developed. This type of longer-term information and planning is essential in creating a level of certainty within the catching sector (industry), which in turn allows the development of processing infrastructure and domestic and export markets.

Overview of Management of the Tasmanian Scallop Fishery

The Tasmanian commercial scallop fishery extends to 200 nm, except Bass Strait, where jurisdiction covers 3-20 nautical miles offshore (DPIPWE, 2005) (see Table 1 for a summary of the fishery). The fishery is managed by an individual transferable quota (ITQ) program, which was implemented in 1986, as well as several input controls. Since 2003, the fishery has been managed under a spatial management approach, referred to as a paddock fishery, whereby all areas are closed to fishing, except that certain areas can be opened after a stock assessment is completed. The current Tasmanian scallop fishery management plan, implemented in March 2010, is a collection of detailed fishery rules governing the fishery. A draft document, *A Management of the Tasmanian Scallop Fishery – Policy and Decision Making Guidelines*, describes the framework for management of this fishery, including goals, objectives, and strategies.

This strategy specifies some main criteria that need to be satisfied for a specific area (paddock) to be opened (and remain opened) to fishing:

1. Minimum size or age – At least 80% of scallops must be greater than minimum legal size (90 mm SL) or at least 80% of scallops are ages 3+, corresponding to at least two major spawning opportunities. Alternative minimum size limits can be established, in cases where it can be established that scallops have had the opportunity to spawn at least twice prior to harvest.
2. Commercial viability – Potential fishing areas are prioritized based on anticipated economic returns, catch rates, market suitability, and estimated costs of fishing. Commercial viability is subjectively determined by the Scallop Fishery Advisory Committee (ScFAC), which is largely comprised of industry members.
3. Listing candidate open areas – The spatial management regime requires areas to be assessed to characterize population structure and extent of candidate scallop beds before being considered for commercial harvesting. Initially, state-wide surveys are conducted using industry scallop vessels that can retain limited tonnages of located scallops (50 t survey area cap for six areas; 300 t State-wide, see Figure 4). If surveys reveal that the size structure indicates a discard rate no larger than 20% prior to an opening, then the surveyed area can be considered as a candidate area for a fishery opening. The effect of the spatial management regime is essentially a rotational harvest system.
4. Discard threshold – If a vessel has more than two dredge tows in which ≥20% of scallops are less than minimum size, then the vessel should move at least 250 m. If such discard rates persist, then the coordinates should be reported for potential mitigation measures.
5. Meat recovery guideline – As a general guideline, meat recovery (adductor muscle and roe) should be >11.8 g corresponding to <85 scallops/kg.

Table 2: Summary of the Tasmanian scallop fishery

Area	The area of the fishery extends from the high-water mark to 20 nautical miles into Bass Strait and from the high water mark out to 200 nautical miles off the rest of the State of Tasmania.
Fishery status	The target species within Tasmanian waters is currently considered to be overfished.
Target Species	Commercial scallops (*Pecten fumatus*)
By-product Species	Doughboy (*Mimachlamys asperrima*) Queen scallop (*Equichlamys bifrons*)
Gear Commercial	Benthic scallop dredge
Recreational/Indigenous	Dive only – D'Entrecasteaux Channel closed to fishing
Season	Peak catch and effort occurs between winter and spring/early summer (Fishery closes 31 December).
Primary landing ports	Stanley, Triabunna, St Helens
Fishing licences	72
Active vessels	11 in 2015 season. Most operators also have access to one or both of the Victorian and Bass Strait Central Zone (BSCZ) scallop fisheries
Value of commercial harvest	Up to $6 million, with the 2004 beach value of scallops being $5.5 million
Management arrangements	Output controlled through: • TAC based on aggregation of 10,366 scallop bag units • the Minister can set and alter the quota unit value by public notice Input controlled through: • limited entry (fishers must also hold a scallop entitlement) and a minimum unit holding to operate; • minimum size limits to allow for two spawnings; • spatial management regime, where most of the fishery area is closed and only certain defined areas opened if criteria met; • seasonal closure – fishing only allowed when scallops have reached optimum condition and to maximise recruitment; • limits on number, dimensions, and structure of dredges; • 1 April fishery opens as state-wide survey, survey period to end when an open season is declared or on 31 December.
Export	Mainly a domestic market, although export grew substantially in 2005, particularly to France
Bycatch	Bycatch is relatively low, consisting mostly of molluscs such as dog cockles (*Glycymeris* sp.) and the native oyster (*Ostrea angasi*). Diogenid hermit crabs (*Paguristes tuberculatus*) and the introduced screw shell (*Maoricolpus roseus*) are also taken as bycatch
Interaction with Threatened Species	Considered low, but potentially greater interactions with syngnathids. Possible minor interactions with seals, sharks, cetaceans and seabirds

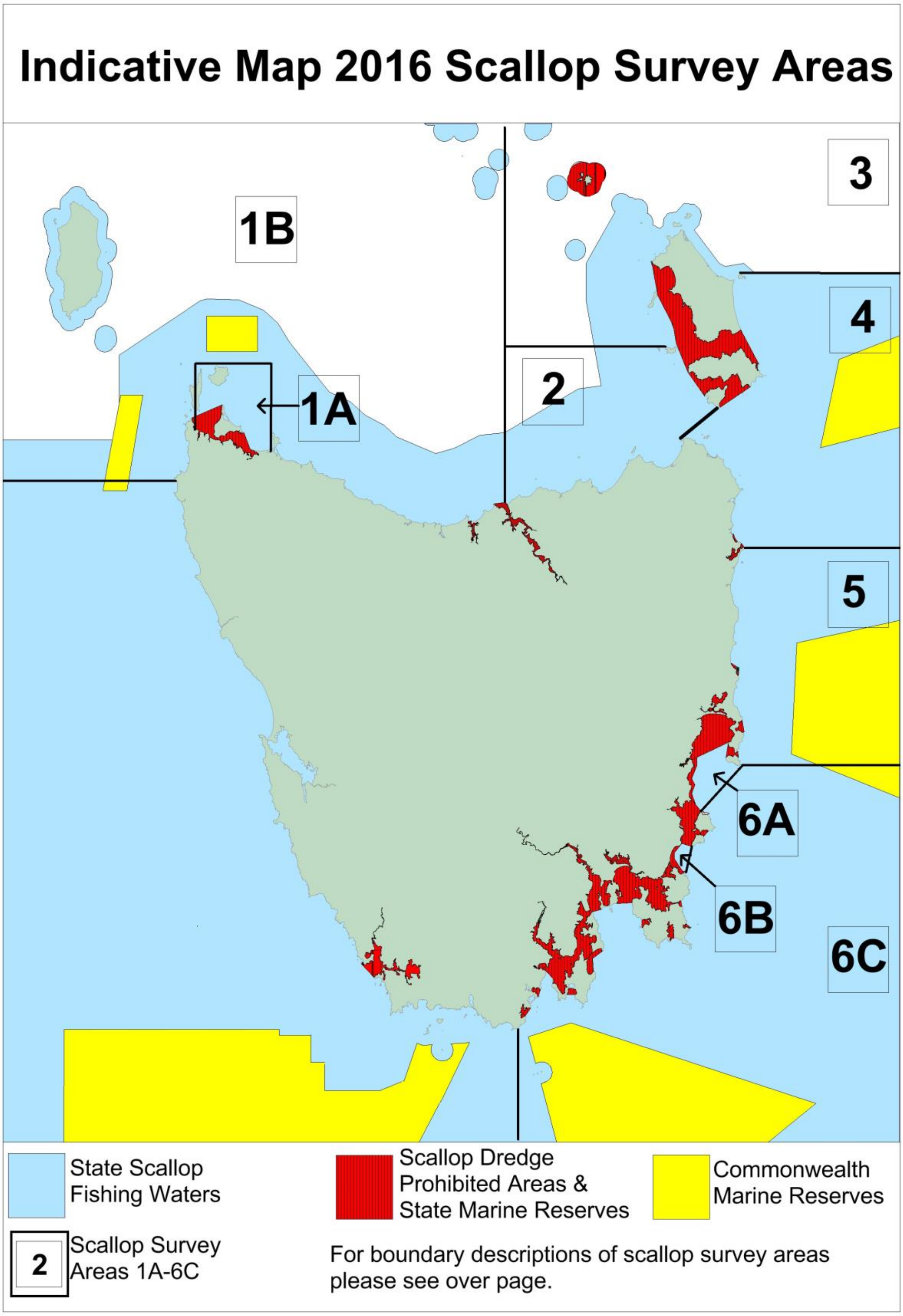

Figure 7. State-wide survey areas.

Recreational fishery

Recreational fishing for scallops has a long history in Tasmanian waters and, like the commercial fishery, has been characterised by open seasons followed by extended closures for stock rebuilding. The current recreational dive-only fishery for scallops (commercial, queen, and doughboy scallops are targeted) commenced in 2006 and catches are input controlled with open seasons, closed areas, size limits, bag limits, possession limits, and a specific scallop diver recreational license. Although the entire Tasmanian coast was initially open to recreational effort, TAFI (now known as IMAS) recreational fishing surveys showed that fishing was primarily focused in the D'Entrecasteaux Channel, and consequently IMAS conducted seven scallop dive surveys of the channel between 2006 and 2011. This research established that the total number of scallops in the channel declined by 87% between 2006 and 2011 (commercial scallops declined by 93%). These surveys and subsequent D'Entrecasteaux Channel surveys in 2012 (dive), 2016 (dive), 2017 (video and dive) and 2020 (video) found that no significant recruitment pulses had occurred since 2007. On this basis, the D'Entrecasteaux Channel component of the recreational fishery has been closed to fishing since 2012 and is likely to remain closed for the foreseeable future due to low abundance of juveniles.

The recreational scallop dive fishery elsewhere around the state has supported open seasons each year from 2012 and approximately 13,000 and 130,000 scallops landed in the 2013 and 2018 recreational seasons respectively, primarily from the central east coast of Tasmania (Lyle *et al.*, 2014; Lyle *et al.*, 2019).

Basic commercial scallop biology

Commercial scallops (*Pecten fumatus*) are filter feeders that sift plankton and detritus from the water column. They are simultaneous hermaphrodites and highly fecund, with up to1 million eggs produced by an individual scallop. Reproduction is by broadcast spawning, where individuals release sperm first followed by eggs, (Minchin, 2003). In Tasmania, *P. fumatus has* a protracted spawning season involving several partial spawning events, as spawning lasts 5–6 months during spring and summer (Mendo *et al.*, 2014a). After external fertilization, larvae remain in the water column for 30 d before settling on fine to coarse sand (generally without organic sediment) forming aggregations commonly referred to as "beds" (Mendo *et al.*, 2014a). The longevity of scallop beds depends on cohort structure. If beds consist of a single cohort, the whole bed disappears when the animals reach the end of their lifespan (Hortle and Cropp, 1987). The size of scallop beds can vary from 5 to 30 square nautical miles (17–100 km^2) (Haddon *et al.*, 2006). The settled scallops grow quickly and reach 70 to 75 mm shell length (SL) in around 18 months. Age and size at maturity are 2 years and 70-80 mm SL, and maximum age and size are 7 years and 120mm; however, these parameters are known to vary by region.

2. Fishery peer review

A peer review of the scallop assessment process was conducted by Dr Gordon H. Kruse in 2015 (Kruse, 2015). Dr Kruse was employed from 1985-2001 at the Alaska Department of Fish and Game, first as the State-wide Shellfish Biometrician and then as Chief Marine Fisheries Scientist; and from 2001 to present has been the President's Professor of Fisheries at the University of Alaska Fairbanks. With respect to scallops, he led the development of the State of Alaska's scallop fishery management plan and co-authored the first federal scallop fishery management plan for Alaska. He served on the Scallop Plan Team of the North Pacific Fishery Management Council for 8 years and is in his 15^{th} year as a member on the Scientific and Statistical Committee of the North Pacific Fishery Management Council, where he conducts reviews of the annual Stock Assessment and Fishery Evaluation (SAFE) reports for scallops and other species. Recently, he conducted a scientific review of the weathervane scallop fishery in Alaska for Monterey Bay Aquarium's Seafood Watch Program.

In addition to the state and federal management plans for scallops, he has published 11 peer-reviewed papers and agency reports on the scallop fishery in Alaska.

The review was informed by interviews with industry, researchers and fishery managers and through documents including scientific papers, survey reports, and minutes of advisory committee meetings relating to application of research data for decision-making. The review was first prepared as a draft, and then provided to Government and Institute for Marine and Antarctic Studies (IMAS) to enable any correction of factual errors or oversights. The aims of the review were:

1.Evaluate the adequacy of life history information delivered by the current assessment program to fishery assessment and management decision-making processes.

2.Evaluate the adequacy of monitoring data used for assessing current status of the stock and used for informing management decisions and the annual harvest strategy (i.e., open areas and Total Allowable Catch, TAC, setting).

3.Evaluate the adequacy and application of methods used to translate life history and monitoring data into scientific guidance on the state of the stock and harvest scenarios.

Reviewer's Recommendations

The reviewer's recommendations were in three categories, as detailed below. Text in italics outlines how this has been addressed:

1. Improved understanding of *Pecten fumatus* life history through research into:
    - Stock structure using genetic and larval drift methods

Addressed in FRDC 2008/022: Establishing fine-scale industry based spatial management and harvest strategies for the commercial scallop fishery in Southeast Australia (see page 14)

- Reproductive biology

Addressed in FRDC 2008/022 and FRDC 2012/027: Determining when and where to fish: Linking scallop spawning, settlement, size and condition to collaborative spatial harvest and industry in-season management strategies (see page 11).

- Age, growth and maturity

There is currently no simple reliable and repeatable technique for accurately ageing scallops. As such, age is currently estimated from a previously defined shell length to age relationship.

Growth has been examined in FRDC 2003/017: Juvenile scallop trashing rates and bed dynamics: testing the management rules for scallops in Bass Strait, using modal analysis of length frequency data (see page 15) and was further addressed using this technique in FRDC 2012/027.

The current monitoring program is generally adequate to inform the current paddock fishing strategy, although future improvement could include allocation of size limits specific to growth rates by area.

A lower minimum size limit (85 mm SL) is applied to scallop beds in the north-west bed given the historically slow growth rates in this region and the fact that most scallops of this size are still 3+ years old, and hence have had two major spawnings (Martin et al., 1988).

2. Improved scientific guidance to management of the fishery through provision of regular stock assessment reports including:
    - Historic landings: *See pages 4-10.*
    - Survey results including size frequency distributions: *Survey undertaken in 2020 identifying size frequency distributions and legal sized density across fishery reported by Ewing and Semmens (2020)*

- Catch per unit effort (CPUE) reporting: *Fishery closed since 2015.*
- Economic performance of the fishery: *Fishery closed since 2015.*

3. Economic data

As there is no economic data to report for 2020, given the fishery was closed, a brief economic summary is given for the most recent open season 2015 to provide an indicator of the current economic status of the fishery.

In 2015, 11 of the 69 Tasmanian scallop quota unit holders participated in the fishery. The participating fishers leased quota from 42 of the non-participating fishers, and 16 unitholders neither participated nor leased their quota. Participating fishers owned 34% of the quota units and leased a further 60% giving a total of 9454 quota units active in the 2015 fishery. A greater range of economic data will be included in future stock assessments, where possible, such as:

- Quota trading and lease prices
- The number of people employed on vessels
- Gross value of production (GVP)
- Processor information

4. Stock status

STOCK STATUS	RECOVERING
The Tasmanian Scallop Fishery (TSF) is managed with a harvest strategy where surveys are undertaken to estimate abundance and decision rules are used to open areas to fishing with total allowable catches (TACs) based on the estimated abundance. Biomass in the Tasmanian Scallop Fishery (TSF) is historically overfished (Caton and McLoughlin, 2004), with recruitment and production levels now affected. In 2013, 2014 and 2015, surveys generally found low scallop densities and limited evidence of successful recent recruitment but did identify two beds (one on the north-west coast and the other on the east coast) containing commercial quantities (Ewing *et al.*, 2016). Surveys in 2016 and again in 2017 generally only found very low levels of scallop abundance and limited evidence of successful recruitment, with no area considered to contain commercially viable quantities in either year (Ewing *et al.*, 2017; Semmens *et al.*, 2018). This includes the east and north-west coast beds fished in 2013-2015, which appeared to have been fished down to a commercially unviable density, with no subsequent recruitment evident. Given the results of the 2016 and 2017 surveys, there was a low expectation that conducting pre-season surveys in 2018 and 2019 would yield the presence of commercially viable scallop beds, and as such, pre-season surveys were not conducted. In 2020, a pre-season survey was conducted, consisting of 635 survey dredge tows and around 1300 commercial tows across all areas of the fishery. Although the survey results were dominated by low to moderate densities of legal sized scallops, several areas demonstrated signs of recruitment that suggest the possibility of supporting a tightly managed commercial fishery in the near- to medium-term. Fishing mortality is managed with the aim of restricting catches to beds of mature scallops near the end of their lifespan. The combination of the harvest strategy and depleted biomass has led	

to a history of closures due to low abundance. In recent times, the fishery was closed between 2000-2002 and again between 2009 and 2010. Areas with commercial density of scallops towards the end of their lifespan were opened to fishing each year between 2013 and 2015. On the basis that biomass is depleted, and large-scale recruitment is impaired, but that current restrictions of fishing mortality have led to some recovery of recruitment, the TSF is classified as recovering.	
STOCK	Tasmanian Scallop Fishery
INDICATORS	Size structure, catch, effort and CPUE trends

5. Bycatch and protected species interaction

Bycatch and protected species interaction from the recreational fishery are effectively nil as scallops are hand collected. Vessels usually anchor at dive locations but anchors are deployed on unconsolidated sediment so there is no concern with habitat interaction.

Bycatch impacts of the commercial fishery are also low because volume is low and almost all bycatch is returned alive and healthy. Common bycatch species are molluscs such as dog cockles (*Glycymeris* sp.) and the native oyster (*Ostrea angas*). Diogenid hermit crabs (*Paguristes tuberculatus*) and the introduced screw shell (*Maoricolpus roseus*) are also taken as bycatch (see a more detailed list from scientific analysis of scallop dredge catches at White Rock in 2006, Table 4).

Interactions with threatened, endangered or protected species (TEPS) are rare. There are low levels of interactions with syngnathids (seahorses and related species) observed, but these are usually released unharmed and interactions with syngnathid populations are limited, given that most of the fishing effort takes place in habitats that are not generally favoured by syngnathids (i.e., sandy bottoms with low levels of habitat structure). Gear is towed at low speed so interactions with mobile protected species like seals, sharks, cetaceans and seabirds are not observed.

When the fishery is opened, scallop fishers need to record any interactions with TEPS, and record retained by-product. However, fishers are only authorised to retain scallop species, so by-product only consists of queen (*Equichlamys bifrons*) and doughboy (*Mimachlamys asperrima*) scallops, of which very little is retained. Fishers do not record bycatch caught in the dredge. Scallop fishers participating in state-wide surveys may make notes and observations about bycatch in log sheets, but this is not compulsory. For targeted surveys, where there are observers on board, the observers (IMAS or DPIPWE staff) may make some more detailed observations, including any interactions with TEPS, but the bycatch from each dredge tow is not quantified. More detailed collection of bycatch information during surveys should be considered, given that these are the only means of collecting this data for the fishery.

Habitat interaction from the commercial fishery has been of some concern in the past when gear interacted with sponge habitat. This problem is now overcome with the system of smaller spatial boundaries for beds opened in the TSF. This process takes account of sensitive habitats to ensure no gear interaction.

Table 4: List of scallop bed species retained in commercial gear during the two scallop dredge surveys conducted at White Rock in 2006.

Category	Common Name	Scientific Name
Commercial Scallop	Commercial Scallop	*Pecten fumatus*
Bivalves	Doughboy Scallop	*Mimachlamys asperrima*
	Queen Scallop	*Equichlamys bifrons*
	Mud Oyster	*Ostrea angasi*
	Mussel	*Mytilus edulis*
	Dog Cockle	*Glycymeris striatularis*
	Razor clam	*Atrina tasmanica*
Other Molluscs	New Zealand Screw Shell	*Maoricolpus roseus*
	New Holland Spindle Shell	*Fusinus novaehollandiae*
	Tulip Shell	*Pleuroploca australasia*
	Triton Shell	*Charonia lampas*
	Cowrie	*Cypraea hesitata*
	Pale Octopus	*Octopus pallidus*
	Southern Keeled Octopus	*Octopus berrima*
Crustaceans	Hermit Crab	*Strigopagurus strigimanus*
	Unidentified Hermit Crab	Unidentified sp.
	Spider Crab	*Leptomithrax gaimardii*
	Hairy Shore Crab	*Pilumnus tomentosus*
	NZSS Hermit Crabs	Unidentified spp.
Seastars	11-Arm Seastar	*Coscinasterias muricata*
	Astropectinid	*Bollonaster pectinatus*
	Oreasterid	*Nectria ocellata*
Urchins	Common Urchin	*Heliocidaris erythrogramma*
	Pencil Urchin	Unidentified sp.
Fish	Crested Flounder	*Lophonectes gallus*
	Lachet	*Lepidotrigla vanessa*
	Shaw's Cowfish	*Aracana aurita*
Rays	Tasmanian Numbfish	*Narcine tasmaniensis*
	Banded Stingaree	*Urolophus cruciatus*
Other Species	Pumpkin Sponge	Unidentified sp.

6. Conclusions and recommendations

The 2020 preseason survey suggested that scallops remained in very low densities around most of the Tasmanian coast (an overall average density of legal-size of 9.3 kg/1000m^2 and median 1.1 kg/1000m^2). Small patchy beds of higher density were encountered in the northern portions of Sub areas 6A and 1B, and a more uniform area of higher density scallops were encountered adjacent to Babel Island in Areas 3 and 4.

FRDC 2008-022 (Mendo *et al.* 2014b; Semmens *et al.* 2015) demonstrated that individual scallops are more likely to spawn when at higher densities and at closer proximity to other scallops, with the potential benefits of increasing encounter rates between gametes (eggs and sperm), and the likelihood of spawning success. Maintaining regions of high scallop density is, therefore, considered an important strategy to enhance recruitment success, partly due to the improved fertilization rates at greater densities, but also due to the indirect effect on synchronization of spawning, i.e., more scallops spawn at the same time when there are more of them, and they are closer to each other (higher density beds).

There were relatively small areas of higher density scallops in some regions of the fishery, although they are generally spatially separated (i.e., there were no large beds with high densities). Of the beds sampled in the 2020 Preseason Survey, the relatively small patch in Area 3 near Babel Island offered the most uniform distribution of tows of higher density (average 23.2 kg/1000m^2 and median 11.4 kg/1000m^2 of legal-sized scallops), and a low discard rate (5.1% at 90 mm). Noting, however, that it had already yielded over 40 t (area survey allowance was 50 t) from 227 targeted dredge tows. Given its small size and the catch already taken, this area was thought not likely to support a commercial fishery in isolation. Additionally, this small bed was adjacent to a higher density bed in Area 4 that yielded a very high discard rate (29%); suggesting that discard rates may not be uniformly low in the Area 3 bed. Furthermore, the Area 3 Babel Island survey shots included scallops as small as 44 mm, which may be underrepresented due to small scallops not being maintained in the dredge in large numbers.

The current depleted nature of the Tasmanian commercial scallop fishery and the recent closure following the likely premature opening of the fishery in 2015, suggest the precautionary principle may need to be applied in the absence of further information. Given that few higher density beds were encountered in the survey, that they are of vital importance in promoting potential recruitment, and that they have already been reduced by targeted fishing during the survey, there were no obvious beds that clearly meet the requirements of areas that could support a commercial fishery in isolation. This was also exacerbated by the fact that there were high discard rates in some areas.

Consequently, a precautionary approach was taken to maintain the closure of the fishery until evidence of more widespread recruitment is observed, or harvesting can be undertaken without damaging the stock rebuilding process. Allowing more widespread recruitment is more likely to support a fishery unmarred by regular closures. The isolated patches of higher density scallops encountered in this survey, while a positive sign, may be best utilised for stock re-building to support a future sustainable fishery. The presence of juvenile scallops in Areas 4, 3 and sub-Areas 1A and 1B presented some promising evidence of stock rebuilding beginning in these regions.

The survey scheme used in and prior to 2020 was conceived when biomass in the Tasmanian Scallop Fishery was not depleted and was a practical tool for achieving surveys at that time. However, its shortcomings are amplified in a depleted fishery. Although the survey tows conducted in the survey scheme in 2020 were unlikely to impact density and hence potential recruitment, they were accompanied by targeted fishing associated with the survey quota allocation of 50 t/survey area (Figure 7). For example, the 2020 survey entailed 635 dredge tows and over 1300 targeted fishing shots. This targeted fishing occurs in the densest areas found during the survey, reducing the density of the beds, which may in turn impact potential recruitment in a depleted fishery, prior to a decision being made as to whether the biomass can support a fishery and what areas should be closed due to undersized scallops. This effect was pronounced in Area 4 during the 2020 preseason survey where discard rates were particularly high (up to 44%) in higher density beds likely to be targeted to collect the survey quota. It should be noted that the survey scheme was adjusted in 2021 to limit the impact of targeted fishing.

Along with targeted fishing, the survey scheme used in and prior to 2020, did not use randomly designated dredge tows. The data from the 2020 survey showed that this was leading to the fishers sometimes clumping survey shots around legal sized scallops, rather than fully surveying the area, or alternatively not fully investigating an area when legal sized scallops were not initially found. Both these unconscious behaviours limited the effectiveness of the surveying. It should be noted that the survey scheme was adjusted in 2021 to encompass a random survey design. Unlike the clumped/limited sampling in the 2020 survey, the random sampling method better reflects the variation in density of scallops across the defined area of interest.

Video surveys offer an advantage over dredge surveys due to: (i) lower costs for data collection; (ii) enhanced precision of size structure; (iii) information on recruitment in recent years; (iv) minimal impact on the seafloor and benthic biota and (v) no mortality of sub-legal scallops. Their continued use is recommended for providing data for management of the TSF, in conjunction with dredge surveys. However, adoption of video surveys will require review of the criteria for closures in the fishery to account for the difference in selectivity of dredge surveys compared to video surveys. Dredge surveys, both industry standard and modified to account for recruits, could be conducted in parallel with video surveys for a pre-determined period to correctly calibrate closure criteria of the latter. It is also recommended that concurrent with this use of the technique, further development of the video survey method is undertaken, such as methods to reduce the processing costs of video analysis through techniques such as machine learning. These recommendations will be undertaken in the recently funded FRDC project 2020-030 “Wider investigation of the use of video survey techniques to determine commercial scallop abundance in inshore and offshore waters, closed areas and juvenile beds”, which will commence in January 2022.

7. Acknowledgements

Thanks to James Parkinson (DPIPWE) for his review and constructive comments.

8. References

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