Assessment of abalone stocks in NSW

Submission to the TAC setting process for 2024-25

Abalone Council of NSW

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Summary

This report provides an assessment of stocks of abalone in NSW, consistent with the fishery's interim Harvest Strategy, and prepared for consideration during the TAC setting process for the 2024-25 Fishing Period. The report updates data from catch reporting, including catch, catch rates and the average weight of abalone landed within each of the four Spatial Management Units (SMU), which are Primary Performance Indicators in the fishery's interim Harvest Strategy. The report also updates information from GPS logger data following the change to real-time logger technology and the requirement for use of loggers by divers from March 2019. Logger data includes detailed spatial information about fishing effort and is combined with diver's daily catch to estimate an index of legal-sized abalone biomass, which is also a Primary Performance Indicator in the fishery's interim Harvest Strategy. Measuring logger data includes information about change in the length of abalone landed which is a Secondary Performance Indicator in the Harvest Strategy. A fishery-independent survey was also completed in 2022, and included sampling at sites from Bermagui to Cape Howe where comparisons with historical data were possible. This assessment and report were prepared in the same format as previous years to aid comparison, and a description of technical methodology is in an Appendix.

The commercial abalone fishery in NSW changed the direction of its strategic management in the early 2000s. Following development of the fishery in the 1960s, for over 30 years until the early 2000s the commercial fishery averaged a catch rate of about 20-30 kg per hour, while the annual catch declined from over 1000 t to 333 t and below. The combined impact of the commercial fishery, other catching sectors including the illegal catch, and external impacts such as disease, led to a significant decline in abalone stocks and with the commercial fishery becoming more concentrated on the south coast. Further significant reductions in Total Allowable Commercial Catch were made from 2005 to a low of 75 t, in an attempt to rebuild stocks and increase catch rates in the commercial fishery. Catch rates increased strongly from 2005, and above 40 kg per hour in 2013 and until 2016, when a large north-east storm impacted much of the shallow coastal reef on the NSW south coast. Following the storm in 2016, catch rates declined, and the annual catch was again reduced to 100 t. In recent years, the annual catch of 100 t has been maintained and catch rates have remained mostly above 40 kg per hour averaged across the fishery, but the commercial fishery is increasingly concentrated on the far south coast. There is also evidence to suggest the impact of the illegal catch of abalone has increased in recent years.

There were large external impacts on the commercial abalone fishery and its markets from late 2019. Bushfires in coastal parts of NSW in early 2020, together with ongoing effects of the Coronavirus and its impacts on overseas markets, impacted abalone fishing, processors and marketing. Beach prices declined substantially together with the ability to reliably land and market catch through the year. Market disruptions in 2020 led to some catch (i.e. 17.5 t) being carried over and landed in 2021-22, and together with ongoing market disruption and the return to a financial year TAC, total catch from 2020-23 remained about the 100 t TAC for each Fishing Period (i.e. 94-103-99 t), but catch per Calendar year was more variable (i.e. 64-115-84-101 t). Further, catch has been concentrated in the last few months of the Fishing Period (i.e. catch of 57-43-49 t in final 3 months of the 2020-21, 2021-22 and 2022-23 Fishing Periods, an average of 50% of the 100 t TAC). After 6 months of the 2023-24 Fishing Period to December 2023, a total of 32 t of the 100 t TAC has been landed (compared to 29 t of the 2022-23 TAC by December 2022), and leaving 68 t to be caught in the final 6 months of 2023-24. Such large variation in catch within the Fishing Period has contributed to variation among and within the year in fishery Performance Indicators and stocks. Market conditions, and the ability to land and market catch, have improved, but remain uncertain.

The timing and spatial distribution of catch during the last three years has been impacted by difficult market conditions impacting processors and the fishery. The distribution of catch in 2023 and 2023-24 has been broadly similar to recent years, with ~95% of catch landed south of Bermagui, and ~75% landed south of Eden. Catch has remained concentrated in the south of the fishery, with only 1.0 t caught in the northern Areas 1-6 (i.e. SMU 1, north of Tuross) in the 2023-24 Fishing Period and 3.3 t in the 2023 calendar year (1.5 t in 2021-22 and 2022). In March 2023, three catch caps were implemented in the fishery in an attempt to improve the spread of catch; 15 t (Redhead-McEwan, Area 2-9), 60 t (McEwan to Wonboyn, Area 10-18) and 35 t (Wonboyn to Cape Howe, Area 19-21). Catch in 2022-23 remained within these caps, and further consideration of the caps is proposed. In addition to the catch caps, a size limit of 117 mm was also implemented in March 2023 (i.e. Red Head-McEwan). Catch from this area in the 9 months since March 2023 was 3.9 t compared to 3.1 t in the 9 months prior to March 2023, and catch rates increased.

During the period of high catch in April-June 2021, fishery Performance Indicators were at record highs (e.g. including a record daily catch in 2021, and higher catch in May 2022). Since then, indicators of catch rate and biomass have declined to a varying extent in all SMU, while individual abalone weight has remained stable or increased. While this may suggest a period of reduced recruitment to the fishery (e.g. smaller year-class or lower growth), abalone weight has been increasing with some consistency for several years. Patterns in Performance Indicators have been relatively consistent across the fishery, increasing to record highs during 2013-2016, and then declining ~20-30% from their peak, before increasing again to 2020-21 following significant management change (i.e. TAC reduced for 2-3 years, and size limit increased), declining ~20-30% until the end of 2022, and recovering to 2023-24. While variation in stocks and market conditions may remain, a more stable and extended period of consistent catch would aid interpretation of fishery Performance Indicators and understanding of status and productivity of stocks.

Across the fishery, average daily catch rate remained stable at about 200 kg per day from 2015, before increasing to a peak above 250 kg per day in late 2019 (i.e. following TAC reduction from 130 to 100 t in 2018), before increasing to almost 300 kg per day in early 2020. The running 12-month average catch per day remained above 250 kg until early 2021, before declining following the large catches in April to June 2021, and remaining about 200 kg until the end of 2023. Following similar increases to a peak in 2014-16, and several years of decline to 2018-19, raw and standardised catch rates increased in all SMU to another peak in 2020-21, followed by decline to 2022-23 and increase in 2023-24 in all SMU. Catch rates remain historically high and near the peak of the last 20 years (i.e. and the recorded history of the fishery). This includes a peak in the frequency of higher catch days in 2020-21, followed by decline and some recovery in 2023-24, and record daily catches (i.e. highest on record in the southern part of the state since at least 1982) of 687 kg landed in July 2021 and 718-782 kg in May 2022. Since then, there have been 3 days over 590 kg, 8 days over 500 kg in 2023, and 3 days over 500 kg to December 2023 in the 2023-24 Fishing Period with the winter fishing season remaining in coming months.

Following reductions in TAC in the early 2000s, the average weight of abalone landed has increased quite consistently for almost 20 years, and remains near historic highs, particularly following the recent size limit increases in 2018-19. Landed abalone in the 2022-23 and 2023-24 Fishing Period are now on average 5-6% heavier (i.e. among SMU) than 2017 prior to the size limit changes. Ongoing increases in the weight of abalone landed have led to complementary reductions in the number of abalone landed for the same TAC, with 17% less individual abalone landed in 2021-22 compared to a similar total catch in 2010-11. Despite the longer-term increases, the average weight of abalone landed over the last 3 years is a Performance Indicator in the interim Harvest Strategy, and over this period has declined 1-2% in SMU 2-4. As longer-term change in the average weight of abalone has stabilised, the indicator may be more responsive to change in recent fishing mortality, and related to similar decline in catch rate in recent years.

Real-time GPS logger coverage while diving has stabilised at a high level across the fishery (i.e. 95% in 2023-24, with some manual loggers still to download), and provides several types of information about the fishery and stocks. As well as detailed spatial-information about the location of fishing effort, GPS data about dive events can provide an index of the area fished by divers to land their daily catch, that may respond more quickly, and be more closely related, to changes in the legal-sized abalone biomass than other indicators (i.e. that may be more hyper-stable). This index of legal-sized abalone biomass (i.e. standardised by diver and spatial location) increased to peaks consistent with those in standardised catch rates in 2014-16, and following the large increase in catch in April-June 2021, but declined sharply up to the end of 2022 (e.g. as did catch rate) before recovering to 2023-24. The index of biomass density is also extrapolated to estimated areas of productive reef from loggers (i.e. 3-year rolling activity within 1 Ha grid) to calculate a total biomass of legal-sized abalone associated with fished-areas within each SMU. Change in estimates of total biomass suggest Surplus Production from the stock in recent years has been variable and declined sharply coincident with the large east coast storm in 2016, and following the large catches in April-June 2021 until the end of 2022, before recovering to 2023-24. While estimated Harvest Fractions (i.e. catch as a proportion of estimated total legal-sized biomass) were decreasing up to 2020-21, the sharp decrease in estimated density of biomass since mid-2021 and increase in catch in 2021 (i.e. 114 t), led to reduced estimates of biomass with increased commercial catch Harvest Fraction, before reversal in 2023-24 from recovery in estimates of biomass density. Harvest Fractions within SMU 2-4 during 2022-23 and 2023-24 remain near previous highs since 2010.

The high coverage of GPS loggers now also provides detailed spatial information about catch and effort in the fishery (e.g. summarised in detailed heatmaps to display local change in effort through time), better information about the area of reef used by the fishery, and Performance Indicators that suggest diver's fishing behaviour has changed in response to recent changes in the stock. For example, in other abalone fishery dashboards displaying real-time maps of recent fishing effort, including comparison with other times and fishing periods, have been developed and are shared among divers to help improve distribution of effort away from sites recently fished. Further development and use of information from GPS logger data as fishery performance indicators, is consistent with development in most other abalone fishery.

Other research priorities include;

- Update of real-time GPS logger on all boats (i.e. 3g to 5g), with extension to other linked sensors (e.g. recent extension to water temperature, and planned use of acoustic tags and listeners linked to VMS).
- Further expansion of the re-established program measuring landed abalone and its extension to undersize abalone and fishery-independent surveys with commercial divers.
- Repetition and extension of the survey of abundance on southern reefs with commercial divers.
- Continuation and expansion of the survey of Diver Observations.
- Further investigation of catch rate standardisation to investigate potential for effort creep.
- Further development of automated reporting of Performance Indicators from cloud site to diver's devices and for use in effort planning and ongoing stock assessment.
- Further development and completion of the fishery's Harvest Strategy.

Two measures of Stock Status are determined and relate to different approaches to assessment of the stock. Assessment of fishery-wide Stock Status uses the National Reporting Framework of the Status of Australian Fish Stocks, and is made by comparison to Reference Points for the fishery as a whole (i.e. including Sustainable, Depleting, Depleted, with Reference Points agreed during development of the interim Harvest Strategy). In this assessment, the fishery is considered **Sustainable**, because fishery-wide catch rates are above the Sustainable Reference Point (i.e. 40 kg/hr fishery-wide catch rate, and related indicators). Shorter term assessment of change (i.e. 3-year trend as Stable, Increasing, Decreasing) is summarised separately for each SMU. SMU 2 from Tuross to Eden is assessed as **Stable-Increasing** as the three-year trend in catch rates is stable (i.e. -4% per year), and the biomass index is increasing (+15%), with most fishing in the southern part of the SMU. SMU 3 from Eden to Wonboyn is assessed as **Stable**, as the three-year trend in catch rates is decreasing (-6%) and the biomass index is increasing (+12%). SMU 4, south of Wonboyn, is assessed as **Stable-Increasing** as the catch rate is stable (+1%), while the biomass index is increasing (+17%). In SMU 1, there remains little consistent data available for assessment of the extent of local spatial-depletion and broader ongoing recovery (e.g. particularly from previous *Perkinsus*-related mortality). With very limited catch and more variable Performance Indicators in SMU 1 and the northern part of SMU 2, these areas are considered likely to be **Spatially depleted and Stable** (i.e. consistent with adjacent SMU 2). Short-term assessments in each SMU have changed in recent years, from where most SMU were considered Increasing in early 2021, to most SMU being Stable in early 2022, then most SMU having some declining indicators in early 2023, to this year with one declining indicator (i.e. catch rate in SMU 3) and most biomass indicators increasing.

Management changes implemented with the intent to increase stocks, including a TAC reduction to 100 t since 2018 and more recent size limit changes, initially impacted catch rates and other indicators, but these quickly returned to levels similar to those prior to the management change. With reduced catch associated with external factors (e.g. bushfires, covid and markets), there was further increase in fishery Performance Indicators up to mid-2021, which provided evidence for increasing stocks throughout most of the active fishery. Large catch in April to June 2021 just prior to the end of the Fishing Period, quickly reduced fishery Performance Indicators to levels where they have remained until the end of 2023. The recent Management change to implement and develop the use of catch caps, together with a 117 mm size limit, offers the potential to spread catch better across productive stocks, and so reduce the impact of fishing where its concentrated. Large variation in catch through time within the Fishing Period (i.e. large catch prior to the end) and concentration of catch in the south of the fishery, impact interpretation of Performance Indicators, contribute to uncertainty in the assessment and the ability of stocks to support current catches while maintaining fishery Performance Indicators.

In recent years, uncertain market conditions have affected the fishery, its impacts on the stock, and interpretation of fishery Performance Indicators. While market conditions have improved, they remain uncertain and contribute to ongoing uncertainty about catch. In 2023-24, there is some evidence for an increasing spread of catch through the Fishing Period (i.e catch to Feb in 2023-24 of 46 t compared to 40 t in 2022-23), and change in fishery Performance Indicators to return to more positive trends, but threats remain to stocks and the fishery (e.g. illegal catch, recruitment and growth variation, water temperature). Conservative decisions about catch and TAC should ensure fishery Performance Indicators are maintained or increased as the catch is maintained at levels consistent with the TAC. Demonstrated performance of the fishery at catch levels consistent with the current TAC, over longer time and spread across all productive reefs, would provide greater evidence for production from the stock.

Background

Assessment of abalone stocks in NSW is currently based largely on information collected from the commercial fishery, similar to most abalone fishery in Australia. Earlier reviews of the fishery in NSW recommended that stock assessment be based on data from commercial catch and effort reporting, combined with fine-scale data from GPS loggers operated by commercial divers. An interim Harvest Strategy was prepared in 2015 and developed further in 2023, which defined key Performance Indicators for the fishery and their interpretation. A fishery-independent survey of abundance and size-structure of abalone on key southern reefs was completed in 2013, and provided both a strategic assessment of stocks on the southern reefs, and information to calibrate estimates of density coming from GPS loggers. Another survey was completed independent of fishing in 2022, where the length-frequency and collection rate of abalone was sampled at 23 sites, most with comparable historic data, from Cape Howe to Bermagui. The combination of information from multiple sources, and its use in assessing stocks, is similar to that being developed and used for TAC setting in other state's abalone fishery. Current FRDC-supported research projects are also further developing a national approach to abalone stock assessment, that combine multiple data sources geo-referenced by GPS loggers while fishing, and are available in near real-time, to help extend use of the information in fishery assessment and management and its testing within formal Harvest Strategy.

This report has been prepared to provide an analysis, summary and interpretation of data contributing to an assessment of stocks of abalone in NSW. The report updates the assessment released in March 2023, with data from commercial fishery logbook catch reporting, including catch, catch rates and weight of individual abalone landed which are Primary Performance Indicators (PI) in the fishery's interim Harvest Strategy within each of the four Spatial Management Units (SMU). The report also updates GPS logger data following the change to real-time logger technology and a requirement for use of loggers by divers from March 2019. Logger data includes detailed spatial information about fishing effort and is combined with daily catch records, and extrapolated to estimate legal-sized abalone biomass, which is also a PI in the fishery's interim Harvest Strategy. Secondary Performance Indicators include other indicators about dive events from GPS loggers and trends in the length of abalone landed, measured by GPS-enabled abalone measuring devices. A description of technical methodology is available in Appendix 1. This report was prepared by the Abalone Council of NSW as an independent, not-for-profit company contracted to NSW DPI. Initial development of the GPS logger and measuring program was funded directly by fishery Shareholders with the support of the broader Industry and NSW DPI, and this cooperation continues in the further extension of this important program.

This report presents updated Primary and Secondary Performance Indicators from the fishery's interim Harvest Strategy. Primary Performance Indicators at the scale of SMU include standardised catch rate and the average weight of abalone from logbook reporting, and an index of biomass calculated from GPS logger and catch data. Secondary Performance Indicators include other measures of catch and effort from logbook reporting, landed abalone lengths from measuring loggers, and other measures of dive events available from GPS loggers. Data presented here extend information presented to previous TAC setting process, including summaries of the commercial fishery logbook catch data (i.e. updated from 2022 to December 2023), and GPS loggers (i.e. updated from 2022 to December 2023). Data from the recently re-established program measuring the length of abalone with GPS-enabled Measuring loggers is presented with a comparison to earlier measuring programs with data from the 1990s and 2010s. Preliminary data from the survey of Diver

Observations is also presented. Further development of the methodology and interpretation described here will be guided by ongoing development of the fishery's Harvest Strategy (i.e. see draft in Appendix 6).

The Total Allowable Fishing Committee (TAFC) made several recommendations in their annual determination from April 2023. These include particularly; 1. Catch rates be standardised to explain factors that may have changed in the fishery, such as spatial changes and technological or effort creep, and 2. Development of a pre-recruit indicator of abalone coming into the fishery is needed to address a growing concern about recruitment patterns. While catch rates are already standardised for several factors, including spatial differences, extension to effort creep is complicated by the lack of available data, similar to other abalone fishery. Experience in other abalone fishery has suggested incorporation of information about diver experience in the standardisation of catch rates, but has found little evidence for resultant change in trends through time unless there are broad changes in diver experience. Change in the spatial extent of the fishery (i.e. reduced extent at a local scale into shallower water) are likely to have the greatest impact on estimated change in catch rate trends through time, but again any historic data on actual change in the extent of local productive reef are very limited. Challenges to standardisation and interpretation of commercial catch rates suggest the importance of fishery-independent surveys, calibration with fishery-dependent indices, and particularly focussing on abalone under the size limit (i.e. pre-recruits as suggested in the TAFC recommendations). While surveys have been completed (e.g. in 2013 and 2022) and focussed on under-size abalone and reef productive to the commercial fishery (i.e. as recommended by the Committee), the design and implementation of such surveys are not simple with the likely changing extent of abalone population density and extent. Further, while a leading indicator based on under-size abalone may enable predictions of change in the legal-sized population, other factors such as growth are also clearly important. Predictions of change in the fishery, even with an under-size abalone index, are difficult because of the large influence and unpredictability of variation in growth. As a consequence, the Diver Observation survey was designed in a national project (i.e. currently active in 8 mainland fishery) in an attempt to collect information from commercial divers about under-size abalone likely to recruit to the fishery (see Appendix 5). The difficulty, uncertainty and expense of more detailed and fishery-independent information on recruitment and change in stocks, emphasises the importance of detailed investigation and calibration of commercial fishery data, particularly at a fine-scale using GPS loggers, and assessment of observations and interpretation by divers spending extensive time in the water and observing abalone populations (i.e. as was recommended in previous reviews of the NSW fishery, and elsewhere e.g. FRDC 2018-212).

Primary Performance Indicators

Catch and catch distribution

A total of 98.9 t from the 100 t TAC was caught in the 2022-23 Fishing Period (Table 1). Similar to previous years, catch in the last 3 months of the 2022-23 Fishing Period was high at 48.8 t (i.e. 56.9 t and 43.2 t in 2020-21 and 2021-22). In particular, catch during the single month of May 2023 was 31.4 t (see Figure 2), with 23.4 t caught south of Eden (i.e. highest monthly catch south of Eden since May 1999). This recent distribution of catch within the year, with an average of 50% of the 100 t TAC landed in the last 3 months of the Fishing Period, can be compared to earlier Calendar and Financial year Fishing Periods. For example, during the Calendar year Fishing Periods from 2016-18, only ~30% of the TAC was landed in the 3 months Apr-Jun, with ~20% in Oct-Dec at the end of the Calendar year TAC. Similarly, during earlier Financial year TAC from 2010-12, which averaged a 108 t TAC, where only 20% of the TAC was landed in Apr-Jun at the end of the Financial year.

Similar to recent previous Fishing Periods, there was a reduction in catch early in the 2023-24 Fishing Period, following the increase in catch at the end of the 2022-23 Fishing Period. Catch was lower in the first 6 months of the 2023-24 Fishing Period (i.e. 32.0 t, compared to 29.4 t in 2022-23), contributing to a full 2023 calendar year's catch of 101.4 t (i.e. compared to 64-115-84 from 2020 to 2022). With 32.0 t caught from the 100 t TAC in the first 6 months of the 2023-24 Fishing Period, 68.0 t remains to be landed in the remaining 6 months. By the end of February 2024, there was 46.3 t (40.3 t in 2022-23) caught of the 100 t TAC in the 2023-24 Fishing Period.

The timing and spatial distribution of catch during the last three years has been impacted by difficult market conditions impacting processors and the fishery. While the distribution of catch in 2023 and 2023-24 has been broadly similar to recent years, with most catch landed south of Bermagui (94.9-95.4%) and Eden (75.0-76.9%), there have been some ongoing patterns in catch among Areas (Figure 1). For example, following mid-2016 (i.e. June 2016 north-east storm) catch was reduced on the north-east facing Green Cape (i.e. Areas 14-16), and increased in the south facing Disaster Bay (i.e. Areas 17-18). During 2018, this was reversed, with the proportion of catch on Green Cape recovering, while reducing in Disaster Bay where it remained low before starting to recover (e.g. from 17.5% of catch in 2017-18, to 4.7-5.2% in 2021-22 and 2022-23, and increasing to 9.7% in 2023-24). Similarly, in 2019, the proportion of catch landed from closer to Eden increased further (i.e. Area 14-16 from 14.8% of catch in 2016-17, to 35.6% in 2019-20, 30.9-34.8-36.9% in 2021-22 to 2023-24). There has also been a gradual, longer-term decline in catch from northern Areas (Figure 1). More recently, catch north of Tathra (i.e. Area 9-10) increased to 15% in 2015-16 before declining to 4% in 2020-21, and remaining lower at 10-7-7% from 2021-22 to 2023-24.

In August 2022, Industry and DPI agreed to a new approach involving catch caps, and this was implemented in March 2023, together with a 117 mm minimum length between McEwan Point (i.e. on Araganu Beach, near Bunga mid-way between Bermagui and Tathra) and Redhead Beach (near Newcastle, see Table 1). Three catch caps of 15 t (Redhead-McEwan, Area 2-9), 60 t (McEwan to Wonboyn, Area 10-18) and 35 t (Wonboyn to Cape Howe, Area 19-21) were agreed, and catch was monitored against the caps through the year, with weekly and daily assessment as catch approached some caps near the end of the Fishing Period. Because of the timing of catch reporting, reconciliation, monitoring and reporting against caps, an implementation error of up to 1-2 t was expected. Catch in 2022-23 remained below each catch cap, with 5.8 t landed from the 15 t cap, 59.7 t landed from the 60 t cap, and 31.3 t landed from the 35 t cap (Table 1). Catch from the area north of McEwan Point increased in the 9 months following March 2023 to 3.9 t compared to 3.1 t in the 9 months prior, and catch rates increased sharply (see yellow in Figure 1 and Appendix 4). The northern boundary of the 60 t cap is implemented at Mimosa Rocks (i.e. not the Area 10 boundary at Bunga), which is the nearest catch reporting boundary to McEwan Point. Catch caps and their extension to areas such as north and south of Eden will be considered during the upcoming TAC process, and could further improve spatial catch control in the fishery. Development of a system for planning the spatial distribution of catch, with flexible and regulated catch caps and targets with regular review are used in most other abalone fishery, and facilitate planning of catch as part of fishery-wide TAC, monitoring of the fishery against catch plans, and spatial assessment of stocks against Performance Indicators. Such an approach has been proposed and should be further considered as part of further development of the Harvest Strategy.

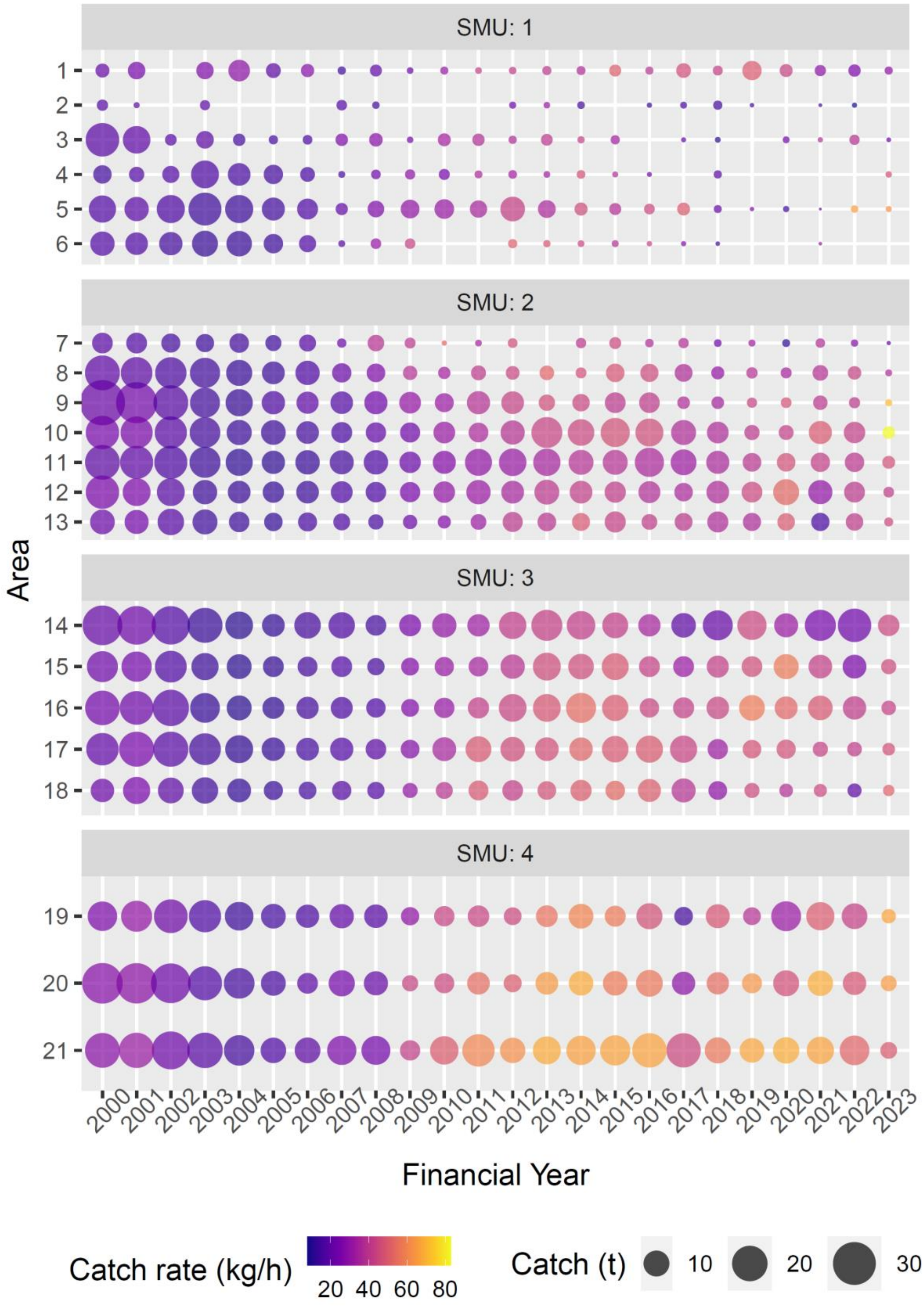


Figure 1. Catch (circle size) and catch rate (circle colour) per Area and SMU for each financial year from 2000 to 2023 (i.e. 2023-24 Fishing Period).

Table 1. Catch data for each Area and Fishing Period from 2016 to the end of December 2023, including Catch Caps implemented since 2022-23. Total catch is shown for each Spatial Management Unit with minimum size limits of 120-117-120-120-125 mm. Note, the size limits boundary at the McEwan line for 117-120 mm is just south of the Bunga and Mimosa Rocks boundary for catch reporting. Note also, the division of the 60 t catch cap from Bunga to Wonboyn (Area 10-18), into totals north (Area 10-13) and south (Area 14-18) of Eden.

Area	Nth point	2016	2017	2018	H1 19	2019 20	2020 21	2021 22	2022 23	2022 23	Catch Cap
1	Tweed	1.0	2.6	0.8	0.0	5.1	1.6	1.3	1.7	0.5	
	Total	**1.0**	**2.6**	**0.8**	**0.0**	**5.1**	**1.6**	**1.3**	**1.7**	**0.5**	**No cap**
2	Swansea	0.1	0.3	0.9	0.2	0.1	0.3	0.1	0.1	0.0	
3	Kiama	0.3	0.1	0.0	0.1	0.0	0.3	0.1	1.1	0.1	
4	Ulladulla	0.2	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.3	
5	Sth Brush	0.6	1.8	1.3	0.0	0.1	0.2	0.0	0.4	0.2	
6	Batemans	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	
7	Tuross	0.9	0.6	1.0	0.1	0.4	0.5	0.9	0.4	0.0	
8	Narooma	5.4	5.1	3.1	0.5	1.4	1.3	3.1	2.1	0.3	
9	Bermagui	4.1	3.8	1.5	1.5	1.0	1.2	2.5	1.3	0.4	
	Total	**11.7**	**11.8**	**7.8**	**3.1**	**3.0**	**3.8**	**6.7**	**5.4**	**1.3**	**15**
10	Bunga	11.5	11.8	8.4	2.4	2.9	2.8	7.7	6.5	1.8	
11	Moon Bay	12.3	11.8	7.7	4.2	4.7	4.6	5.1	5.2	1.9	
12	Turingal	7.8	6.3	5.3	4.3	6.1	10.0	8.5	6.1	1.2	
13	Long Beach	5.2	3.8	4.4	3.7	4.4	4.1	4.5	4.1	0.7	
	Total (10-13)	**36.8**	**33.7**	**25.7**	**14.6**	**18.1**	**21.5**	**25.8**	**21.9**	**5.6**	
14	Eden	9.6	6.0	12.7	7.2	13.1	8.4	14.9	17.6	6.6	
15	Saltwater	9.5	6.1	6.3	3.3	6.0	9.3	8.2	8.2	2.9	
16	Bittangabee	9.1	5.3	7.3	3.2	9.8	7.6	8.9	7.9	2.6	
17	Greencape	10.8	14.2	6.5	1.9	4.7	5.0	2.9	2.6	1.8	
18	City Rock	6.7	10.2	5.3	1.8	3.1	2.2	2.0	2.4	1.4	
	Total (14-18)	**45.7**	**41.8**	**38.0**	**17.4**	**36.7**	**32.5**	**36.9**	**38.7**	**15.3**	
	Total (10-18)	**82.5**	**75.6**	**63.7**	**32.1**	**54.8**	**54.0**	**62.7**	**60.5**	**20.9**	**60**
19	Wonboyn	6.5	9.1	6.6	3.6	4.2	13.7	12.0	9.8	2.5	
20	Saltlake	9.4	10.7	6.3	4.3	5.5	10.0	9.5	8.0	3.2	
21	Howe	18.8	19.0	13.0	6.1	9.9	10.4	11.3	13.5	3.6	
	Total	**34.7**	**38.8**	**25.8**	**14.0**	**19.6**	**34.1**	**32.8**	**31.3**	**9.3**	**35**
	Total	**129.8**	**128.8**	**98.2**	**49.1**	**82.5**	**93.5**	**103.5**	**98.9**	**32.0**	

Monthly catch for the fishery reduced from an average above 10 t per month consistent with the 130 t TAC in 2017 (light blue line in Figure 2), to about 5.1 t per month (range 2.0-12.1 t) for 21 months from July 2019 to March 2021, related to difficult market conditions. From April 2021, catch per month increased sharply in April and June (i.e. 3 month average of 19 t) immediately prior to the end of the Fishing Period, and almost doubling the trailing 12-month average catch from 5.1 t in March 2021 (i.e. annualised 61 t), to 9.8 t per month in November 2021 (i.e. 118 t annualised). The 12-month average catch remained above 8.3 t (i.e. annualised 100 t) until June 2022, the end of the 2021-22 Fishing Period, before declining to 6.5 t (i.e. annualised 78 t) by the end of 2022. Catch in the final 3 months of the 2020-21, 2021-22 and 2022-23 Fishing Periods was high, and averaged 19.0, 14.4 t and 16.2 t (i.e. annualised 224-173-195 t). Catch in the single month of June 2021 was mostly south of Bunga (i.e. 27.0 t of 29.2 t from Area 10-21) and within this area this was higher than any previous month since June 1985 during a very different TAC and size limit. Catch in the single month of June 2023 was 31.4 t, with 23.4 t south of Eden, which are both higher than any previous monthly catch since 2000. With 6 months remaining in the 2023-24 Fishing Period, a monthly average catch of 11.3 t (i.e. annualised 136 t) is required to land the 100 t TAC.

Similar to catch, effort per month for the fishery has also declined from 50-55 diver-days per month in 2016 and 2017 (Figure 3a), to an average of 23 diver-days per month in 2020 (range 7-58 days, with 36 day average in 2019). This increased in 2021 to an average of 41 days per month (range 15-103), including peaks of ~100 diver-days in April and June 2021, June 2022, and over 150 diver days in May 2023. During 2023, there was an average of 41 days per month, with a peak in March-June 2023 (i.e. 72 day average for 4 months), declining to a 24 days per month average from July to December 2023.

Average catch per diver-day reached a peak of 250 kg in mid-2016 (i.e. prior to a major storm on the NSW coast in June 2016), and declined slightly until late-2019, when catch per day increased above 250 kg per day coincident with strong south-westerly winds in mid-2019 (Figure 3a). Through 2020 and early 2021, catch per day continued to increase to between 250-300 kg per day, including during the summer months often associated with less favourable onshore weather. Following the large monthly catch and effort in April-June 2021, daily catch started to decline again to about 200 kg per day, and has remained mostly stable since mid-2022. Change in catch per diver-day can also be summarised by the frequency of different daily catch (Figure 3b). Since 2009, the frequency of >200 kg catch increased from under 5%, to over 70% of diver-days in 2020-21, reducing to 56% of days in 2021-22 and 44% of days in 2022-23, and recovering to 52% in 2023-24. Similar changes have also occurred in the frequency of larger catches >300 kg and >400 kg per day. A daily catch of 687 kg was landed in July 2021, which was the highest on record in the southern part of the state since at least 1982. In May 2022, a daily catch of 782 kg was landed, and in June 2022 a 615 kg catch was landed. Since June 2022, there have been 8 days with catch >500 kg, including during August 2023, and 2 more days with catch >600 kg including during June 2023.

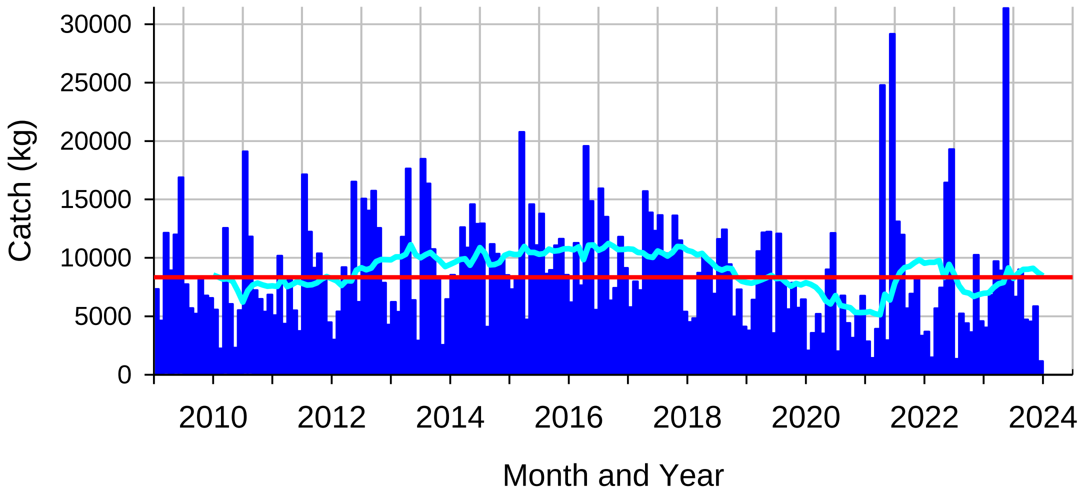


Figure 2. Catch (kg) per month for the fishery from 2009 to Dec 2023 (blue bars), with a trailing 12-month moving average (light blue line). With 32.0 t caught by Dec 2023 from the 100 t TAC in the 2023-24 Fishing Period, a 6 month catch of 68.0 t is required at an average of 11.3 t per month. The red line is for reference and shows a monthly catch of 8.3 t, equivalent to a 100 t TAC.

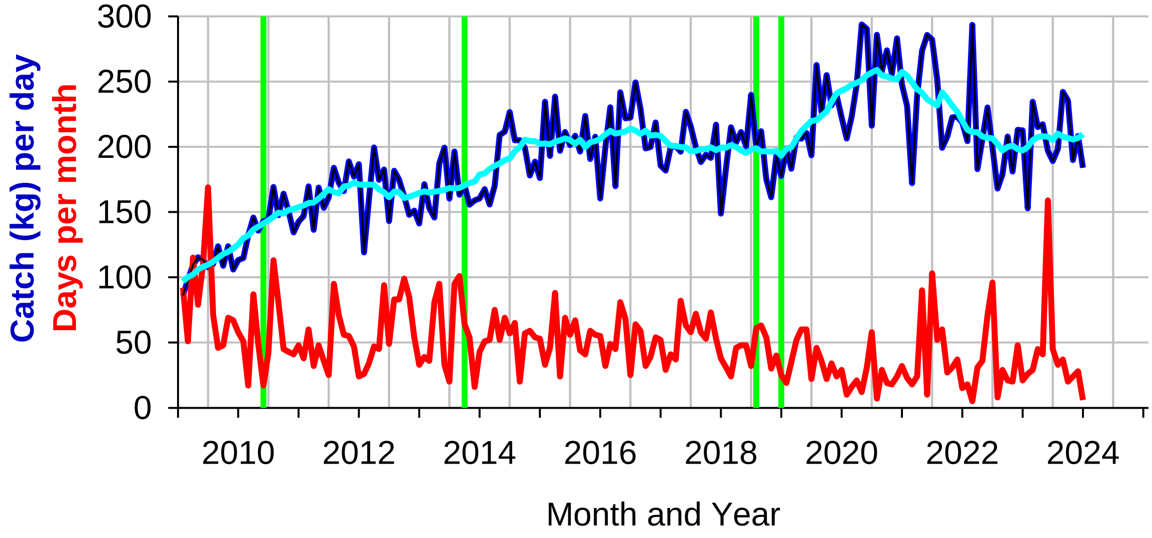


Figure 3a. Average catch (>30 kg) per diver-day for the fishery from 2009 to Dec 2021 (blue line), with 12 month centered moving average (light blue line), and Days diving per month (red line) for the fishery. Size limit increases in 2008, 2010, 2013, 2018 and 2019 are shown as vertical green lines.

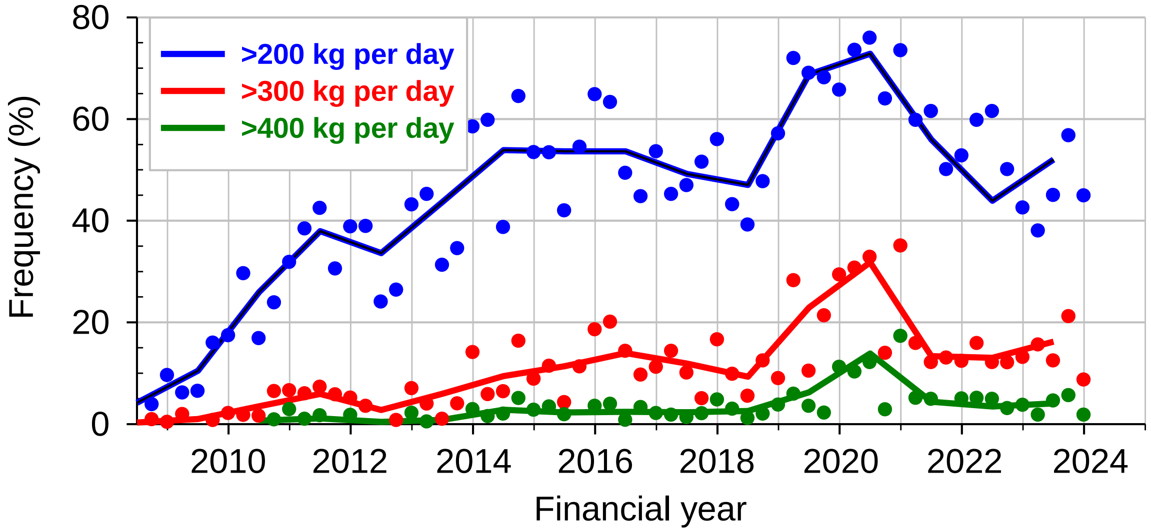


Figure 3b. Frequency of diver-days in the fishery with catch >200 kg (blue dots and line), >300 kg (red dots and line) and >400 kg (green dots and line), each quarter and year from 2008-09 to Dec 2023 (i.e. as a % of days with catch >30 kg).

Catch rate

Raw and standardised catch rates are presented annually since 1999 for each SMU (Figure 4 top), and monthly for 3 years (Figure 4 bottom). Raw catch rate is also presented annually by Area since 1999 (Appendix 3), and raw and standardised catch rate by Area over the last 26 months (Appendix 4). Standardised catch rate is calculated by removing effects of differences in catch rate among Divers, Areas and Months of catch, in an attempt to provide an index of catch rate that is more closely related to the availability or biomass of abalone. The trend in standardised catch rates over 3 years for each SMU is a Primary PI of the interim Harvest Strategy.

Raw catch rate (i.e. total catch divided by total effort, see Technical Methods and use in Appendix 2) throughout the fishery increased from a low of 13 kg/h in 2004-05, to record levels above 40 kg/h from 2012-13, and peaked in 2014-16 over 48 kg/h. Catch rate then dropped to 39 kg/h in 2018-19 (i.e. prior to the TAC reduction from 130 t to 100 t), before increasing to 49 kg/h in 2019-20 and 55 kg/h in 2020-21 following lower catch in the two Fishing Periods (i.e. 81-94 t), before declining again to 46 kg/h in 2021-22 and 44 kg/h in 2022-23, and recovering to 49 kg/h in 2023-24. All fishery-wide catch rate indicators (i.e. alternative methods of calculation) currently remain above the 40 kg/h, high catch rate Reference Point for Sustainable in the “Reference Points for the NSW Abalone Fishery” developed in 2014 (Appendix 2). Only 10 years in the history of the fishery (i.e. 11 of the last 12 years, with estimates since 1975) have been recorded at an average catch rate above 40 kg/h, and the catch rate in 2020-21 was the highest on record.

Annual raw and standardised catch rate are shown for each SMU in Figure 4 top. There is a generally similar pattern among SMU in raw and standardised catch rate, with strong increases up to 2016 followed by declines of 20-30%, some recovery up to 2020-22 before a further decline in 2022-23 and recovery in 2023-24 up to December 2023. Recent recovery and decline was strongest in SMU 3 on Green Cape, which was heavily impacted by the 2016 storm, but within both SMU 2 and 4 standardised catch rates are close to their peaks, while SMU 3 remains some way below. Recent catch rate in SMU 1 continues to be more variable with changes in daily catch (e.g. small quantities), total catch, and spatial location (e.g. both local divers with more consistent catch and catch rate, and more variable travelling divers targeting weather and higher catch). Differences between raw and standardised catch rates are particularly related to changing spatial patterns of fishing among divers with different catch rates, and particularly those divers with higher catch rates landing more of the catch in some areas (Figure 4 top). Standardised catch rates in SMU 4 in recent years are different to patterns in raw catch rates, and appear related to some change in key divers fishing the area.

Monthly standardised catch rate over the last 3 years have followed a generally similar pattern in SMU 2-4 (Figure 4 bottom). Some high catch rates were recorded with high catches in April-June 2021 and 2022, in the 3 months prior to the end of the fishing period. Catch rates then declined in the following months, and during Winter when catch rates are often higher. The frequency of months with higher catch rates (i.e. which often occur during good weather), has declined over the last 3 years, particularly in SMU 2 and SMU 3. Recent catch and catch rate in SMU 1 have been more variable, associated with more days of smaller daily catches, and less larger daily catches targeted more by travelling divers.

Figure 4. Standardised catch rate (dark blue lines) per SMU and year since 1999-00 (top) with raw catch rate (black dots) and catch (grey bars, top), and per month for 3 years (bottom). Standardised catch rate is normalised to raw in 2000 with SE (top), and bias-corrected with 95% CI (bottom).

The interim Harvest Strategy Primary PI of the 3-year linear trend in monthly standardised catch rate per SMU was calculated from January 2021 to December 2023 (i.e. expressed as a % of the 2021 average) and varied among SMU. The linear change in standardised catch rate varied from an increase in SMU 1 and SMU 4 (+0.5% and +1% per year) to decreases in SMU 2 and SMU 3 (-4% and -6% per year). These annual changes correspond to change over the three-year period of +1.5% and +4.1% for SMU 1 and SMU 4, and -12.8% and -20.2% for SMU 2 and SMU 3. With the recent large change in catch within the year (e.g. high catch and catch rate at the end of the Fishing Period, followed by lower catch and catch rate), recent within-year change in catch rates have not been linear, so linear trends should be interpreted with caution. Further, catch in 2020 prior to the start of the 3-year period was only 64 t, suggesting catch rates may have been higher than if a 100 t catch were landed.

Several factors can influence change through time in the estimated catch rate of abalone, including changes in approaches to measurement and calculation of landed weight of abalone. The landed weight of abalone is calculated from the validated bin weight of abalone, which is estimated from the total bin weight net an allowance for the bin and associated weight. There have been some recent changes in the approach to estimating the allowance for the bin and associated weight (e.g. current use of a 6 kg bin weight, that used to be used as 6.5 kg, or a 2.5% increase in weight for a bin with 20 kg of abalone), in addition to past changes in quantities being processed live or for canning. Variation among divers and days in catch reporting approaches is also increasing, and leading to some additional uncertainty in estimating catch rates.

Weight of abalone

Raw and standardised average weight of abalone per bin are presented annually since 1999 for each SMU (Figure 5 top), and monthly for 3 years (Figure 5 bottom). Raw weight of abalone is also presented annually by Area since 1999 (Appendix 3), and with raw and standardised weight of abalone by Area over the last 26 months (Appendix 4). Standardised weight of abalone is calculated by removing effects of differences in average weight among Divers, Areas and Months of catch, in an attempt to provide an index of the weight of abalone landed that is more closely related to the weight of abalone available to the fishery. The trend in standardised mean weight of abalone over three years by SMU is a Primary PI of the interim Harvest Strategy.

The raw weight of abalone throughout the fishery has been increasing each year since 2004 (i.e. ~280-290 g prior to 2004), to record levels above 320 g per abalone since 2012-13, above 350 g from 2018-19, and a peak of 370 g in 2020-21 before declining to 368 g in 2021-22, increasing again to 378 g and 377 g in 2022-23 and in the first 6 months of 2023-24. Raw weights are influenced by the amount of catch in different Areas and SMU with different size abalone, and standardisation is used in an attempt to remove this effect. Despite that, the pattern of the gradually increasing raw weight of abalone almost every year since 2004 is relatively consistent across SMU (Figure 5 top), despite generally larger increases in SMU 4 (i.e. with 4 larger size limit increases). Increases in the weight of abalone landed reduce the number of abalone landed for a given catch or TAC. For example, when ~94 t of abalone was landed in 2010-11 a total of 303 407 abalone were estimated to be landed, while in 2020-21 when ~94 t of abalone were landed this is estimated to have included only 250 842 abalone (i.e. 17% less), and at the average weight in 2023-24, 303 407 abalone would weigh 114.4 t.

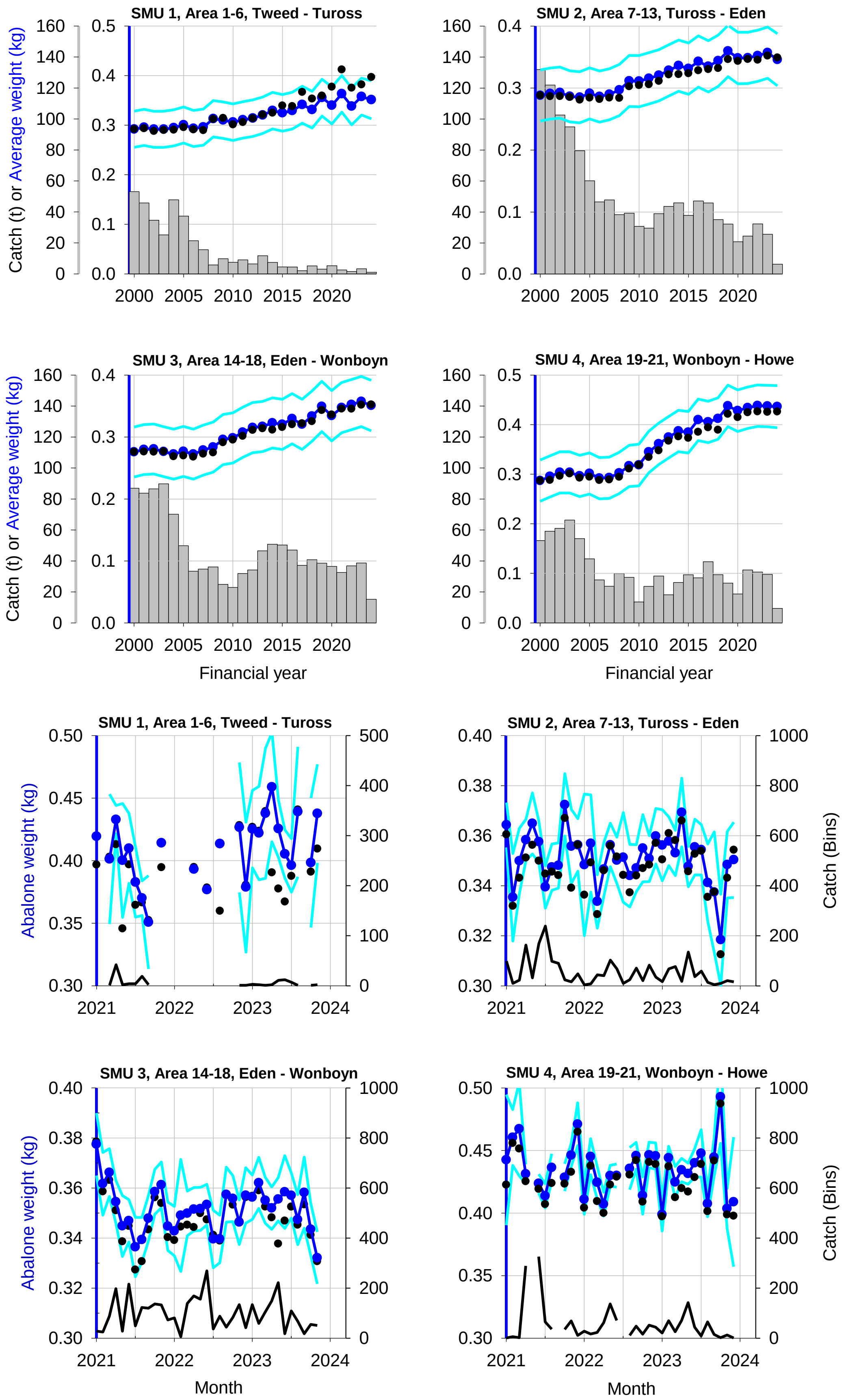


Figure 5. Standardised weight of abalone (lines with light blue SE) per SMU and year since 1999-00 (top) with raw mean weight (black dots) and catch (grey bars), and per month for 3 years (bottom) and number of bins (blackline).

Estimates of the weight of individual bins of abalone, and the number of individuals contained, were first required by regulation in 1999, but several factors can confound direct interpretation of change in the average weight of landed abalone as an indicator of stocks. Increases in minimum size limits from 115 to 117-120 mm north of Wonboyn, and 115 to 125 mm south of Wonboyn, have contributed to the increased average weight of abalone landed. Change in market preference and price influences divers, and the distribution of catch, can also influence the size of abalone landed. Further, it was noted in the October 2018 Assessment Report that the length of abalone landed (i.e. hand measuring individuals with a logger) in recent years appeared more sensitive to changes in length and had not consistently increased like the weight of abalone landed (i.e. bin weight and number of individuals provide an average weight for the bin). This suggests changes through time in several methodological and processing factors (e.g. changing bin weights and processing methods), may also confound interpretation of change in average abalone weight through time.

Annual change in raw and standardised weight of abalone per SMU are shown in Figure 5 top. There is a generally similar pattern in raw and standardised weight of abalone, with an ongoing increase in weight in all SMU, that has stabilised in recent years. Within SMU 2-4, raw and standardised data suggest abalone landed in 2022-23 and the first 6 months of 2023-24 have a higher average weight than most previous years. Despite that, at the scale of months within the last 3 years, there have been small declines in the raw and standardised weight of abalone (i.e. see below). Increasing average weight of abalone can be related to both increasing stocks of large-heavy abalone, or a reduction in the frequency of small abalone (e.g. reduced recruitment or growth). Use of weight or length frequency data can aid this interpretation, to suggest the likely influence of change in frequency of small (e.g. change in recruitment or growth) or large abalone (e.g. effects of fishing). Targeted fishing of market-preferred sizes of abalone have mostly landed larger abalone, particularly in SMU 4 and Area 19, and with small daily catch more common in recent years. Change in the weight of abalone landed among months appear related to change in catch, with lower catch or effort often followed by landing of large abalone, and higher catch and effort often followed by smaller abalone and subsequent recovery (e.g. SMU 3-4 in late 2020-21). Differences between raw and standardised weight are generally small, but are influenced by differences among divers in estimation of bin weights, and their changing spatial patterns of fishing (e.g. Figure 5 top).

The interim Harvest Strategy Primary PI of the 3-year linear trend in monthly standardised abalone weight per SMU was calculated from January 2021 to December 2023 and was generally similar among SMU. The linear change in standardised mean weight varied from an increase in SMU 1 (2.4% per year) to decreases in SMU 2-4 (-0.6%, -0.4% and -0.7% per year). These annual changes correspond to change over the three-year period of +7.6% for SMU 1, and -2.2%, -1.3% and -2.2% for SMU 2-4. Fishing to market size preferences has been more common in recent years, particularly in SMU 1 and SMU 4, and may have influenced these changes. With recent change in catch within the year (e.g. high catch at the end of the Fishing Period), recent within-year change in mean weight have not been linear, so linear trends should be interpreted with caution. Further, catch in 2020 prior to the start of the 3-year period was only 64 t, suggesting abalone weight may have been higher than if a 100 t catch were landed.

Several factors can influence change through time in the estimated weight of abalone, including directed fishing for market-preferred sizes of abalone, and approaches to the calculation of average abalone weight. Weight of abalone is calculated from the validated total bin weight of abalone, which is estimated from a measured total bin weight, net an allowance for the bin and associated weight, and combined with the number of abalone per bin (i.e. mean abalone weight = (total validated weight

– bin weight)/number of abalone). As a result, estimates of abalone weight can be influenced by variation in the allowance for the bin and associated weight, which has been related to processing (e.g. simple bins with dry abalone for canning, or bins with slats/ropes and wetter abalone for live product). It appears that there have also been recent changes in the approach to estimating the allowance for the bin and associated weight (e.g. current use of a 6 kg bin weight, that used to be used as 6.5 kg, or a 2.5% increase in weight for a bin with 20 kg of abalone), in addition to past changes in quantities being processed live or through canning.

Index of biomass

Since March 2019, a licence condition has required divers to operate a GPS and depth logger while fishing. A total of 38 Succorfish GPS loggers were installed on boats, together with the continued use of manual-download Scielex GPS loggers (i.e. about 3-4). Real-time GPS coverage was limited by access to new loggers with supply constraints during Covid (e.g. most VMS units had limited supply), but additional units were sourced and installed in 2022. Manual-download loggers have now mostly been replaced by real-time GPS loggers that send data directly to the cloud, as this provides more immediate data for use in stock assessment and catch planning. The Succorfish loggers commence logging as divers activate their boat's 12v system, but some are attached to power at all times, and all contain a small internal battery. When powered, the loggers locate GPS Satellites and the GSM (i.e. mobile phone) network and send the position of the boat each minute to a cloud database, that can display position on a map within about 10-15 seconds of being logged (i.e. where an active GSM connection). Essential logger service, and purchase of replacements, accessories and spares was delayed (i.e. impacted by Covid lockdowns on suppliers), as was deployment of depth loggers that connect by Bluetooth to the Succorfish boat logger to replace the Reefnet depth loggers that require manual download from volatile memory. A new model GPS logger (i.e. 5G and updated components) with additional capacity (e.g. acoustic tag monitoring and depth) and an alternative model and supplier (e.g. reduced cost and function) have been trialled and provide alternatives.

Logger coverage is monitored each month against reported catch, and there have been 157 diver days of catch by 18 divers in the 2023-24 Fishing Period. Manual download has not been finalised for 2023-24 for 2 divers, and full processing of existing logger data has not been completed where 2 divers work off one boat with a single logger. In contrast, logger breakdowns and service have been minimal. As a result, GPS data is currently available for 95% of diver days. This level of coverage is consistent with that in similar programs in other abalone fishery. Use of Succorfish loggers within VMS regulations has been permitted in Victoria for several years, and coverage has been similar and permitted only with formal exemptions if loggers are not operating.

Following storage in a cloud database, logger data are exported and combined into a local database for analysis using a system of queries and scripts (i.e. AbTrack, SQL Server, R and Manifold GIS). The database currently includes over 4 million logged GPS points from over 17 000 dive events in NSW. GPS loggers are now used in most Australian abalone fishery, and several projects, including 3 FRDC-supported projects, are currently considering and extending existing approaches to greater use of logger data in Harvest Strategy for abalone fishery (e.g. Mundy, Using loggers to determine stock status, Sainsbury, Calibrating different indicators and Dichmont, MSE). The national Abalone Assessment and Management Workshop in 2019 recommended extension of the use of GPS loggers in abalone fishery assessment to enable more frequent and ongoing assessment of the fishery.

An index of the density of legal-sized abalone biomass (Table 2 and Figure 6), and an estimate of total legal-sized biomass (Table 2-4), are calculated from logger data and catch reporting, presented annually for each SMU and represent a Primary PI of the interim Harvest Strategy. The index of biomass density is calculated from each diver's daily landed catch (kg) and an estimate of the daily area of fishing dive events from loggers (i.e. area in Ha of 50% GPS point volume for each dive event), to calculate a legal-sized biomass density (i.e. kg/Ha) for each day fished. Estimates of biomass density are standardised by removing effects of differences among Divers and Sites of catch, and calibrated to the fishery-independent abundance survey on southern reefs in 2013 (i.e. estimate for the 70% CDF diver), in an attempt to provide an index that is more closely related to the biomass of abalone available to the fishery. While calibration has not been repeated since 2013, the change in minimum size limit (i.e. 117 to 120 mm in SMU 1-3, and 120 to 125 mm in SMU 4) suggest the calibration and its use remains conservative (i.e. biomass estimates above 125 mm are compared to those above 120 mm at calibration). For example, sampling in 2013 and 2022 suggest biomass of 120-124 mm fish that are now protected from fishing, have become a smaller component of the total biomass >120 mm (i.e. 2013 40% of biomass or almost as large as >125 mm stock, and 2022 20% with >125 mm x4 larger), suggesting the legal biomass in 2022 >125 mm has increased in comparison (i.e or a particularly low year-class of 120-124 mm abalone, see particularly Figure 2 in the 2022 Survey Report).

The index of biomass density is also used to estimate a total legal-sized biomass of abalone, by extrapolation of standardised biomass density (i.e. currently >125 mm, and was >120 mm in 2013) to the estimated productive area of the fishery within each SMU. The productive area of the fishery has been estimated in several ways for comparison and sensitivity tests, but currently is estimated from the activity of loggers (i.e. 90% of point volume of dive event) within a 1 Ha grid for each SMU. The sensitivity of estimates of total biomass to alternative estimates of productive area are also presented. Estimates of total biomass are then used with total catch to calculate a Surplus Production (i.e. annual change in total biomass including commercial catch) and a Harvest Fraction (i.e. commercial catch as a proportion of total legal-sized biomass) for each SMU. Logger coverage and minimum size limits have varied among years and coverage increased significantly since March 2019, and both may confound comparisons of logger indicators with earlier data. For example, as several additional divers are now included in the standardisation, the estimated index of biomass density for the average diver has changed (i.e. new set of divers) and may need to be recalibrated (e.g. including repeat and possible expansion of surveys). Comparison of logger indicators from individual divers through time have been used for some indicators to demonstrate any confounding by changed logger coverage is limited.

Estimates of the standardised biomass density of legal-sized abalone from logger data are summarised by financial year and SMU (Table 2 and Figure 6). Two alternative estimates of density are provided for each year (Table 2), including an estimate of density based on the average diver (i.e. noting this estimate of density was well below that observed in the comparable abundance survey) and for a diver that produced a more similar estimate of density to the abundance survey (i.e. 70% CDF diver from past calibration to abundance survey). These alternative estimates are also provided to allow investigation of the sensitivity of extrapolated total biomass estimates to uncertainty in biomass density.

The index of standardised biomass density generally increased in SMU 2-4 from 2009-10 (i.e. start of more consistent logger coverage across divers) until a peak in 2014-16, before declining 20-35% over 2-5 years, and then increasing over 1-3 years to a smaller peak in 2020-22 (Figure 6). Following large catch during April-June 2021, late in the 2020-21 Fishing Period, estimates of biomass density declined through 2021-22, before some recovery 2022-23 and 2023-24. While other indicators such as catch, catch rates and weight of abalone also declined and recovered during this time, it is noteworthy that the index of biomass declined a greater amount than the other indicators which are often associated with hyper-stability. This decline was also associated with a shift in the location of catch, and area of reef used by the fishery late in 2021-22 and 2022-23, making spatial standardisation of indicators important to interpretation of change. Importantly, following the large catches late in the last 3 Fishing Periods, and associated decline in the index of biomass, as catch moderated the index also recovered in the following Fishing Period, leading to the index increasing in each of SMU 2-4. In total, the index of biomass density in SMU 2-4 increased about 100% from 2009-10 until 2015-16, and was again increasing toward similar levels in 2023-24, suggesting an approximate doubling of legal biomass available to the fishery since 2009-10, and in addition to the increase in minimum size limits (Figure 6).

Despite the consistent patterns through time, there has also been variation among SMU in the trend of biomass density (Figure 6). In particular, in recent years biomass density increased for 3 years to a peak in 2019-21 in SMU 3-4, while in SMU 2 biomass density decreased until 2019-20 and only increased in 2020-21, while each SMU 2-4 declined from 2020-21 and recovered to some extent by 2023-24. The interim Harvest Strategy Primary PI of the 3-year linear trend in the standardised index of biomass varied among SMU, although limited catch and logger data was available from SMU 1. The linear trend of the index of biomass from 2021-22 to 2023-24 was +15% per year in SMU 2, -+12% in SMU 3, and +17% in SMU 4 (i.e. last year -8%, -14%, and -11%). Recent change in biomass density have been non-linear, so linear trends should be interpreted with caution. Further, catch in 2020 prior to the start of the 3-year period was only 64 t, suggesting estimates of biomass density may have been higher than if a 100 t catch were landed.

Within SMU, standardised estimates of biomass density in early 2023-24 are above their long-term average in 7 of 14 Areas (i.e. 2022-23, 3 of 14) with consistent logger coverage, including Area 10 (i.e. north of Tathra), Area 14 (near Eden), Area 17 (i.e. in Disaster Bay) and Area 20-21 (i.e. Saltlake-Howe). In contrast, Area 8 (i.e. south of Narooma), Area 12 (i.e. north of Merimbula) and Area 16 (i.e. on Green Cape) are below their long-term average (i.e. ~15-20% below long-term average). Comparison of legal-sized biomass density among years is confounded by changes in minimum size limits that define the legal-sized population. For example, in 2023-24 estimates of legal-sized biomass density are above current size limits (i.e. 117-120-125 mm), while those in previous year's include those with lower size limits (e.g. only 115 mm until 117 mm in May 2010). Historic information about length-frequency can be used to reduce this confounding. For example, abalone length measuring and use of a length-weight relationship, suggest 34% of the legal-sized biomass was below 120 mm in 2009-10 on the 115 mm size limit. Alternatively, 66% of the biomass was >120 mm in 2009-10, allowing calculation of an estimate of the biomass density of >120 mm abalone in 2009-10 and a more direct comparison with 2023-24 (e.g. 2023-24 biomass density >120 mm for SMU 2 and SMU 3 of 1.5-3.5 times that of >120 mm in 2009-10).

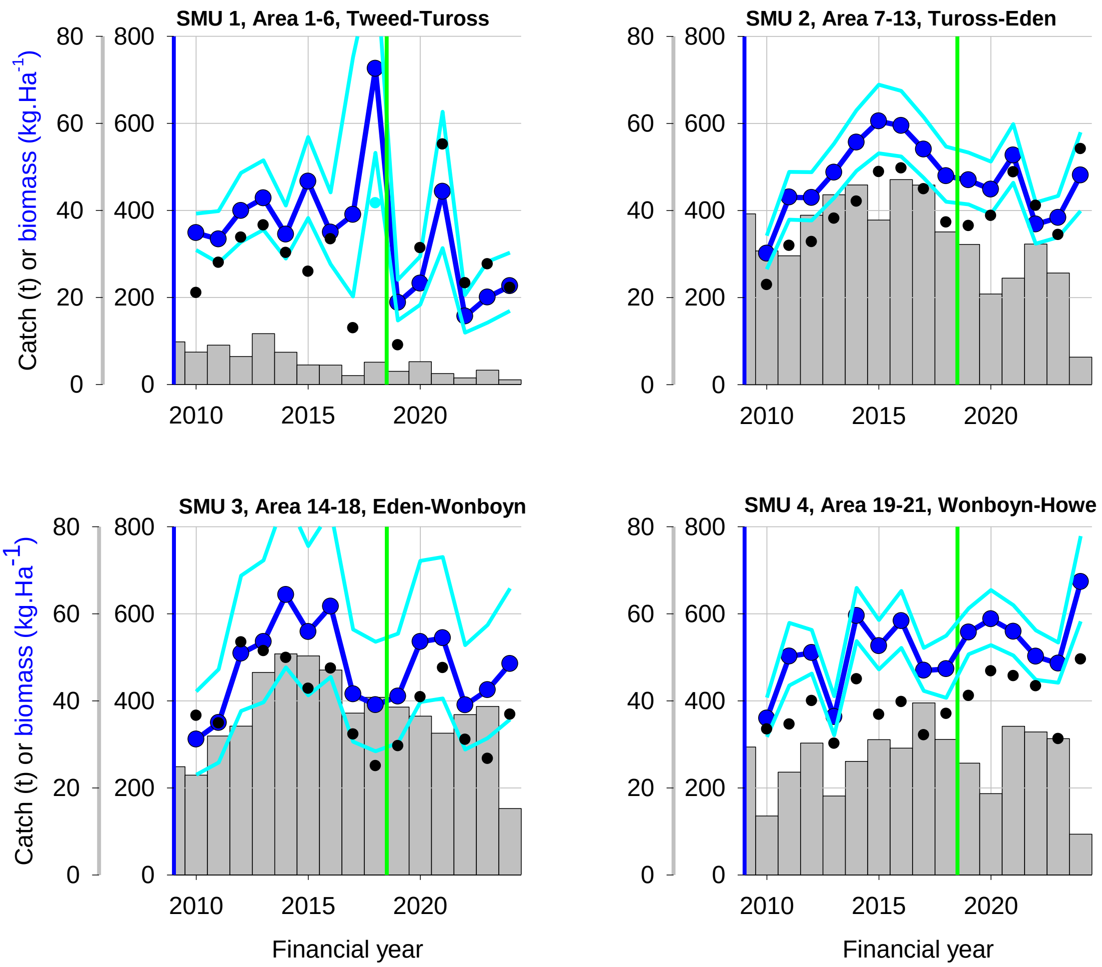


Figure 6. Standardised index of legal-sized abalone biomass (blue lines with light blue SE) per SMU since 2009-10 (i.e. for 70% CDF diver), with raw biomass density (black dots) and catch (grey bars). Note, estimates of density >120 mm from loggers were calibrated to an independent abundance survey in 2013-14 in Area 20 and 21 within SMU 4, and the size limit was increased in May 2010, Sep 2013 and Jul 2018 (vertical green line) in SMU 4, and Jul 2018 and Jan 2019 for SMU 1-3.

Table 2. Estimates of biomass density (kg/Ha) of legal-sized abalone per SMU and Year. Estimates of density are calculated from daily catch (kg) and dive event area (i.e. 50% KUD in Ha) and include those standardised to the 50% and 70% diver CDF (i.e. cumulative distribution function), noting the 70% diver was selected previously to calibrate with survey abundance. Note, the definition of biomass density has changed with minimum size limits in May 2010, Sep 2013 and Jul 2018 in SMU 4 and Jul 2018 and Jan 2019 for SMU 1-3.

	SMU 1	SMU 2	SMU 3	SMU 4
	Area 1-6	Area 7-13	Area 14-18	Area 19-21
Financial Year				
	Density (kg/Ha)			
2009-10	273 - 348	236 - 301	244 - 311	282 - 359
2010-11	262 - 334	337 - 430	274 - 349	394 - 502
2011-12	313 - 399	336 - 429	399 - 509	400 - 510
2012-13	335 - 428	382 - 487	420 - 535	284 - 363
2013-14	270 - 345	436 - 556	504 - 643	467 - 595
2014-15	366 - 466	474 - 605	438 - 558	412 - 526
2015-16	274 - 349	466 - 595	483 - 617	457 - 583
2016-17	306 - 390	424 - 540	326 - 415	368 - 469
2017-18	569 - 725	376 - 479	306 - 390	371 - 473
2018-19	147 - 188	368 - 470	321 - 410	437 - 557
2019-20	182 - 232	351 - 448	420 - 535	461 - 588
2020-21	347 - 443	413 - 527	426 - 544	438 - 559
2021-22	123 - 157	289 - 368	306 - 390	393 - 502
2022-23	157 - 200	300 - 383	333 - 425	381 - 486
2023-24	177 - 226	377 - 481	380 - 485	528 - 673

Logger data is also used to estimate the area of reef used by the fishery in each SMU (Table 3). Several different methods of estimating the area of reef have been assessed in previous reports, but the standard approach has been to use the 3-year rolling count of the active area of reef (i.e. 90% dive event activity in 1 Ha grid). Using dive event activity within a 1 Ha grid over the past 3 years (labelled 2021-23, 3 year in Table 3), a total of 2138 Ha of reef was estimated to be productive throughout NSW, compared to 2107-2175 Ha in the previous 2 rolling 3-year period (i.e. 2019-21 and 2020-22). Estimates of active reef area in SMU 2-4 have mostly been stable, varying by 6-12% from their average, while SMU 1 has been more variable. The cumulative area of reef logged throughout the fishery continues to increase, although further annual increases are slowing considerably. Since 2009-10 throughout NSW, a total of 4489 Ha (i.e. 4272-4351 Ha in previous 2 years) of reef were estimated to be productive based on logged dive event activity within a 1 Ha grid.

Reef area estimated from the most recent 3-calendar year rolling period (labelled 2021-23, 3 year in Table 3) are generally similar to those prior to regulated logger coverage within each SMU, despite larger annual changes in reef area used in SMU 1 (i.e. northern areas) and a trend to more fished reef area in SMU 3 (i.e. near Eden) that are consistent with increased catches in these areas in recent years. While estimates of reef area in recent calendar year are similar, during 2021-22 the area of reef used by the fishery increased in particularly SMU 2 and 3 as divers spread their catch in response to the increased total catch in the fishery. Both the area of productive reef used by the fishery in recent years, and the 3-year rolling estimates, are well below estimates of the total area used by the fishery since 2009-10, particularly in northern parts of the fishery. The cumulative area of reef used over the last 3 years represents 13% of the total cumulative reef area for SMU 1, 53% for SMU 2 (i.e. recent reduced activity in north), 79% for SMU 3 and 66% for SMU 4 (i.e. recent reduced activity deeper offshore, and increase inshore on northern edge).

Estimates of the density of legal-sized biomass from dive events are extrapolated to estimates of reef area from dive event extent, to calculate an estimate of the total biomass of legal-sized abalone available to the fishery. While considerable uncertainty exists with each of the estimates, and their combination in calculating total biomass, this approach has provided plausible estimates of biomass that are consistent with other approaches (e.g. dive survey density, lidar area and integrated model-based) in several different applications and fishery (e.g. different fishery, state and abalone species). Alternative estimates of density and reef area are provided to enable assessment of the sensitivity of estimates of total biomass to some of this uncertainty (Table 4). In each case, the estimate of biomass density for the standardised 70% CDF diver was used, and the productive area of reef was held constant among years. As in previous reports, the standard approach used the reef area estimated over 3-years (i.e. 2021-23, 3 year in Table 3), while two alternatives (in brackets in Table 4) used the reef area from last year's assessment report (i.e. 2020-22 3 year in Table 3) and 80% of that from all years since 2009 (i.e. All years in Table 3).

As estimates of biomass density are extrapolated to a constant area of reef through time, trends in estimates of biomass are the same as those of biomass density (Table 4). Legal-sized biomass increased significantly since 2010 in all SMU (i.e. all SMU total biomass ~680 t in 2009-10 of >115 mm abalone), and peaked within SMU 2-4 during 2014-16 ranging from ~200-500 t among SMU (i.e. all SMU total ~1200 t) and peaked again in 2020-21 ranging from ~200-450 t among SMU (i.e. all SMU total ~1150 t of >120 and >125 mm). Estimates of biomass in 2023-24 are based on only 6 months of data about biomass density, but estimates of total legal-sized biomass remain near their peak at ~1050 t of >117, >120 and >125 mm abalone. While the current TAC of 100 t suggests an average harvest fraction by the commercial fishery of about 10%, spatial differences in the distribution of catch and biomass density (e.g. most catch concentrated in the south, and a large stretch of coast in the north with very little commercial catch), point to considerable spatial variation in actual harvest fractions (see also later discussion).

Table 3. Estimates of area (Ha) of the fishery and productive stock per SMU from GPS loggers. Estimates of area are calculated for different time periods from dive event activity in a 1 Ha grid. Estimates of area are sensitive to the level of dive activity required to include a 1 Ha grid (e.g. any activity, 10 min or 30 min per grid).

	SMU 1	**SMU 2**	**SMU 3**	**SMU 4**
	Area 1-6	**Area 7-13**	**Area 14-18**	**Area 19-21**
Financial Year				
	Area (Ha)			
2019-21, 3 year	194	885	747	349
2020-22, 3 year	92	829	790	396
2021-23, 3 year	183	837	760	358
2021-22, 1 year	55	614	525	232
2022-23, 1 year	41	593	665	293
2023-24, half year	118	136	448	129
All years, until 2021-22	1340	1531	894	507
All years, until 2022-23	1340	1560	931	520
All years, until 2023-24	1409	1571	968	541

Table 4. Estimates of total biomass (t) of legal-sized abalone per SMU and Year, calculated from estimates of biomass density and reef area, with best estimates of density from the 70% diver and Area 2020-22, 3 year (i.e. outside brackets). Alternative estimates inside brackets are calculated from the same Density and both Area 2020-22, 3 year and 80% of All years. Annual estimates of density and area are replaced by 3 year averages for SMU 1 from 2020, because of limited catch and logger data. Note, the definition of legal-sized biomass has changed with minimum size limits in May 2010, September 2013 and July 2018 in SMU 4 and July 2018 and Jan 2019 for SMU 1-3.

	SMU 1	**SMU 2**	**SMU 3**	**SMU 4**
	Area 1-6	**Area 7-13**	**Area 14-18**	**Area 19-21**
Financial Year				
	Biomass (t)			
2009-10	64 (59 - 393)	252 (250 - 379)	237 (224 - 241)	129 (120 - 156)
2010-11	61 (56 - 376)	360 (357 - 541)	266 (252 - 271)	180 (168 - 217)
2011-12	73 (67 - 450)	359 (356 - 539)	387 (366 - 394)	183 (171 - 221)
2012-13	78 (72 - 482)	408 (404 - 612)	407 (386 - 415)	130 (122 - 157)
2013-14	63 (58 - 389)	466 (461 - 699)	489 (463 - 498)	213 (199 - 258)
2014-15	85 (78 - 526)	507 (502 - 761)	424 (402 - 432)	188 (176 - 228)
2015-16	64 (59 - 394)	498 (493 - 747)	469 (444 - 478)	209 (195 - 252)
2016-17	71 (66 - 439)	452 (448 - 679)	316 (299 - 322)	168 (157 - 203)
2017-18	133 (122 - 818)	401 (397 - 602)	297 (281 - 302)	169 (158 - 205)
2018-19	34 (32 - 212)	393 (389 - 590)	312 (295 - 317)	199 (187 - 241)
2019-20	42 (39 - 262)	375 (372 - 563)	407 (385 - 415)	210 (197 - 254)
2020-21	81 (74 - 500)	441 (437 - 662)	413 (392 - 421)	200 (187 - 242)
2021-22	29 (26 - 176)	308 (305 - 463)	296 (281 - 302)	180 (168 - 217)
2022-23	37 (34 - 226)	321 (318 - 482)	323 (306 - 329)	174 (163 - 210)
2023-24	41 (38 - 255)	403 (399 - 604)	369 (349 - 376)	241 (226 - 291)

Estimates of the total biomass of legal-sized abalone are combined with commercial catch (i.e. other catches are uncertain and not included) to calculate the annual Surplus Production from the stock within SMU 2-4 (Figure 7). Change in estimates of total biomass, are combined with the commercial catch, to estimate total production by the stock (i.e. change in biomass plus commercial catch). Estimates of Surplus Production are impacted by management changes, including TAC and size-limit changes, and the resulting shifts in effort and catch, but estimates of stock production were mostly larger than commercial catch in each SMU from 2010 to mid-2016, consistent with a general increase in biomass through that period. A major storm in June 2016 heavily impacted abalone stocks along most of the NSW coast, but particularly the north-east facing Green Cape in SMU 3. Surplus Production declined in all SMU between 2015-16 and 2016-17, with an estimated 100 t loss of biomass in SMU 3 (Figure 7). The TAC was reduced from 130 t to 100 t in 2018. Biomass and production then recovered within each SMU, and particularly in SMU 3. Estimates of Surplus Production in 2020-21 were well above recommended catch in SMU 2 and SMU 3, but remained about the same as catch recommended for SMU 4. Estimates of Surplus Production in 2021-22 reduced significantly in SMU 2 and SMU 3 (i.e. but not SMU 4) because of decline in estimates of biomass density (i.e. landed catch per dive area) and related to the higher catch in the 2021 calendar year (i.e. 115 t). Estimates of surplus production in each of SMU 2-4 recovered to be positive in 2022-23 and 2023-2024.

Estimates of legal-sized biomass are also combined with the commercial catch within each SMU to estimate a Harvest Fraction, which are shown by year for each SMU in Figure 8. The Harvest Fraction is only shown for the best estimates of biomass density, reef area and total biomass. Estimates of the Harvest Fraction in 2023-24 increase from north to south, with SMU 1 at 8%, SMU 2 at 8%, SMU 3 at 12% and peaking in SMU 4 at 18% (i.e. these estimates are very similar to 2022-23). Estimates of Harvest Fraction from both SMU 1 and northern SMU 2 are related to very low catch on large sections of coastline, and will be higher where catch is concentrated. For several years from 2009-10 there was a similar pattern in Harvest Fraction among SMU 2-4, with gradually increasing biomass and catch, and the Harvest Fraction remained mostly stable. Reduction in estimates of total biomass and production from the stock following the 2016 storm, led to increases in estimates of Harvest Fraction (i.e. even with similar catch), before reductions in TAC and catch from 2018. Increase in estimates of biomass and production were associated with declines in Harvest Fraction to 2019-2020 and 2020-21 in SMU 2-3 (i.e. not in 2020-21 for SMU 4 where catch increased). In 2021-22, estimates of biomass decreased in SMU 2-4, and led to increases in Harvest Fraction, despite mostly similar catch, and increased in 2022-23 and 2023-24. Application of similar approaches to estimation of total biomass and production in other abalone fishery (i.e. empirical and model-based), while noting some areas can maintain higher Harvest Fractions, have found a generally similar range of Harvest Fractions, and few biomass increases at higher values (e.g. ~20%, and a greater likelihood of increase at ~10%).

Using the estimate of total biomass from 2023-24, the current TAC of 100 t is estimated to be a ~10% Harvest Fraction, and varies spatially (e.g. 8-18% among SMU, and more variable within SMU), with higher harvest fractions where catch is concentrated. These estimates of current legal-sized abalone above the 120-125 mm size limits can also be compared to previous DPI model-based estimates of biomass above the 115 mm size limit in 2007 when catch rates were much lower, of about 1100 t for south of Jervis Bay (e.g. 618 t using logger based estimates in 2009-10). Unfortunately, a logger-based estimate of biomass is not available for 2007, but considering the large increase in commercial catch rates between 2007 and 2009-2023, it is likely that the logger-based method would provide a considerably lower and more conservative estimate of biomass in 2007 than that from the population model. Traditional population models for abalone have often produced large and less productive estimates for stocks, when they are likely to be smaller but more productive.

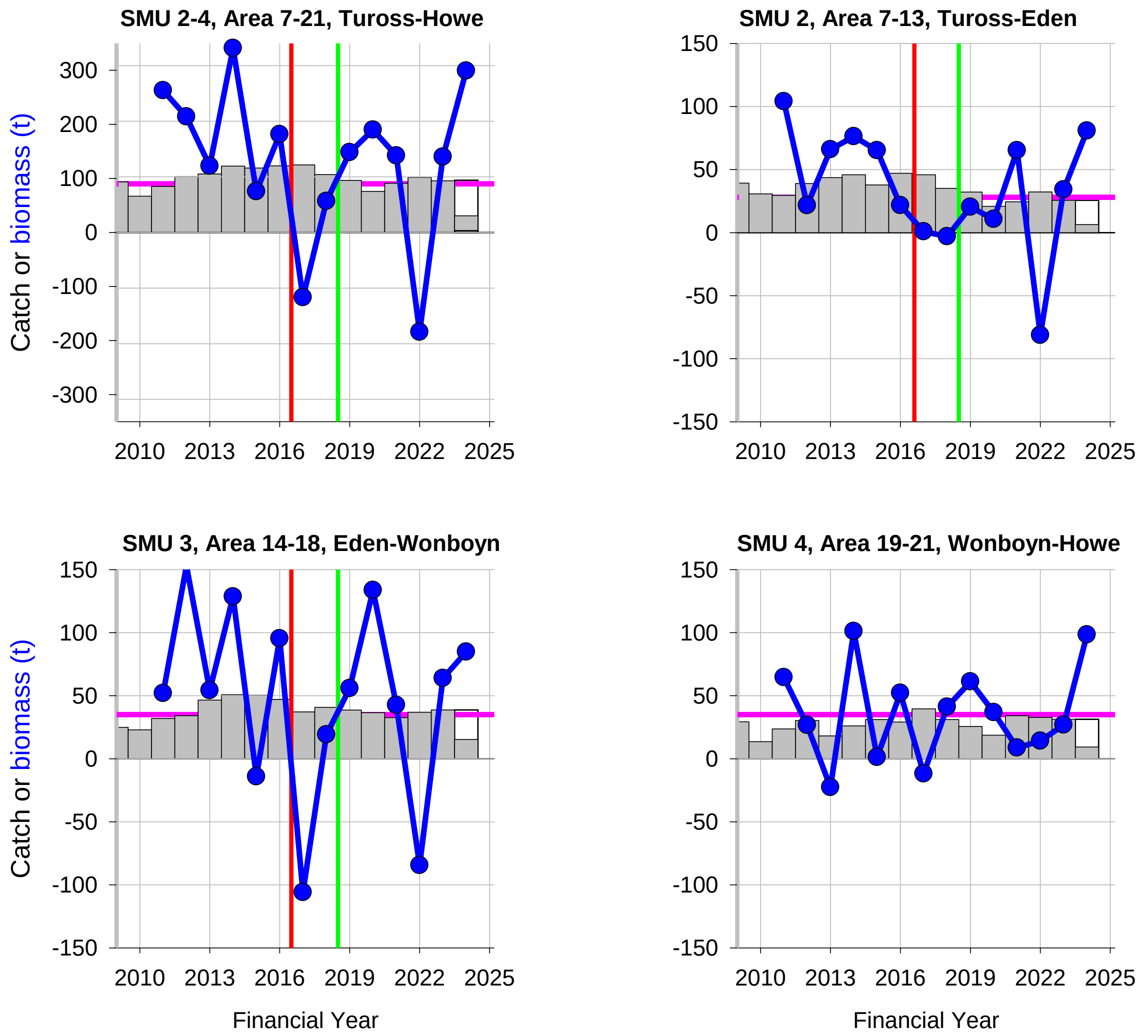


Figure 7. Estimated Surplus Production by the stock in SMU 2-4 (biomass in t, blue line, with only first 6 months of 2023-24) and Catch (grey bars) to December 2023, with a projected catch of 100 t in 2023-24 (i.e. white bar, same as 2022-23), with catch caps (horizontal pink line at ~25, 35 and 35 t for SMU 2-4), recent size limit change (vertical green line) and major storm in 2016 (vertical red line). Note, the size limit was increased in May 2010, September 2013 and July 2018 in SMU 4 and July 2018 and Jan 2019 for SMU 1-3.

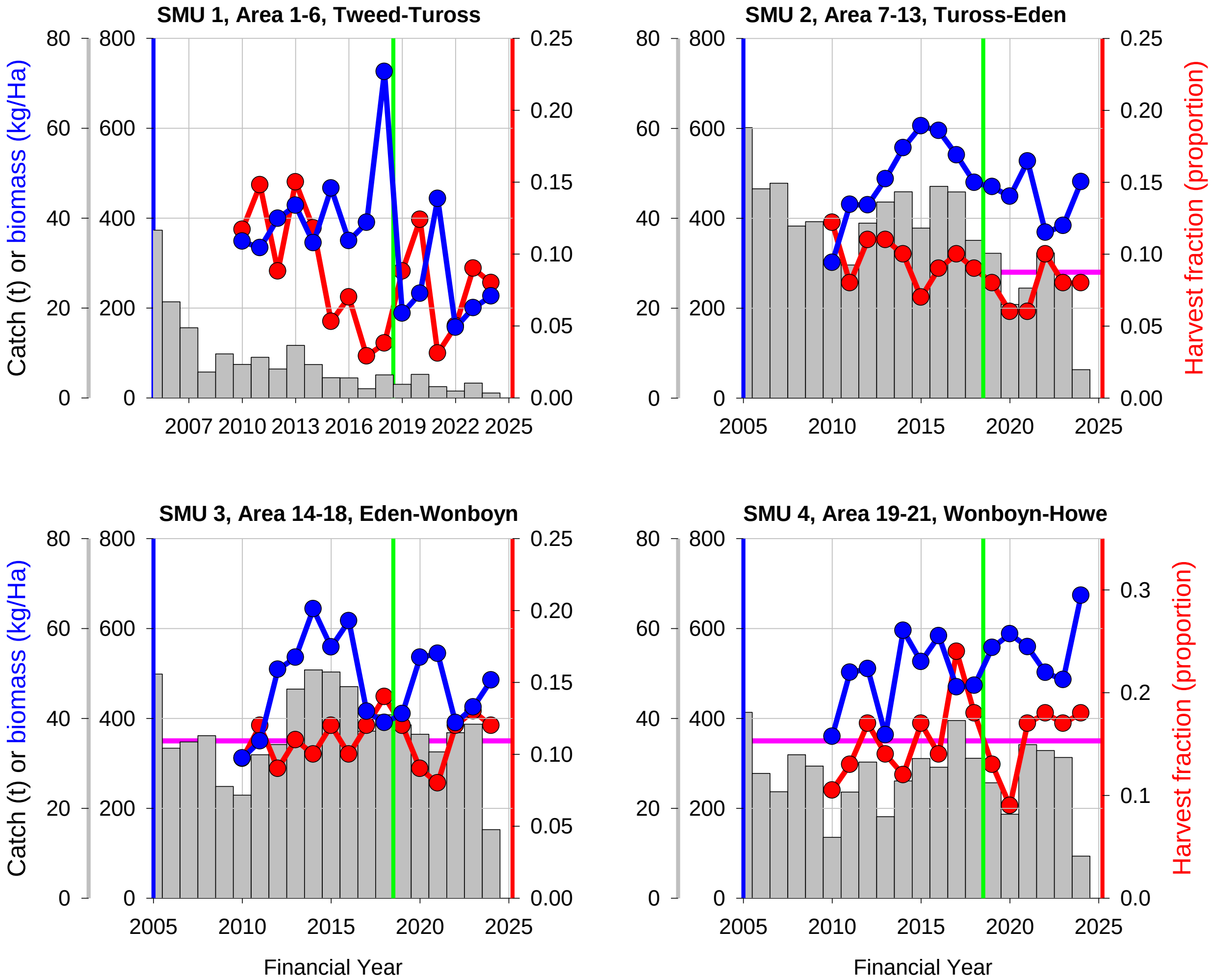


Figure 8. Estimated legal-sized Biomass density (blue line), Catch (grey bars) and estimated Harvest Fraction (red line) to December 2023, with catch caps (horizontal pink line, ~25, 35, 35 t) per SMU since 2009-10. Note, the size limit was increased in May 2010, September 2013 and July 2018 in SMU 4 and July 2018 (vertical green line) and Jan 2019 for SMU 1-3. To calculate Harvest Fraction for the current Fishing Period, catch per SMU was extrapolated to 100 t.

Estimates of an index of biomass density, total biomass and harvest fraction are used in the Harvest Strategy for the Victorian Western Zone abalone fishery, and being considered throughout the 3 Victoria Fishery. In Western Zone, estimates of change in legal-sized biomass within each SMU are provided as guidance to an open workshop, with other fishery indicators, that develop a bottom-up, subzone-based TAC proposal that must remain below a specified harvest fraction (i.e. 15%) when summed to the SMU-scale. During this process both fishery-independent abundance survey and fishery-dependent, logger-based estimates of biomass have been presented. The interim NSW Harvest Strategy also suggests change in TAC proportional to change in biomass, estimated from both catch rates and loggers, and proposed a limit harvest fraction. Further development is needed to consider and detail how fishery Performance Indicators would be used to provide guidance in TAC setting, while spatial catch planning and effort monitoring are also considered, within development of a formal Harvest Strategy in NSW.

The licence condition introduced in NSW during March 2019 for compulsory use of GPS loggers while fishing, has significantly increased the coverage of GPS logger data in NSW, improving the information available for stock assessment. Higher coverage logger data has only been available since March 2019 and will become more valuable as further years of data accumulate, and local-scale trends in fishing effort can be monitored. GPS logger coverage has increased to very high levels with the increased supply of units, better maintenance and the support of divers. Despite that, challenges remain to the supply (e.g. VMS supply) and operation of loggers to ensure high coverage (e.g. 3g turn-off in Sept 2024). Logger data adds significantly to other fishery-dependent and fishery-independent data available to the fishery and used as fishery Performance Indicators in its assessment, and should continue to be collected by divers in the fishery. For example, in other abalone fishery dashboards displaying real-time maps of recent fishing effort, including comparison with other times and fishing periods, have been developed and are shared among divers to help improve distribution of effort away from sites recently fished and broader fishery assessment. Recent extension of the NSW logger program, to water temperature loggers on 10 divers operating in NSW and eastern Victoria, should also be extended to more divers and developed to included other linked logging devices (e.g. Bluetooth temp loggers, acoustic location tags and listeners linked to VMS). Further development and use of information from logger data as performance indicators, is consistent with development in most other abalone fishery.

In recent years the high variation in catch within the Fishing Periods has influenced interpretation of fishery Performance Indicators. Variation in future catch of the TAC in the current Fishing Period also remains uncertain because of ongoing market conditions. Variable catch has influenced and may continue to influence the fishery and interpretation of fishery Performance Indicators. As a consequence, more conservative decisions about management and TAC are also prudent until catch returns to levels more consistent with the TAC and spread more evenly through the year and fishery, to enable consistent interpretation of fishery Performance Indicators and demonstrate consistent production from the fishery. The fishery and interpretation of Performance Indicators would benefit considerably from a more stable period of catch both consistent with the TAC, and distributed more broadly through across productive reef.

The method used to estimate biomass from GPS logger data appears to provide a simple and intuitive way of estimating an index of biomass and its change through time, to provide advice and potentially guide catch within a broader harvest strategy (e.g. see use in WZ Vic and Tas fishery). While the method offers promise, there are still several directions for possible further development, including particularly consideration of the index as either a relative or absolute indicator, and its calibration with other indicators such as abundance surveys and size-based data. Recent FRDC-supported projects have commenced to further investigate and validate the logger-based approach to biomass estimation and test its use in Harvest Strategy. Finally, the estimated biomass index and harvest fractions in NSW appear mostly within the range of those tested in an MSE of harvest fractions in the Victorian Western Zone Fishery that would mostly lead to ongoing recovery in that fishery. Despite that, some higher harvest fractions, less consistent with long-term recovery (e.g. >15%), are still occurring in some areas of the NSW fishery, particularly as catch is concentrated in space and time.

Secondary Performance Indicators

Length of abalone

Indicators of the length of abalone landed are identified in the interim Harvest Strategy as Secondary Performance Indicators, and are used in stock assessment of most of Australia's abalone fishery. GPS-enabled loggers have been used in NSW to measure the length of abalone landed since 2009-10 (i.e. in addition to late 1990s and early 2000s), and have been used both at abalone Receivers (i.e. selected bins with catching diver and day identified to link with catch records), and at sites chosen by divers (i.e. first bin or two of the day with GPS of catch also linked to catch records). The database since 2010 currently includes 170k abalone (i.e. equivalent to ~50 t) on over 880 diver days, including many with the GPS point of catch and measuring. Data from both approaches to measuring abalone were combined to present standardised estimates of the average length of abalone landed by SMU and Area (i.e. see 2020 Assessment report).

Factors impacting fishing and processors in 2020 prevented sampling and measuring of a representative sample of catch, and the measuring program was put on hold following the loss of trained-staff and ongoing market impacts on the fishery and processors. Three abalone measuring loggers were fully serviced and upgraded in 2021-22 to provide data direct to the cloud in real-time. A measuring program was recommenced in August 2021, with 3 divers spread along the coast selected to allow deckhands to operate the boards and measure abalone while diving. Divers will either measure the first 1-2 bins of abalone per day, or attempt to measure all abalone landed per day. By December 2023, over 5000 abalone had been measured on 22 diver-days, with the sample influenced by limited fishing and its distribution. It is proposed to re-train staff to measure abalone in processors, and divers to measure while diving, as markets and catching of abalone becomes more stable.

Detailed spatial data about the location of catch is important to interpretation of change in the length of abalone over broader scales. Measuring abalone with the GPS of catch allows estimation of trends in size of local populations through time, and following standardisation, trends at broader scales such as Subzones, Area and SMU. Earlier data shown in previous reports has also made clear that length measuring appears more sensitive to change in local abalone populations, and can deliver spatial detail to trends not evident in the less-sensitive bin weight indicator, which is influenced by changes in processing (e.g. frequency of live or not processing, and longer-term change in fishery and processing practices). Commitment of significant resources to similar measuring programs in other abalone fishery emphasises the importance placed by Industry on understanding the dynamics of landed abalone sizes to help interpret changes in abalone stocks.

While previous assessments (e.g. 2020 assessment) have provided detailed spatial information on variation in length of abalone measured during from the 1990s, a brief summary of historical data will be provided here, together with new data collected following recommencement of the measuring program from August 2021. Further historical summary data prior to 1993 is available about landed abalone lengths in the fishery, but is not available in detail. To reduce confounding from variation in minimum length limits in historical data and spatial differences, two main Performance Indicators (i.e. the average length of abalone landed and proportion of abalone above 130 mm) are provided. Both the average length of abalone and the proportion of abalone >=130mm have changed in a similar way from 1993 to 2021, suggesting they are strongly correlated (Figure 9). Abalone measured >=120 mm (i.e. current size limit) through the 2010s were larger than those measured during the 1990s (i.e. also >=120 mm), and there were more larger abalone >= 130 mm. Both indicators also appear to reflect changes in the fishery, such as an increase in stocks prior to the mid-2016 east coast storm, and recent period of reduced catch followed by intense catch. Since 2021, much fewer samples are available from a much lower number of diver days, with most abalone measured during the periods of high catch near the end of the fishing periods. The limited samples from 2021-23 are not likely to be representative of the fishery, or through the full Fishing Period, and ongoing sampling should provide more representative samples over a longer period with greater catch sampled.

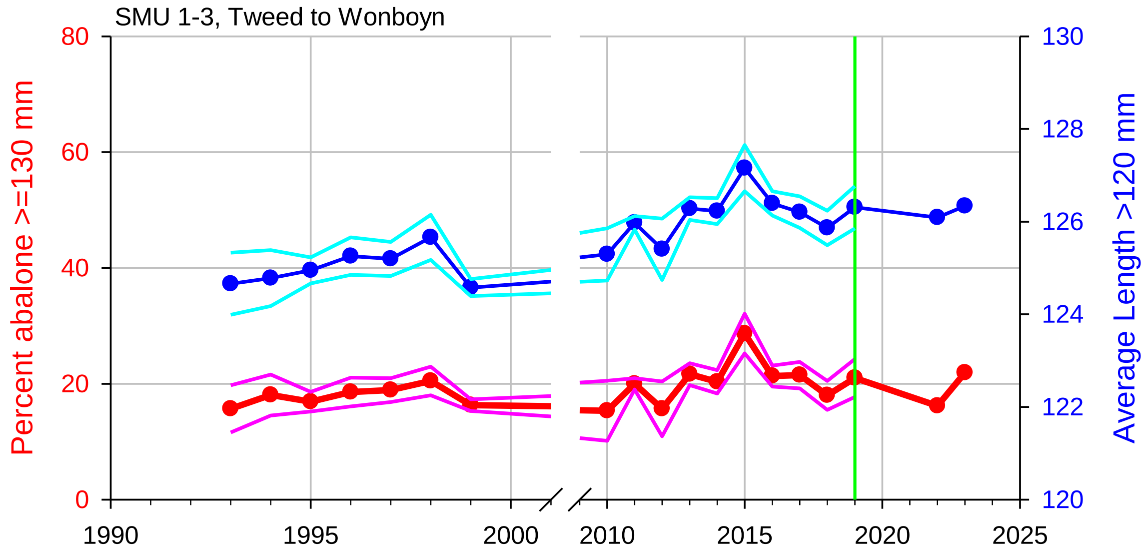


Figure 9. Frequency of abalone >= 130 mm (red line and pink SD among days) and average length of abalone >=120 mm (blue line and SD among days) from samples of abalone measured at processors and by divers since 1993 for SMU 1-3. Samples included measurement of over 225k abalone on almost 1870 diver days. Larger samples were measured in 1999, 2011 and 2013-2018. Only limited samples are available since recommencement of the measuring program in late 2021, with over 5000 abalone measured on 22 diver days in the last 2 Fishing Periods. These data have not been standardised here, but a standardisation is presented in the 2020 assessment. The size limit was increased in May 2010 (117 mm), September 2013 (120 mm) and July 2018 (125 mm) in SMU 4 and May 2010 (117 mm), July 2018 (118 mm) and Jan 2019 (120 mm) for SMU 1-3. Green lines show size limit changes to 120 mm or above.

Further information about the size of abalone was collected during a survey independent of fishing during October 2022, and a brief summary is repeated here. Historical data from length-frequency collections were available at 20 of the sites sampled, and included data from the 1990s (18 sites) and from the 2013 independent survey (2 sites). Larger abalone were more common in the survey during 2022 than in historical surveys, although length distributions remain limited above about 135 mm north of Wonboyn. Mature abalone (i.e. >90 mm) at the 7 sites north of Bunga had a greater proportion of biomass below 117 mm (i.e. that would be protected by a 117 mm size limit), than sites south of Bunga below the current 120 mm size limit (i.e. average 76% v 72%, Figure 4). The biomass of abalone from 117-120 mm at the 7 sites north of Bunga was on average 68% of the biomass above 120 mm, suggesting that a 117 mm size limit would increase the biomass of abalone available to fishing by the same amount.

The intent of the fishery-independent survey was to provide a baseline, prior to any management change, so that impacts of the management and any fishing changes can be assessed. Performance Indicators from the survey include particularly the length-frequency distribution of abalone, and their abundance estimated by the duration of collection at each site (i.e. a timed-swim survey). These Performance Indicators are likely to respond to change in fishing, with increased catch north of Bunga, and decreased catch to the south, with the intent to ensure ongoing spread of catch away from Eden and north of Bunga. The Survey could be repeated both in the near-term (e.g. 1-2 year) and longer-term (3-5 years) to assess the impact of any management change.

Dive events

Indicators of dive events from GPS loggers are identified in the interim Harvest Strategy as Secondary PI. Previous stock depletion in NSW, Victoria and Tasmania highlighted change in diving behaviour that occurred as stocks declined, while broader-scale logbook-based catch rates were maintained (i.e. and before that decline became clear in other fishery indicators). GPS loggers were developed during the early 2000s, to collect fine-scale and real-time data about the behaviour of divers in response to stock changes, particularly because of the difficulties of broad-scale abalone surveys independent of fishing. Several indicators have been derived from GPS logger data (e.g. effort maps and local-scale trends, kg/Ha, % short dives, # dives per day, area coverage and distance moved etc.) and their use is still being developed in NSW, and other fisheries including Tas, Vic and NZ.

GPS loggers collect data about the behaviour of divers, which can be influenced by a range of factors, including stock condition. Change in the abalone stock can lead to change in diver behaviour that can be recorded by the GPS loggers, but can also be confounded with other influences (e.g. market influences), and may require appropriate interpretation (e.g. open workshop with divers, common in most abalone fishery). While there are a range of Performance Indicators available from logger and related data, which appear to offer significant potential for monitoring fine-scale diver behaviour and its relationship with stocks, it remains unclear exactly how and when each of these will respond to changes in the stock. Current monitoring is only beginning to understand the relationship between logger-based performance indicators and change in the abalone stock in NSW and other state's abalone fishery.

Several key performance indicators derived from logger data are presented here for SMU 2 and Area 16 in SMU 3 (Figure 10). These have been presented as examples for several years to display change in some key indicators derived from logger data. While there are many possible indicators from logger data, several key indicators have been developed and shown to provide informative measures of dive events (e.g. area or length of dive events, number of dive events per day including short dives, area per hour or length per hour) that appear related to changes in the stocks. Here we update several different types of indicators, all of which have been presented in previous year's, including some that appear to have change related to recent changes in the stock (e.g. number of dive events per day), and other indicators that have changed less (e.g. overlap of dive events). Changes in these performance indicators through time may suggest change in diver behaviour that reflect changes in the stock, although differences in these indicators among divers may also confound this comparison, and methods of standardisation have been developed.

Catch, and the estimated density of biomass from loggers, increased from the 2010 to 2015-17 in each of SMU 2 and Area 16, before declining, and recovering briefly in 2020-21 before declining again and recovering in 2023-24 in SMU 2 but not Area 16 on Green Cape (Figure 10). The 2016 storm impacted much of the south coast, but particularly Area 16, where catch and biomass density appears to have recovered more slowly than SMU 2. The pattern of change in catch and biomass density has been relatively similar across most areas in NSW, as have the apparent responses of divers (i.e. recorded on loggers) to changes in the stock. As well as changes in the stock, several management changes have also occurred including a reduced TAC, increased size limit, logger-type and use has also become compulsory in 2019, increasing coverage and additional divers being added to the dataset. There have also been a range of market-related changes including daily catch limits, and greater fishing to market-demands including sizes of abalone. Despite that, the recent pattern of reduced catch, followed by large catch prior to the end of the fishing period, has led to complimentary change in most indicators within the year, which increase with reduced catch and decline following increased catch.

The area of individual dive events declined or remained stable as catch increased to a peak in 2014-16 and the large storm impacted stocks (Figure 10). As stocks recovered, the area of individual dive events increased in both SMU 2 and Area 16 to a peak in 2019-20, before declining particularly following large catch near the end of each fishing period, until 2023-24. Following the 2016 storm where estimates of biomass were reduced substantially, particularly in Area 16, there was an abrupt change in diver behaviour that was also evident at the scale of SMU 2. Divers initially recorded smaller dive events that were more quickly covered, with more short-dives and completing more dive events per day. As catch was reduced and the stock recovered to 2020-21, the changes in logger indicators reversed, so that there were much fewer dive events per day, the dive events were smaller and divers are moving more slowly across them with much fewer short dives. Many of these changes in logger indicators that reversed as the stock recovered and with lower catch, were impacted by the large catches near the end of the Fishing Periods, but not to date in 2023-24.

Since 2020, large changes in the distribution of catch within the year (e.g. particularly low catch early in the Fishing Period followed by large catch near the end) have been followed by changes in logger and other fishery indicators. These changes have also been associated with change in apparent biomass and Harvest Fractions, and have been apparent in most Areas and SMU. Changes in logger performance indicators through time, both within and among years, suggest changes in diver behaviour are responding to changes in the stock, and suggest the opportunity to monitor the behaviour of divers as an early indicator of changes in stocks before they impact logbook catch rates. Other indicators, including overlap of individual dive events, and coverage of the total fished area, have been more stable through time and less responsive to changes in catch and the stock, but have still been influenced by changes in catch and stocks in recent years.

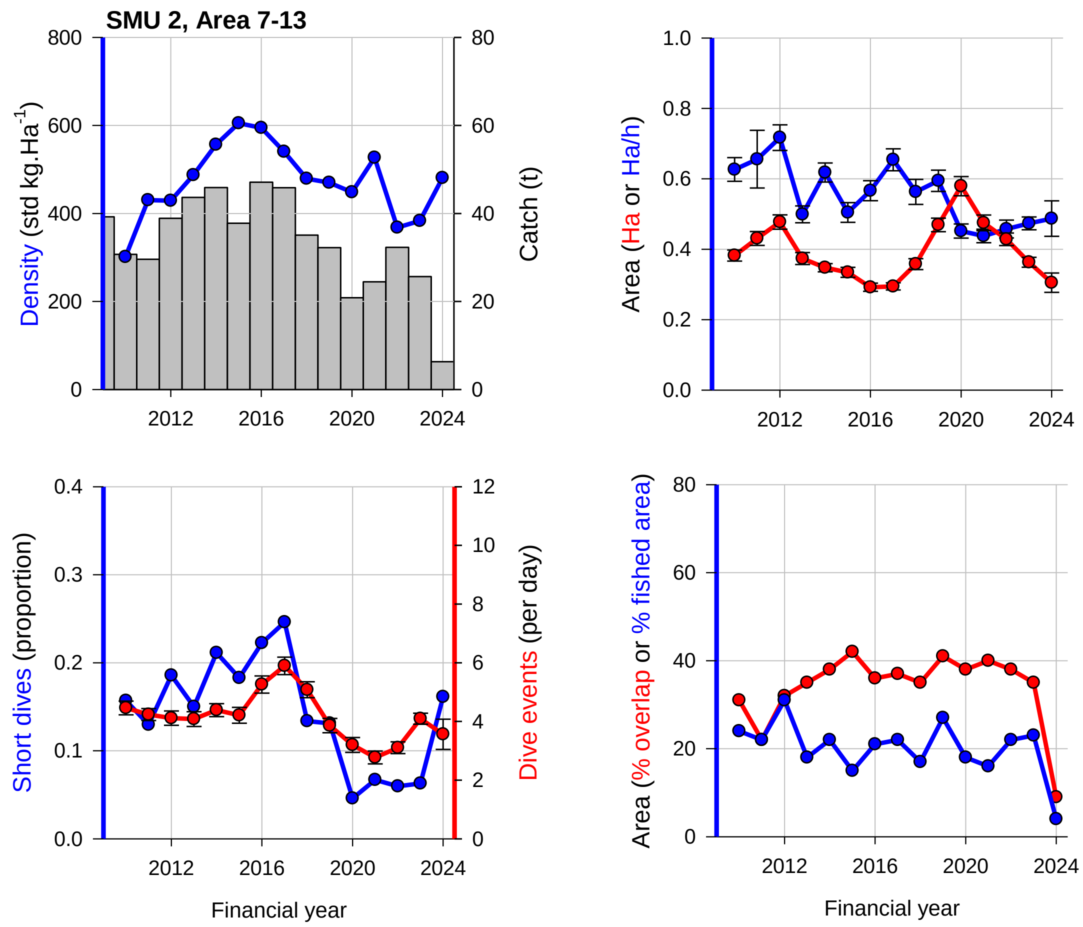
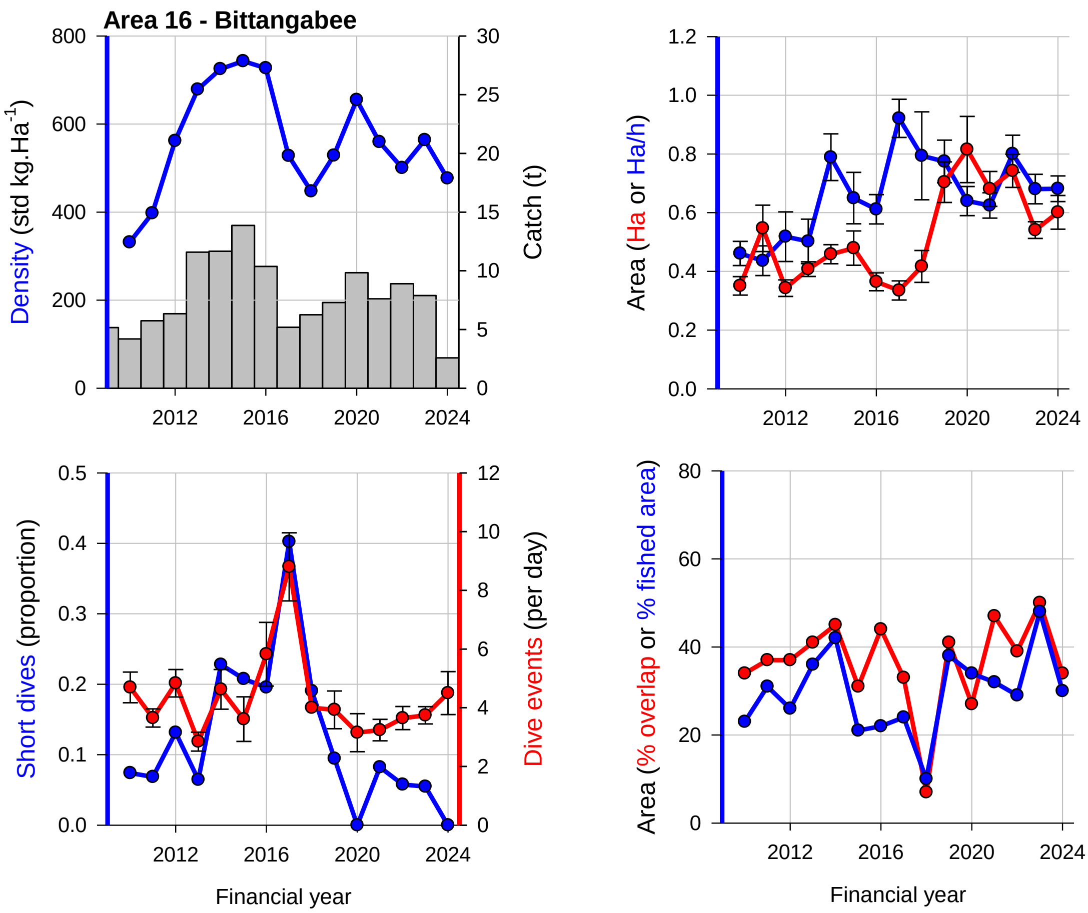


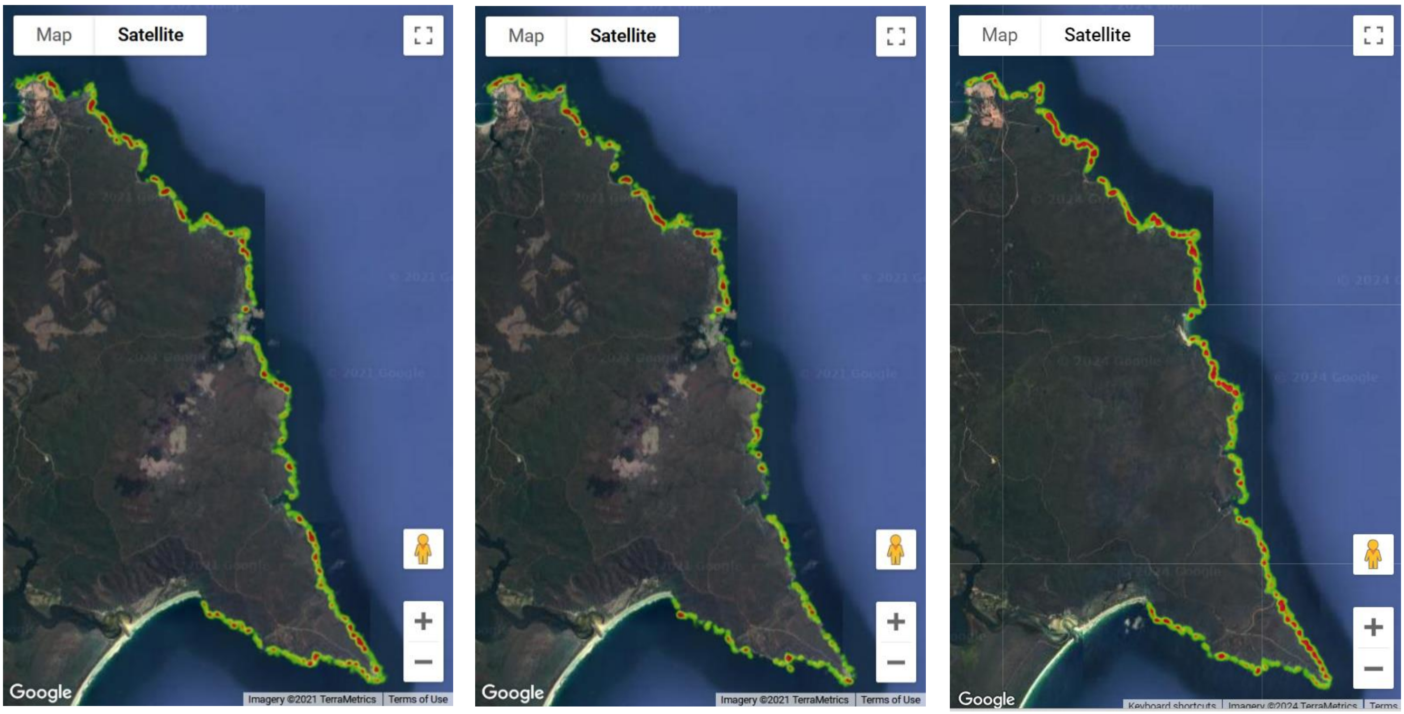
Figure 10. Dive event indicators from GPS logger data for SMU 2 and Area 16 since 2009-10. Indicators include catch (grey bars), legal biomass density (blue line), area and area per hour (red and blue lines), proportion of short dives and dive events per day (blue and red lines) and overlap of dive events and total fished area (red and blue lines). Error bars are SE. Note, data extend to December 2023, and % overlap and % fished area are influence by reduced data from half of a Fishing Period.

Figure 10, continued. Dive event indicators from GPS logger data for three SMU since 2009-10. Indicators include catch, legal biomass density, area and area per hour, proportion of short dives, dive events per day and overlap of dive events and fished area. Error bars are SE. Note, data extend to December 2023, and % overlap and % fished area are influence by reduced data from half of a Fishing Period.



In recent years, there have been some large changes in dive event PI from loggers, that suggest change in diver behaviour and abalone stocks. There have also been confounding changes in size limit and patterns of catch and effort that may also influence logger PI. Interpretation of change in logger PI, with other Primary and Secondary PI, suggest at least part of the change in logger PI is related to divers changing their behaviour in an attempt to maximise their catch rate as stock conditions change, often in response to other recent catch. This includes moving more slowly across the reef and changing the area of their dive events, completing fewer dive events, and few of which are short (i.e. not successful in finding what are interpreted as good catch rate and stock conditions). While these indicators appear to have been related to stock condition in recent years, other indicators such as dive event overlap, which have appeared to be useful at other times, have not changed in a similar way. Again, this supports previous observations that different dive event indicators may be more useful at different times, as the patterns in diver behaviour and stock conditions change. The recent increased coverage of loggers across the fleet will be important in improving useful information from GPS logger data. Greater and consistent coverage of logger data will enable more detailed consideration at smaller spatial and temporal scales (e.g. within subzone and within year), improve standardisation, and provide confidence that the indicators are representative of the fishery. This approach is also being developed in the Tas, Vic, SA and WA fishery.

One example of improvements in data and analysis possible with high logger coverage, involves presentation of trends in fine spatial-scale effort through time. For example, logger data can be used to display areas with reduced or increased effort that may be related to trends in reduced or increased productivity of the local abalone population. Heatmaps are used in several other abalone fisheries with GPS logger data to demonstrate spatial and temporal patterns in effort across large sections of coast (i.e. ~30 km in Figure 11a), while retaining privacy of the data at very fine spatial scales (i.e. limited zoom). For example, Figure 11 shows Heatmaps (i.e. independent html files that can be displayed, accessed and interrogated in digital dashboards) of all Succorfish GPS logger data in 2019, 2021 and 2023 along Green Cape. These heatmaps demonstrate a remarkable consistent and high coverage of fishing effort along Green Cape, despite differences in catch among years. Heatmaps showing the difference in local fishing effort among years can then be used to identify areas where effort is changing among years or longer time periods (Figure 11b). As well as their use in annual assessments to understand trends in local-scale dynamics of fishing and productivity from local populations, these maps can also be produced in near real-time (e.g. automated daily/weekly/monthly), and in the Western Zone fishery in Victoria, are being served online through an app on a diver's phone to make on-the-ramp decisions about where to fish, with privacy retained by limiting access to a certain spatial scale (see discussion at FRDC Abalone Assessment and Management Workshop). Further, heatmaps like Figure 11b can be used to generate and display an index of the fine-scale change in effort within subzones, at weekly/monthly and annual time scales, making simpler the process of monitoring change and identification of areas for further assessment with other local-scale indicators. As high coverage GPS logger data is becoming more common in all Australia's abalone fisheries, novel approaches to its interpretation and use in fishery assessment and management are being developed.



a) Effort in 2019. Effort in 2021. Effort in 2023.

b) Change in effort 2020 v 2019 2021 v 2019 2023 v 2019

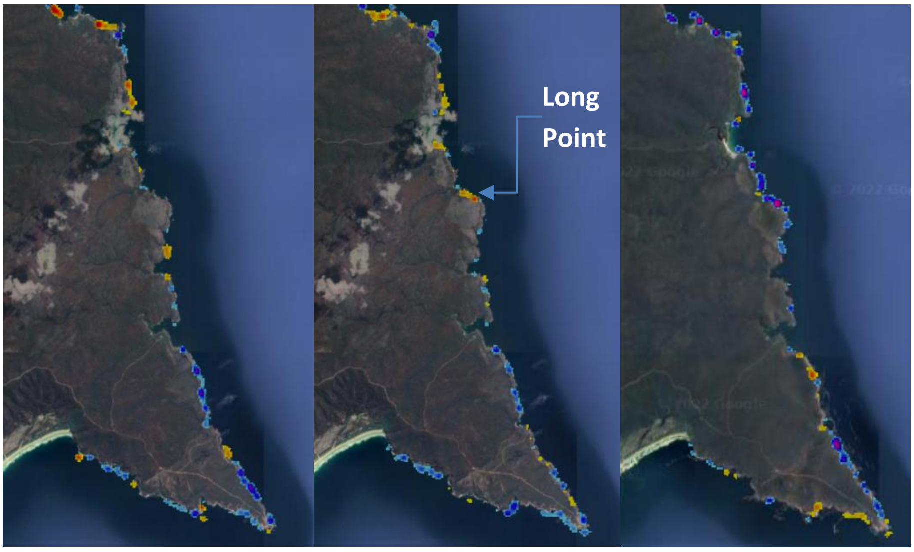


Figure 11. Maps (i.e. html heatmaps) of all Succorfish GPS data showing fishing effort on Green Cape in a) 2019, 2021 and 2023. Heatmaps show fishing effort as red for high density and yellow low density. Maps of b) spatial difference in effort density between 2019, 2020, 2021 and 2023 (i.e. within a 50 m^2 or 0.25 Ha grid, where red shows an increase, and blue a reduction in effort density. Increased effort in 2021 compared to 2019 on north side of Long Point (shown yellow-orange by arrow) represent an increase in effort during 2021 of 6.7 h over an area of 8.75 Ha or 45 min per Ha. Effort density at Long Point in 2023 was reduced from 2019 and 2021, showing the rotation of effort by the fishery at an individual site among years. Further spatial detail has not been shown here to retain privacy.

Diver observations

Observations made by divers while fishing have become an important source of information considered in assessments in most state's abalone fishery (e.g. particularly Vic and SA, where they are used in formal Harvest Strategy). A recent national FRDC project, developed an approach for a cost-efficient and standardised approach to collecting observations made by divers and recorded soon after fishing. The Diver Observations app (i.e. progressive web application) is available at obs.abdiver.link, and can be accessed by a diver's mobile device and completed soon after fishing each day. The survey of daily observations includes questions and the opportunity to provide subjective, categorical answers about abalone stocks above and below the size limit, and impacts of various factors on fishing (see summary at end of Appendix 5). While some fisheries have been completing similar surveys for several years (e.g. EZ Vic and WZ SA), 6 divers have been involved in the survey during 2021-23 in NSW (i.e. divers representing more than 25% of the catch), and several more divers have registered but not completed surveys.

While the Diver Observation survey only commenced in March 2021, a total of 128, 48 and 54 days of diver observation surveys have been completed in the 2021-22-23 calendar years (i.e. 2023 data shown in Appendix 5). A fuller description of summarised results with trends through time will be provided as more data becomes available, and the Diver Observation survey is considered within the fishery Harvest Strategy. Despite that, several patterns in the responses are consistent with other data and Performance Indicators used in the Harvest Strategy, and will be briefly summarised.

Observations in early 2021 suggested several measures (e.g. Legal-sized, Unders and Juveniles, time periods within years, compared to last year, and 2-4 years ago) appeared to be consistently different among Area. For example, for most measures abalone were less abundant in 2021 in Area 16-18 (i.e. Bittangabee to Disaster Bay) and Area 9-10 (i.e. Bermagui to Tathra). In contrast, for most measures, abalone are more abundant in Area 14-15 (i.e. close to Eden) and Area 20-21 (i.e. SMU 4). Similarly, catch rates are more than expected where abalone are abundant, and this is also reflected in diver's overall opinion of stocks and concentration of catch in the fishery. These differences among areas were greatly reduced following the large catch of abalone late in the 2020-21, 2021-22 and 2022-23 Fishing Periods. Observations in most areas showed a reduction for most indicators following the larger catch near the end of the Fishing Periods, and a recovery soon after.

In 2022 and 2023, most survey observations have been recorded in SMU 2, between Tuross and Eden, and particularly near Narooma, Merimbula and Eden. Three divers have completed most of the surveys. Observations suggest fishing was impacted on about 10-15% of days by various factors, such as market demand, greater measuring abalone, habitat change and environmental conditions. While data is limited, these observations can contribute to better standardisation of catch and catch rates. Observations of abalone are more positive around Tathra, Saltlake and Cape Howe (e.g. also in Disaster Bay near Green Cape, where urchin catch has been large), and less positive north of Eden, on Green Cape and south of Wonboyn. Full detail of survey responses and comments will be available (i.e. with privacy retained) for Industry workshops considering the data, and a copy of the survey screens is available on the final pages (Appendix 5).

Interpretive summary assessment of stocks

This section provides a summary of an interpretive assessment of stocks within each of the four SMU of the fishery. Interpretation and assessment are based mostly on Performance Indicators from the fishery's interim Harvest Strategy, including raw and standardised catch rates and abalone weight, and estimates of biomass density from loggers (i.e. 3-year trends). Two measures of Stock Status are also presented below and each relate to different approaches to assessment of the stock. Assessment of Stock Status uses the National Reporting Framework of the Status of Australian Fish Stocks (i.e. SAFS as biologically Sustainable, Depleting, Depleted), and is made for the fishery as a whole by comparison to fishery-wide Reference Points (Appendix 2), as a longer-term interpretation of the status of the fishery. Shorter term assessment of change over 3 years (i.e. Stable, Increasing, Declining), consistent with the interim Harvest Strategy, is summarised separately by SMU.

The longer-term assessment of the fishery is considered **Sustainable** because fishery-wide catch rates are above the Sustainable Reference Point (i.e. 40 kg/hr fishery-wide catch rate, and related indicators in Appendix 2). Shorter-term assessment (i.e. as Stable, Increasing, Declining) is assessed by the 3-year linear trend of Primary Performance Indicators with ±5% per year Reference Points consistent with the interim Harvest Strategy. SMU 2 is assessed as **Stable-Increasing** as the three-year trend in catch rates is stable (i.e. -4% per year) while the biomass index is increasing (+15%). SMU 3 is assessed as **Stable**, as the three-year trend in catch rates is decreasing (-6%) while the biomass index is increasing (+12%). SMU 4 is assessed as **Stable-Increasing** as the catch rate is stable (+1%), while the biomass index is increasing (+17%). Each of these assessments has improved from last year, but variation among the key indicators suggest the stock is mostly stable and not clearly increasing. Short-term assessments in each SMU have changed over the previous four years, from where most SMU were considered Increasing (2021 assessment), then to all were Stable (2022 assessment), then all SMU with some declining indicators (2023 assessment), to this year's mostly stable assessment with the biomass index increasing in some SMU. In SMU 1, there remains little consistent data available for assessment of the extent of local spatial-depletion and broader ongoing recovery (e.g. from previous *Perkinsus*-related mortality, and other factors including all sector catch). With very limited catch and more variable Performance Indicators in SMU 1 and the northern part of SMU 2, these areas are considered likely to be **Spatially depleted and Stable**, consistent with other SMU.

Changes in fishery Performance Indicators in recent years has been spatially and temporally variable, but consistent broad patterns of change have also followed recovery from the 2016 storm, change in management and catch, and decreases in recent years followed by some recovery in 2023-24. Recent assessment of Stock Status completed in the 2019 fishery assessment for the TAC process, and by DPI as part of the 2017-18 SAFS process, determined a Depleting status for the fishery. Management changes were made to encourage recovery, including size limit increases and a TAC reduction from 130 to 100 t from 2018 and were followed by further reduced actual catches related to bushfires and market problems from Covid. The 2019-20 SAFS assessment concluded that these external impacts reducing catch in the fishery had precluded determination of a stock status of Sustainable with reasonable confidence, leading to an Undefined status. Catch then increased from early 2021 with catch rates and other performance indicators increasing throughout most of the fishery to peaks in the 2020-21 Fishing Period, consistent with an Increasing status. Despite that, concentration of large catch into several months late in the 2020-21 Fishing Period was followed by declines in most Performance Indicators, and Stock status in last year's assessment was reduced to Stable. While large catch late in the Fishing Period has now occurred for 3 years, during a time where stocks have been declining or stable, some key indicators have turned to increasing in most SMU (e.g. biomass density in 2023-24). While more stable catch within each year and consistent with the

TAC will aid interpretation of fishery Performance Indicators, catch of 32 t from the 100 t TAC by December 2023 again suggest a large catch late in the 2023-24 Fishing Period.

Conservative decisions about future catch and TAC should ensure fishery Performance Indicators are maintained or increased, and with the catch spread more evenly through the year at levels consistent with the TAC. Demonstrated performance of the fishery at catch levels consistent with the current TAC, over longer time and spread appropriately across productive reefs, would provide greater evidence for increased production from the stock. Further development and completion of a Harvest Strategy, with an agreed set of Performance Indicators and Reference Points by SMU, would simplify assessments and provide a clearer guide to future management of the fishery.

Spatial Management Unit 1, Tweed to Tuross

Annual catch in SMU 1 peaked at 250 t in 1984 on a 108 mm size limit (i.e. limited catch records before 1983), and has consistently declined since. It is unclear when mortality related to *Perkinsus* commenced, but anecdotal evidence suggests from the 1980s around Sydney and the Central Coast, before spreading north and south. Apparent 'fronts' of infection, and loss of abalone populations, were spread from Port Stephens to Jervis Bay in the early 2000s, and the area was closed to fishing in 2002. A Structured Fishing survey suggested stocks were heavily depleted in many areas, although some less depleted populations remained, and the area was reopened to fishing. Together with the decline of local abalone populations in SMU 1, local divers and processors gradually declined in the area, and moved south. From about 2005-06, catch rate and average abalone weight started to increase in SMU 1, as it did through the rest of the fishery, following reductions in state-wide TAC. Catch remained low and variable at <10 t t from 2008, with few local divers and processing options limiting further catch. Several divers have done extensive survey work with GPS loggers trying to assess recovery of stocks, but with limited success.

Over the last 3 Fishing Periods, annual catch has remained low at 1.5-3.3 t (i.e. 1.1 t in 2023-24), and catch rate peaked in 2013-17 at the highest on record (>40 kg/h), declined in 2018 (<30 kg/h, in part due to low survey catch rates), but recovered to a new record in 2019-20 (~50 kg/h), before declining to about ~30 kg/h (i.e. 30.4 kg/h in 2023-24) with a higher proportion of days with low catch (i.e. <30 kg). A co-ordinated response by several divers in 2019-20, particularly during July and August in Area 1, led to increased catch of 4.4 t at high catch rates and average weight of abalone. While some catch was landed in these areas in 2021 (i.e. 3.2 t), high catch and catch rates have not been repeated. Average weight of abalone increased to the highest on record, at over 400 g in 2020 and 2023 (i.e. from 290 g in until 2006), following further size limit increases implemented in 2018-19. In 2023, logger data and estimates of biomass are variable and limited, and have been confounded by changes in the spatial distribution of catch and divers (i.e. travelling divers targeting high catch rate with good weather, and local divers landing small consistent catch at lower catch rate), particularly in recent years, and provide limited understanding of stocks. Impacts in recent years from theft and recovery from the June 2016 storm, remain unclear. Abalone stocks in SMU 1 remain spatially depleted by a combination of factors including particularly *Perkinsus*, and despite good catches in several Area's during 2019-20, there is little evidence to suggest ongoing recovery of stocks. There remains little consistent data available for assessment of the extent of local spatial-depletion or broader ongoing recovery. With limited catch and more variable Performance Indicators in SMU 1 and the northern part of SMU 2, these areas are considered to be slowly recovering after high spatial depletion, and in recent years are likely to be Stable, consistent with other SMU in the last 3 years.

SMU 1 recent status: Spatially Depleted and Stable.

Spatial Management Unit 2, Tuross to Eden

Annual catch in SMU 2 peaked at 230 t in 1983 on a 108 mm size limit (i.e. limited catch records before 1983), and 124 t in 2000 on a 115 mm size limit, before declining again to 30-40 t following reductions in state-wide TAC. From about 2005-06, catch rate and average abalone weight started to increase in SMU 2, as it did through the rest of the fishery. Catch in the northern part of the SMU has been low and variable since about 2008-10, and mostly dependent on a few travelling divers, which has been more difficult because of processing limitations. Catch (37-47 t), catch rates (40-45 kg/h) and biomass density peaked around 2014-16, prior to a large storm in June 2016 that extensively disturbed areas of north-east facing, shallow reef throughout NSW. Catch rates and estimates of biomass dropped sharply in 2017 in all Areas of SMU 2, while levels of catch were maintained and increasingly concentrated in southern parts of the SMU, and catch rates (~35 kg/h) and biomass reached a low in 2017-18. Catch declined to 20 t in 2019-20, before increasing to 32 t in 2021-22 and decreasing again to 25 t in 2022-23, with 6.3 t caught in 2023-24, with most concentrated in the southern part of SMU 2. Catch rate has been stable (i.e.~40-46 kg/h 2019-2023, and peaked at 46 kg/h in 2023-24), weight of abalone has been increasing (i.e. ~350 g, peaking above 355 g in 2022-23 and 2023-24). Biomass density has been more variable, declining in 2021-22 and 2022-23, before recovering in 2023-24. While catch has been concentrated in the southern part of SMU 2, there have been low and variable catches in the northern part of SMU 2, with similar variable indicators to the southern part of SMU 2 (Appendix 3). SMU 2 is assessed as Stable-Increasing as the three-year trend in catch rates is stable (i.e. -4% per year), but the biomass index has changed from declining to increasing (+15%), with most stock and fishing in the southern part of the SMU.

SMU 2 recent status: Stable-Increasing.

Spatial Management Unit 3, Eden to Wonboyn

Annual catch in SMU 3 peaked at 140 t in 1983 on a 108 mm size limit (i.e. limited catch records before 1983), and around 88 t in 1999-2001 on a 115 mm size limit, before declining again to 30-50 t following reductions in state-wide TAC in the early 2000s. From about 2005-06, catch rate and average abalone weight started to increase in SMU 3, as it did through the rest of the fishery. Catch (~50 t), catch rates (<50 kg/h) and biomass density peaked around 2014-16, before dropping sharply in late 2016 particularly on Green Cape. The north-east facing Green Cape was exposed to a large storm in June 2016, while the south facing Disaster Bay was comparatively protected, and subsequently catch was reduced on Green Cape, while increasing in Disaster Bay and other adjacent areas from 2017. Catch and catch rates declined to a low in 2017-18 on Green Cape, and with catch moving into Disaster Bay, catch rates declined to a low there from 2018. Then from 2018, this was reversed with catch returning to Green Cape from Disaster Bay and adjacent areas, with a total catch for SMU 3 of 38 t. Catch in SMU 3 declined to 28 t in 2020, before increasing to 36-38 t in 2021-22 and 2022-23 (i.e. and 15 t in 2023-24), with most remaining close to Eden. Average catch rates and biomass in SMU 3 reached a low in 2018 and a peak in 2020-21 (i.e. 37 to 54 kg/h), before declining in 2021 and 2022 (i.e. 43- 41 kg/h) and increasing again to 45 kg/h in 2023-24. Abalone stocks of all sizes in SMU 3, and particularly on Green Cape, were heavily impacted by the 2016 storm, which led to catch increasing in the south-facing and more protected Disaster Bay. Reduced catch on Green Cape initially enabled a recovery of stocks, before large catch late in 2021, and recovery in Disaster Bay has remained weak even with catch reduced (i.e. with some evidence of greater recovery closer to Green Cape in 2023). Catch has increased closer to Eden in SMU 3, with some evidence stocks have increased compared to earlier years. SMU 3 is assessed as Stable, as the three-year trend in catch rates is declining (-6%) while estimates of biomass are increasing (+12%).

SMU 3 recent status: Stable.

Spatial Management Unit 4, Wonboyn to Cape Howe

Annual catch in SMU 4 peaked at 80 t in 1985-86 on a 108 mm size limit (i.e. limited catch records before 1983), and 71 t in 2002 on a 115 mm size limit, before declining again to 20-40 t following reductions in state-wide TAC in the early 2000s. From about 2005-06, catch rate and average abalone weight started to increase in SMU 4, as it did through the rest of the fishery. Catch reached a low (14 t) in 2009-10 and 2012-13 (18 t) following size limit changes, and the shifting of effort closer to Eden. Catch rates (~65 kg/h) and biomass increased to a peak during 2013-15, as catch also increased to a peak of 38 t in 2017 and with effort shifting away from Green Cape after the storm. Catch (26 t in 2018) and catch rates (<60 kg/h) and biomass declined, before catch rates and biomass started to recover as catch remained low (19 t and ~65 kg/h) in 2019-20, before increasing in 2020-21 (34 t and ~70 kg/h) and declining in 2022-23 and 2023-24 (31 t and 9 t at ~60 kg/h). Large catch within Area 21 at the end of the 2022-23 Fishing Period impacted fishery indicators, that have not recovered by December 2023. Some market-based fishing has targeted larger abalone in SMU 4, particularly in Area 19. SMU 4 is assessed as Stable-Increasing as the catch rate has been stable (+1%), while the biomass index (+17%) has increased in the last 3 years.

SMU 4 recent status: Stable-Increasing.

Appendix 1. Technical Methodology

Regulated catch reporting

Landed catch, effort, the number of abalone per bin, and the time each bin is filled, are reported daily by Subzone for each bin landed in the fishery as part of regulated catch reporting managed by DPI. These data are collected as part of regulated quota-based recording through a smartphone App called FisherMobile introduced in late 2017, and on paper logbooks. After the introduction of FisherMobile several changes and errors have occurred in the catch database, these included daily reporting, instead of bin-scale reporting, and a general reduction in apparent quality of bin-based effort reporting.

DPI maintain the catch logbook data as part of the Quota Management System, and an agreement for release of data to the Abalone Council of NSW has been signed by all divers, to facilitate summary, analysis and presentation for stock assessment. Daily information on catch and effort by Zone is available since mid-1982, and although it has been collected since the early 1970s, only summary information and sporadic daily records are available prior to 1982. Subzones within Zones were introduced in 1995, and in 1999 divers were also required to report the number of abalone per bin landed, which enabled calculation of the mean weight of abalone per bin.

Catch distribution, catch rate and weight of abalone

Several spatial groupings of Subzones (i.e. 85 Subzones) are used to summarise the catch data, and include Areas (i.e. 21 Areas selected with similar historic catch levels) and Spatial Management Units (i.e. 4 SMU selected to correspond with historically-used Regions, and spatial management south of Wonboyn, see map in Figure A2).

Catch, catch rate and the weight of abalone are presented, including standardisation, using three approaches. First, catch and effort data are standardised by day for catch rate, and by bin for the weight of abalone, from a 3-year running dataset for Catch Reporting (see Appendix 3 and 4). Second, catch and effort data are used to calculate the PPI of standardised catch rate and mean weight from a 3-year running dataset. The PPI are calculated from a 3-year running dataset to reduce the impact of any actual change in the diver effect through time, when standardising with a fixed diver effect. Third, catch and effort data are used to estimate annual standardised catch rate and mean weight by day since 1999.

Catch Reporting figures are prepared to summarise annual (since 1999) and monthly (for recent 26 months) catch data by Area and SMU from the regulated catch reporting. Logbook catch data is received each month from DPI and stored in a SQL Server database. Javascript is used from Manifold GIS to call R to connect to SQL Server, extract the relevant data, complete the necessary calculations and analysis, produce graphs output as a PDF for each area, and call Latex to produce summary documents (i.e. annual and monthly). Raw and standardised data per bin are plotted for each month and fitted with the R loess command using least squares, normal errors, degree 1 and span 0.5. Several measures are reported on the figures, including catch (actual and target in t, as a % of the fishery and number of abalone), catch rate (total catch/total effort, geometric mean, standardised and loess trend) and mean weight (total catch/total abalone, standardised and loess trend) and % change each year or since the start of the series. Figures also display the percent change of the average values from the last 3 and 6 months compared to a year before. Figures are also released each quarter with a table summarising catch against targets per Area and SMU.

Standardised catch rates are calculated by extracting the relevant data (e.g. 3-year running dataset, or since 1999), removing outliers with daily catch rate <5 kg/h or >150kg/h (and days with effort >0.2 h and <15 h), and implementing the R function glm. Each standardisation fits ln(daily catch rate), with the catch reporting standardisation using terms Month(Year) x Area(SMU) + Diver, calculation of the annual PPI uses terms Month(Year) x SMU + Area(SMU) + Diver, and standardisation since 1999 uses terms Quarter(Year) x SMU + Area(SMU) + Diver, each with normal errors. For catch reporting, after extracting a similar data set by bin, the predict.glm function is implemented to estimate fitted values for each bin. These standardised catch rates per bin are then related to GPS logger data by the time of bin filling reported on the logbook, enabling spatial mapping of this PI. For the PPI and change since 1999, standardised catch rates are reported for the average Diver in the average Area within each SMU, and 1-year and 3-year change in standardised PPI values are estimated by fitting a linear model.

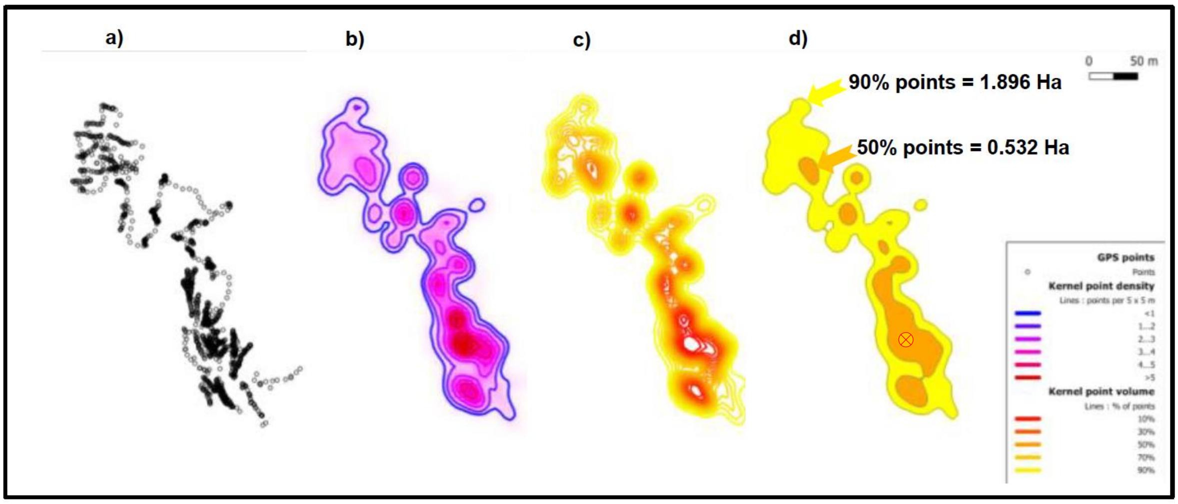
Separate standardisations are also completed to calculate the standardised weight of abalone per bin from logbook data, and are produced by extracting the relevant data (e.g. 3 year running dataset, or since 1999), removing outliers with daily mean weight <0.240 kg or >0.500 kg (and days with effort >0.2 h and <15 h), and implementing the R function glm. The catch reporting standardisation uses terms Month(Year) x Area(SMU) + Bin + Diver, where Bin is a categorical variable describing the number of abalone in the bin, and the model is parameterised to refer a bin size of 60 abalone. Calculation of the PPI of standardised average abalone weight per bin uses terms Month(Year) x SMU + Area(SMU) + Diver, while standardisation since 1999 uses terms Quarter(Year) x SMU + Area(SMU) + Diver. For the PPI and change since 1999, standardised abalone weights are reported for the average Diver in the average Area within each SMU, and 1-year and 3-year change in standardised values are estimated by fitting a linear model.

Since 1999, there have been several changes in how catch and effort is reported, including changes in processing (e.g. size of bins and amount of associated water), and how bins have been used to determine the weight of abalone landed, and particularly during 2017-18, with the change to a standardised bin weight and the introduction of the FisherMobile app. For example, bins that were reported as 6.5 kg, are now being reported as 6 kg, with likely changes in the amount of associated water retained with the abalone and bin, and this may influence estimates of particularly mean weight (i.e. higher bin weight and less associated water, related to lower mean weight). The influence of past changes in catch reporting on estimates of catch rate and mean weight should be further investigated with existing data, although some key data may be unavailable (e.g. data on past changes in reporting, processing, and bin weights used).

GPS loggers

Fine scale location of diving effort is collected through the voluntary use of GPS (Global Positioning System) and DTS (Depth and Temperature sensors) loggers by most divers in the fishery. GPS and depth logger data are sent to a cloud database, and downloaded and stored in the purpose-built AbTrack SQL server database. This requires manipulation and coordination of files before upload, and the database and raw data files are backed up on and off-site (raw data files and Google Earth files of dive events with summary PI are also available to divers on request). Manifold GIS, Jscript, SQL and R are used to link, query and analyse the database to produce PI for dive events that are summarised by Area and SMU each Year. Most PI are based on individual dive events defined by the depth logger (or by boat movements), which records a new dive event following a set amount of time where no depth data are recorded (i.e. 2.5 minutes <0.5 m depth). GPS points (i.e. GPS location of boat when the diver was >0.5 m) from individual Dive events are then summarised using Kernel Density Estimation which describe the spatial density of GPS points during the dive event (Figure A1). This is done by estimating spatial, bivariate-normal distributions for each GPS point from a dive event, which are combined for all points within the Dive event and normalised to produce contours of the area enclosing different percentages of the estimated point density from the dive event. For example, areas enclosing 50% and 90% of the estimated density of GPS points from each Dive event are routinely calculated, available to divers in Google Earth files, and used to calculate PI through time and area.

Figure A1. Method of developing a summary of a Dive event, showing a) GPS points every 10 seconds where diver depth is >0.5 m, b) kernel point density (i.e. estimated density of points per 5 x 5 m shown by pink-red colours) and contours (i.e. estimated density of points per 5 x 5 m grid shown by blue lines), c) kernel point volume contours (i.e. enclosing estimated percent of points with highest density from dive event) and d) kernel point volume contours enclosing estimated 50% and 90% of points, with point of maximum density (red circle) and related area (i.e. Ha).



Secondary PI routinely calculated per Dive event include the average area of dive events and the area covered per hour during dive events, the overlap of different dive events (i.e. % of total dive event area that is overlapping with other dive events within the year and area), the area of dive events compared to the total fished area (i.e. total area within the year and area as a proportion of all years for that area), the proportion of short dive events (i.e. <15 min), the concentration of dive events (i.e. ratio of the area of 50% and 90% of GPS points per dive event), and the depth of dive events. These Secondary PI can easily be extended or revised to include different spatial or temporal grouping. For example, a grid of 1 Ha hexagons is also available, allowing the calculation of all PI for Dive events within each 1 Ha grid cell. Two new logger SPI were recently developed, including the nearest neighbour in time, which shows the average number of days between dive events with centroids within 500 m of each other, and the nearest neighbour in space, which shows the average distance between centroids of dive events within 50 days of each other. Current development is also continuing to investigate the standardisation of logger SPI to remove confounding by consistent differences among divers similar to the catch data, and among Structured Fishing sites, and the use of loess smoothers to describe trends through time, similar to the catch data.

The GPS logger database can also be linked to the Logbook catch database, through the reported time of each bin being filled by each diver, and the time recorded on the GPS logger. In this way, PI available from the Logbook catch data, including catch, effort, catch rate (raw and standardised) and mean weight can be directly related to GPS points, dive events and the 1 Ha grid. The linked databases are also used in producing Google Earth files for all and each diver, and summarising PI from loggers and logbook on detailed maps of the coast.

Data available from loggers has been used to calculate the biomass density of landed abalone, and through calibration with abundance surveys (i.e. with correlations found for the method within and among several abalone fishery), develop a method to estimate the density of legal-sized abalone available to the fishery, and by extrapolation to estimate total biomass. Estimates of the density of biomass landed (i.e. calculated as daily catch in kg reported in the logbook, divided by the daily area of dive events in Ha estimated by the 50% KUD of GPS points per dive event) are calibrated with the abundance survey in Area 20-21 during 2013, and extrapolated over an estimate of the area of productive reef (i.e. calculated from 90% KUD logger activity within a 100 m hexagonal grid in a 3-year running dataset) to provide an estimate of the total legal biomass. A range of assumptions are made during this process, and are generally similar to those used when interpreting logbook catch rate (i.e. as an indicator of biomass), abundance surveys (i.e. selectivity and representative) and related population modelling.

Estimates of density are standardised by extracting the relevant data, removing outliers with density <50 kg/Ha or >1500kg/Ha, and implementing the R function glm, with ln(daily Catch/Dive event area) described by the terms Year x SMU + Site(SMU) + Diver, with normal errors. Estimates of density are calculated from the GLM for the average diver (i.e. 50% diver cdf) and for a diver that provided a density estimate for Area 20 and 21 similar to that found in the abundance survey in 2013-14 (i.e. 597 kg/Ha) and the average of unstandardized density estimates (i.e. 524 kg/Ha). This approach attempts to calibrate the estimates of biomass from logger data, to the comparable estimates of biomass from the abundance survey, as has been done in several similar Victorian examples. Estimates from the GLM of density for the average diver in Area 20 and 21 in 2013-14 were 400 kg/Ha, while all estimates presented unless noted otherwise, were standardised to a diver that estimated a density of 496 kg/Ha (i.e. 70% of diver cdf, or the mean effect + 0.5SD).

The Site factor in the GLM was included to standardise for fine scale spatial variation in the distribution of catch and catch rate. For example, an increase in catch from high catch rate sites can increase apparent catch rate (e.g. Stinkys in SMU 2) with no actual change in the broader average, and comparisons through time can be standardised much like differences among divers. To achieve this, about 100 Sites have been defined to enable fine-scale comparison and standardisation. These sites were established with consideration of diving patterns from existing logger data, and breaks between sites generally selected to coincide with areas of sparse or no diving effort. Defined sites range in size from about 1 Ha of reef with logged dive events, up to 27 Ha of reef, and average about 10 Ha (e.g. 100 m x 1 km). Dive events are allocated to Sites using the location of the maximum density of logged GPS points (i.e. maximum kernel density), and fitted values are presented for a 70% diver at an average Site within each Area or SMU.

Measuring loggers

Data about the lengths of abalone are collected with Measuring loggers in two ways. First, Measuring loggers are operated in abalone processors to provide data about the length of abalone landed that can be associated (i.e. through logbook docket ID, although this link is being compromised where the FisherMobile catch reporting app is used) with diving effort per Subzone in the logbook Catch Reporting and then GPS logger databases. The sampling design attempts to sample the lengths of abalone in proportion to the catch coming from different Areas. Receivers are directed to measure abalone from about 200 bins of abalone, and progress is monitored and adjusted in an attempt to match the sample to the catch distribution among areas. In addition, any catch from northern areas of the fishery is given a high priority for measuring. Second, measuring loggers are operated by divers while fishing to provide data about the spatial location of lengths of abalone landed that can be associated with GPS logger data (i.e. through time fields in both databases) and then Catch Reporting data. Measuring by divers is mostly ad-hoc, although some divers are using them as part of the structured fishing design, providing information from multiple data sources from the same site and diver through time.

Measuring Board loggers record the length of abalone for each abalone passed through them, and data are downloaded and stored in a SQL server database. Length data can be linked either to a GPS point if measured by a diver with a GPS and depth logger, or to a diver's daily catch logbook through recording of the unique docket number by the receiver. Data from receivers and divers are combined by weighting that includes calculation of the mean length of abalone per diver day, before averaging across spatial areas (i.e. not weighted by the number of abalone measured per day). Several PI are calculated including the mean length and proportion ≥130 mm, with estimates first calculated per diver day and then across diver days (i.e. the mean length for an area is the average across diver days from both processor and diver measuring). Estimate of mean length are standardised by implementing the R function glm, with daily mean length described by the terms Year x SMU + Area(SMU) + Diver, with normal errors. For several reasons, it is possible for the measuring loggers to record data below the minimum length and above plausible maximum lengths (e.g. measuring error), so PI are calculated by limiting data to less than 160 mm and greater than 115 mm. To enable comparison of PI from measured lengths with those of mean weight per bin from logbook catch reporting, individual lengths (i.e. mm) are also converted to weight (i.e. g, using 0.000334 x Length ^2.857356), before averaging across spatial areas.

Other information sources

A variety of other information are also available about the abalone stocks and fishery in NSW. This includes information from a series of fishery-independent surveys from 1994-2007, a range of other abundance and fishing surveys, a series of hand-measured (i.e. method not directly comparable to current mean weight series) mean weights, and demographic information such as spatial variation in growth and fecundity. An abundance survey with methods used in Victoria was completed on southern reefs in July 2013, and could be repeated or expanded. Much of this information is documented in previous reports about the fishery.

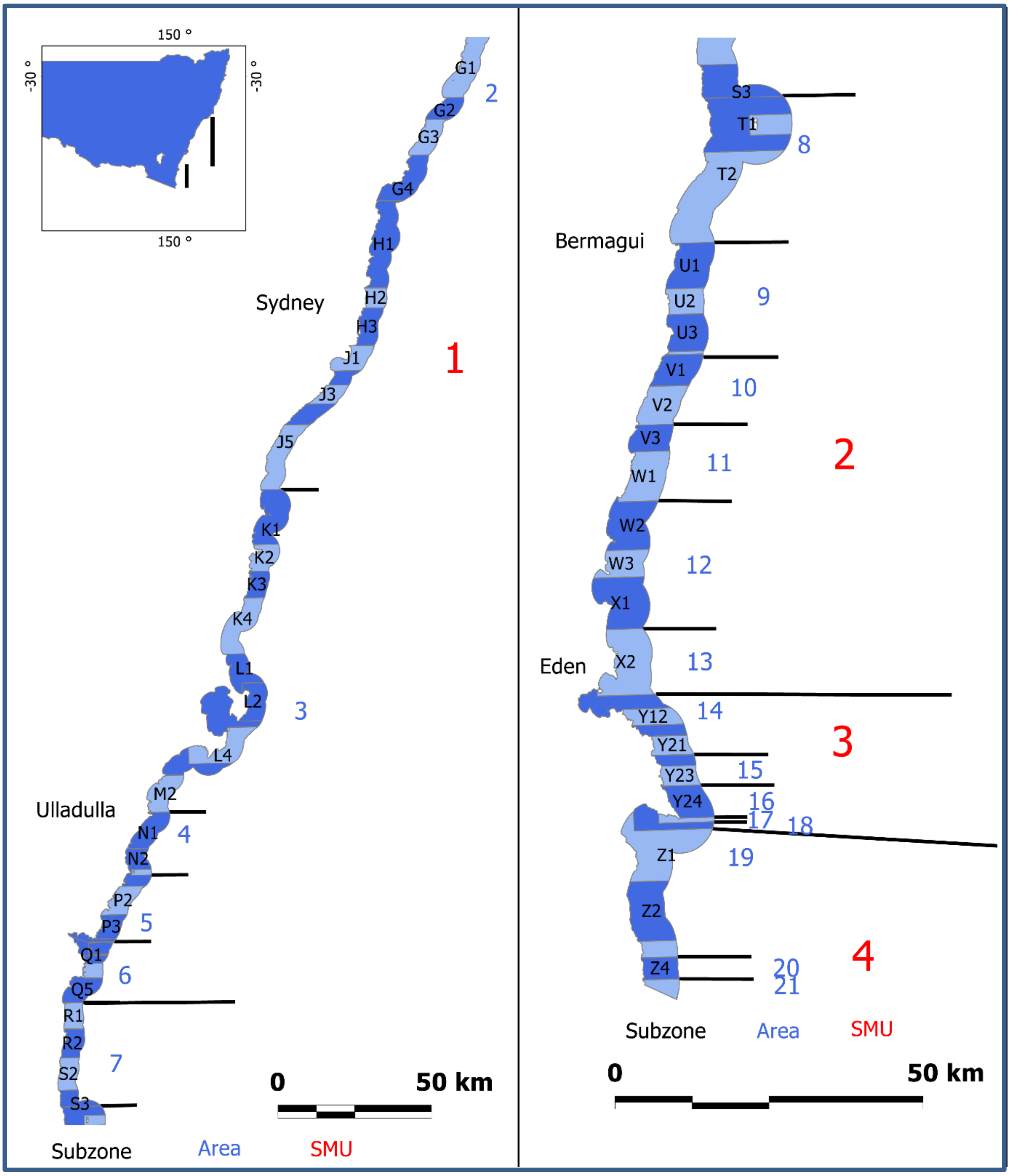


Figure A2. Map of NSW (top left) showing two insets for the central coast (left) from Terrigal to Narooma, and for the south coast (right) from Narooma to Cape Howe. Subzones are coloured to highlight adjacent subzones and overlapping labels are not shown, Areas are numbered from 1 to 21 in blue with black line borders, and Spatial Management Units are numbered from 1 to 4. Insets are shown in the MGA 1994, Zone 56 Projection.

Reference points for the NSW abalone fishery

This document has been prepared to summarise an approach for assessing stocks of abalone in the NSW fishery relative to common fishery management reference points, and to encourage ongoing development of a broader assessment, particularly using potentially more informative performance indicators and greater spatial discrimination.

With the current absence of a formal method of assessing stocks to guide management of the fishery, this approach should provide benefits of greater understanding by stakeholders in the direction of future management and current development of a harvest strategy, greater clarity in the SAFS assessment process, and encourage the ongoing development of the framework.

Following significant changes to the fishery, the reference points described here are likely to update those in the existing fishery Share Management Plan and Management Strategy, where more background and justification for current management is also provided.

Assessing the status of stocks in this fishery is difficult for several reasons. These include particularly, the potential of large depletion of the fishery very early in its development (e.g. 1960-70s) and so the stocks unknown full productivity, significant spatial variation in demography including particularly growth, unknown but significant historical illegal catches and disease-events, and the potential for large-scale environmentally-driven cycles of productivity. A summary of the history of catch and catch rate in the fishery is presented below (Figure 1), although catch records are only available from 1982 and greater uncertainty is related with estimates from earlier years.

This document provides a simple approach for assessment of the state of the fishery relative to commonly-used fishery management reference points, and is based solely on average catch rate in the commercial fishery. The intent is to establish a simple approach to assessment, and then to extend it to include additional performance indicators (e.g. weight and length of abalone, density and biomass of legal-sized abalone etc) and greater spatial discrimination (e.g. regional and finer-scale assessments). A broader assessment of the fishery is already provided by the TAC Setting process each year, but there is a need to develop a more formal and agreed approach to assessment.

The approach to assessment is based on initially using catch rate (i.e. annual catch divided by effort) in the commercial fishery as a proxy for the exploitable biomass of abalone. While catch rate may not be an ideal proxy for biomass, catch rate currently dominate assessment of other abalone fisheries, and the intent is to extend this framework to other indicators. Table 1 shows a proposed relationship between average commercial catch rate, which is used as a proxy for exploitable biomass, likely management actions and classification by SAFS. Related performance indicators derived from current monitoring with GPS and Measuring loggers are also provided, and their values relative to catch rate have been estimated based on actual changes in the fishery in recent years as catch rates have increased from about 20 to 50 $kg.h^{-1}$ since 2009.

Figure 1. Annual (calendar year) catch (grey bars) and catch rate (blue line), from 1955 to end June 2015, in the NSW Abalone fishery. Major management changes include size limit changes displayed on the graph, with 120-123 mm south of Wonboyn, the fishery was restricted in 1980, and quota was introduced in 1989, back-dated to 1988. Catch rate is estimated from daily catch records since 1983 as total annual catch divided by effort, from reported values of annual catch and effort since 1974, and from reported value of catch and diver-months fished (and its relationship to hours fished in 1974) prior to 1974.

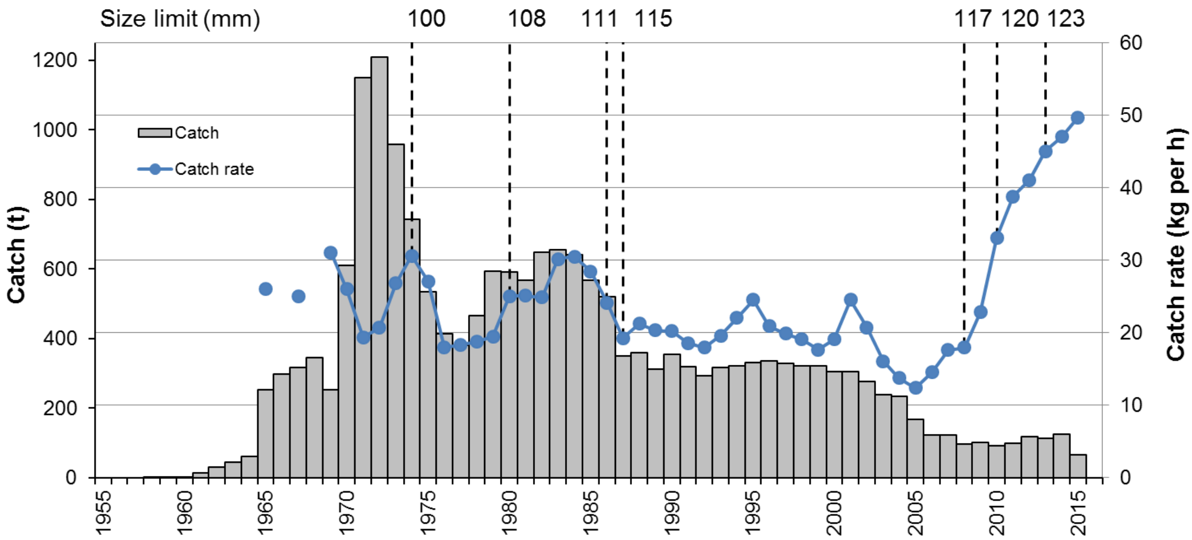


Table 1. Relationship between catch rate, which is used as a proxy for exploitable biomass, fishery reference points, classification by SAFS, and related likely management responses. Note a lower and higher catch rate option is provided. Related indicators based on current monitoring with GPS and measuring loggers are also provided, and refer to current legal-sized abalone.

Performance Indicator		**Related Indicators**				**Reference point**	**Likely response**	**SAFS**
Catch rate (kg/h)		**Density**	**Biomass**	**Length**	**Weight**			
Low	**High**	kg/Ha	t	mm	g			
<20	**<30**	<250	<500	<123	<300	<20%B0	Take urgent action to rebuild	Over-fished (or Over-depleted)
20-35	**30-40**	>250	>500	>123	>300	<Bmsy	Rebuild in specific time frame/plan	Transitional
>35	**>40**	>300	>750	>124	>310	>Bmsy	Aim for Bmey with HS	Sustainable
50	**55**	>450	>1000	>125	>320	Bmey	Investigate further productivity with HS	Sustainable

- Catch rates below 20 or 30 kg/h will indicate an exploitable biomass below 20% of B0, requiring urgent management action to rebuild stocks, and classification as Overfished (i.e. a significant risk of imminent recruitment collapse). Catch rates were below 20 kg/h in the late 1970s (i.e. with a 100 mm size limit) and 1990s, and most recently from 2003-08, including 14 of the 20 years from 1990.
- Catch rates from 20-35 or 30-40 kg/h will indicate an exploitable biomass below that at MSY, requiring implementation of a rebuilding plan prescribing a specific time frame to rebuild, and classification as Transitional. Catch rates were in this range in the early 1980s (i.e. mostly with a size limit below 115 mm), and during peaks in the early 1990s and 2000s, and there were no years above this range until 2011-14.
- Catch rates above 35 or 40 kg/h will indicate an exploitable biomass above that at MSY, but management will continue to target a higher biomass associated with that at MEY and investigate rebuilding in specific spatial areas. Catch rates have been above this level from 2011-14, and while this level is well below current catch rates (i.e. ~70%), it attempts to acknowledge the potential variation in productivity and catch rates related to possible environmental cycles.
- Catch rates above 50 or 55 kg/h will indicate an exploitable biomass above that at MEY, but because of the uncertainty about full productivity of the fishery, and spatial variation in biomass, management may continue to investigate further rebuilding. Recent catch rates were 47 kg/h in 2014, and 50 kg/h in H1 2015.

Following the large changes in the fishery, there is a need to formalise guidance about the strategic direction of management. Likely future management responses can be related to the simple assessment of the stock, although more detailed and broader assessments will also be used in determining future management. At catch rates <20 or 30 kg/h, leading to an assessment of overfished (i.e. or over-depleted if not caused by fishing), it is likely that significant reductions in TAC and other management responses will be used to urgently rebuild stocks. At catch rates <35 or 40 kg/h, leading to an assessment of transitional stocks, a rebuilding plan will be developed and implemented that will likely involve reductions in TAC. At catch rates >35 or 40 kg/h, leading to an assessment of sustainable, there is likely to be a combination of TAC decreases to investigate rebuilding and increases to investigate increased productivity. At catch rates >50 or 55 kg/h, TAC increases are more likely, but further rebuilding and increases in productivity will also be investigated.

During the first half of 2015, catch rates were 50 kg/h the apparent state of the stock varied significantly among different areas. Little catch was taken north of Bermagui, while some areas further south produced catches similar to those taken from 1987-97 (e.g. Y2), at almost double the catch rate. It is not clear what influence broad-scale changes in the environment have had on recovery of stocks (e.g. recruitment and growth), as recent broad-scale environmental change (e.g. recovery from droughts of early 2000s) has been coincident with large TAC reductions. Despite that, it is likely that the strong recovery of the fishery from 2005 would have required strong recruitment and growth in the stock. If large scale environmental change does influence recruitment and growth in the future (e.g. following the return of strong droughts), a buffer of abalone stock above the size limit will help protect against possible excessive fluctuation in the fishery (see also related FMS strategy).

The framework and interpretation described above is a very simple approach to formalising an assessment of stocks for the fishery, and providing guidance about likely management response. In reality, there is a great deal of complexity in assessment of stocks, which is not reflected in the simple approach described above, or available from interpretation of catch rate alone. Despite that, the relationship between catch rate and reference point biomass in the table above is consistent with an interpretation that assumes a linear and proportional relationship, over long time periods, to the common fishery management reference points.

A Harvest Strategy is currently being developed in the fishery, which will ultimately extend the range of fishery performance indicators and their interpretation in assessing stocks. The TAC setting process will also continue to take a more broad and detailed approach to considering an assessment of stocks and appropriate TAC.

NSW Abalone Fishery Logbook catch figures

Abalone Council of NSW

11 January, 2024

Area summary by financial year since 1999
Note catch data up to end December 2023

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Area 14, Eden
Area 15, Saltwater
Area 16, Bittangabee
Area 17, Green Cape
Area 18, City Rock

SMU 4

Area 19, Wonboyn
Area 20, Saltlake
Area 21, Howe

Figure description

Graph 1. Total Fishing Period catch (blue bars and text), target (light blue) and catch rate (red, geometric mean). The change in average catch from the last 3 years, as a proportion of the first 3 years, is shown above the graph

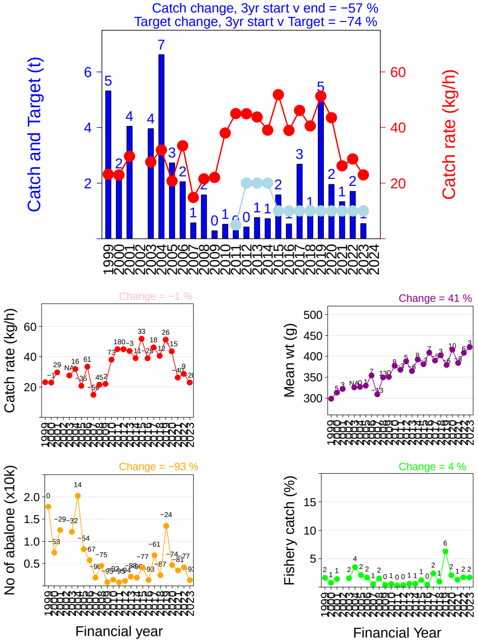
Graph 2. Catch rate (red, geometric mean) and percent change per year (text on graph) and change since 1999 (text above graph).

Graph 3. Mean weight of abalone (magenta) with percent change per year (text on graph) and change since 1999 (text above graph).

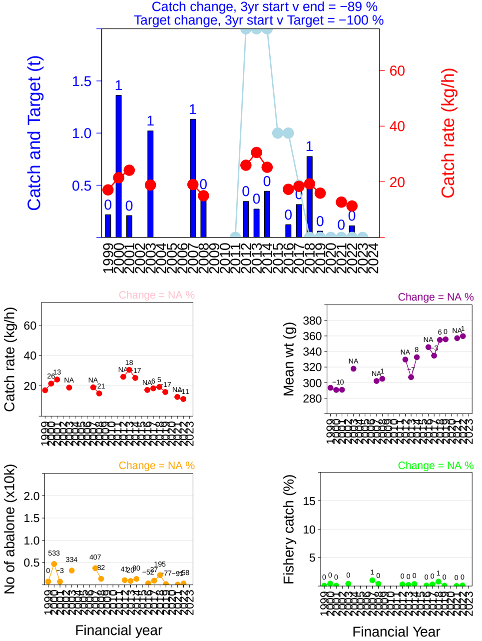
Graph 4. Number of abalone in catch (orange) with percent change since 1999 (text on and above graph).

Graph 5. Total catch as a percent of total fishery catch (green) with percent change since 1999 (text on and above graph).

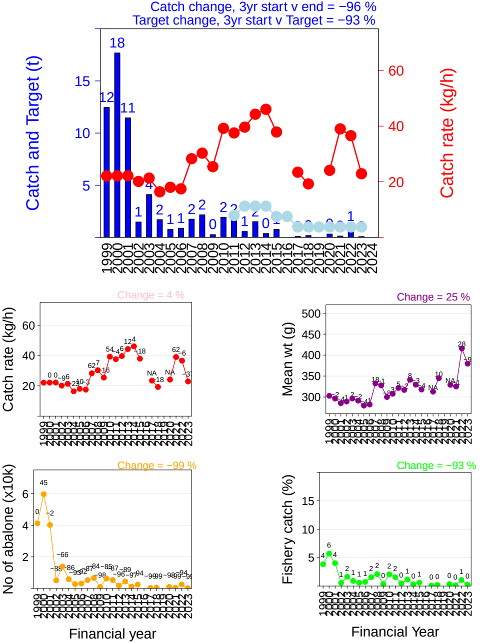
Area 1, Tweed, A-F



Area 2, Swansea, G-J



Area 3, Kiama, K-M



Outline

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Area 3, Kiama
Area 4, Ulladulla
Area 5, South Brush
Area 6, Batemans

SMU 2

Area 7, Tuross
Area 8, Narooma
Area 9, Bermagui
Area 10, Bunga
Area 11, Moon Bay
Area 12, Turingal
Area 13, Long Beach

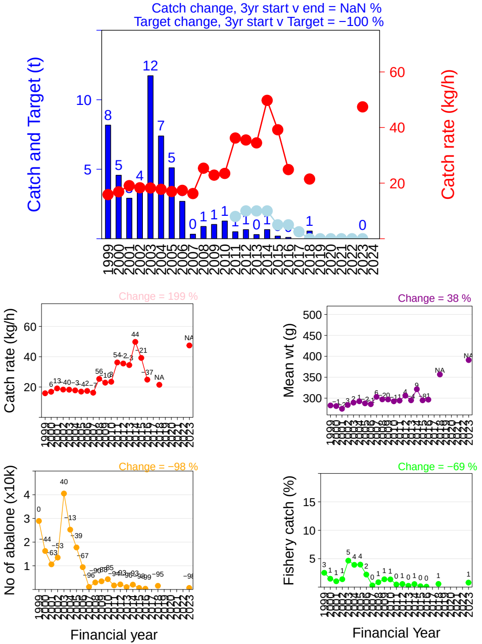
SMU 3

Area 14, Eden
Area 15, Saltwater
Area 16, Bittangabee
Area 17, Green Cape
Area 18, City Rock

SMU 4

Area 19, Wonboyn
Area 20, Saltlake
Area 21, Howe

Area 4, Ulladulla, N



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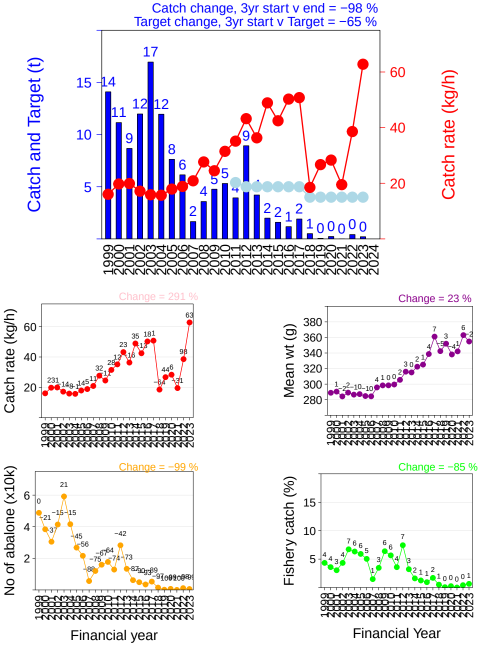

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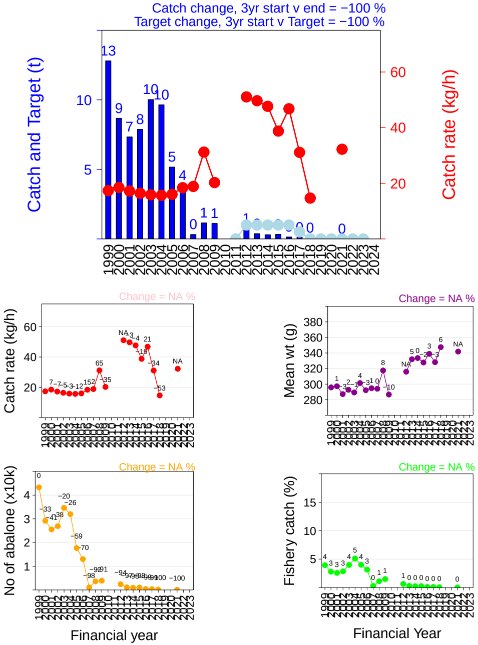
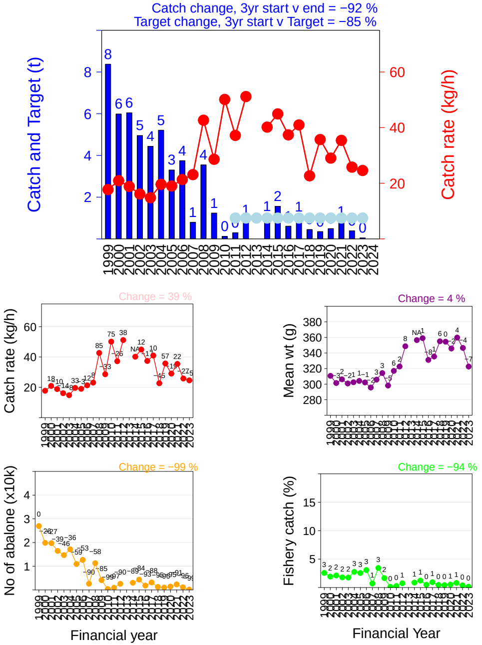


Area 7, Tuross, S



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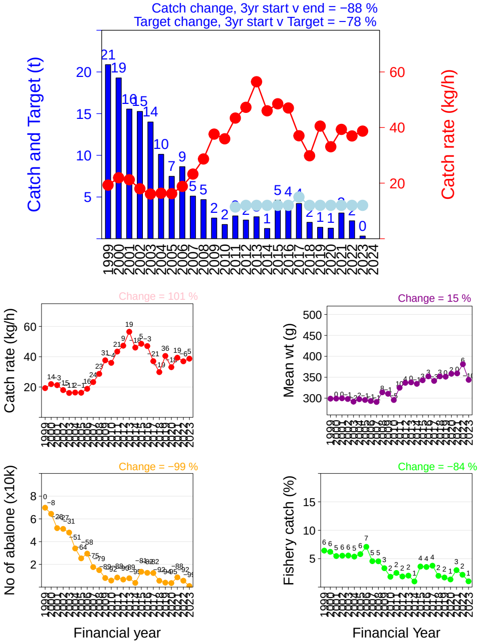
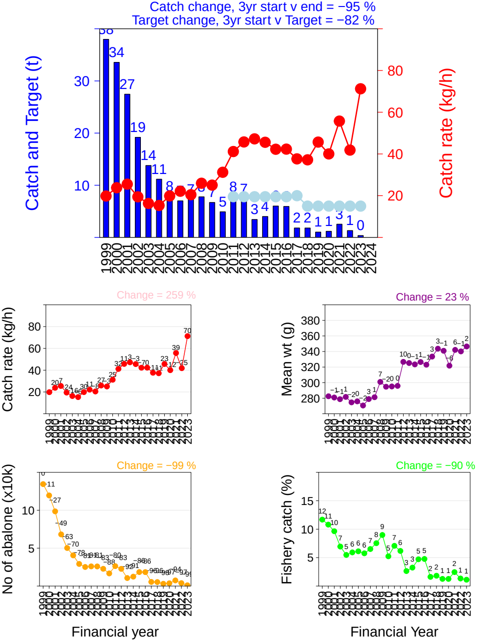


Area 9, Bermagui, U1-3



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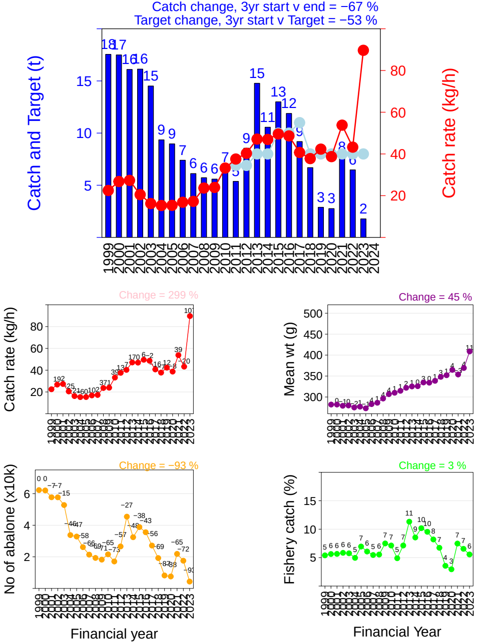

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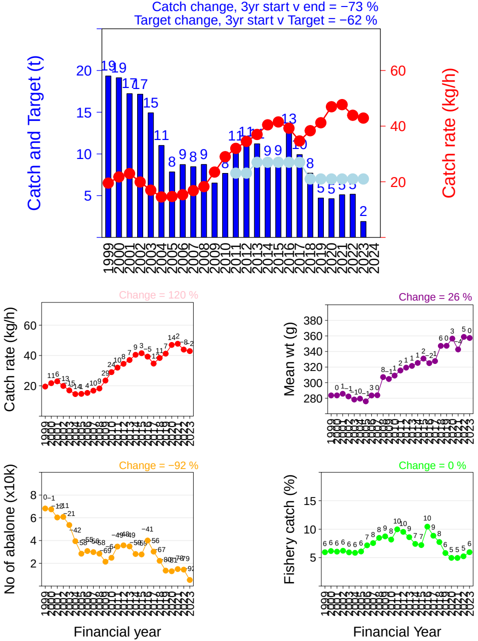

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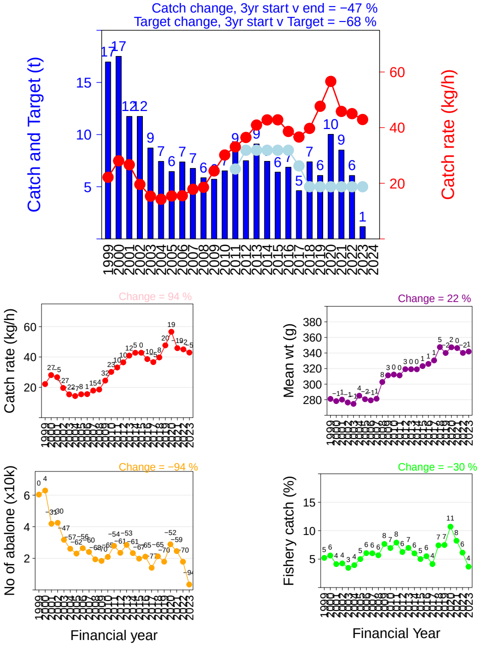
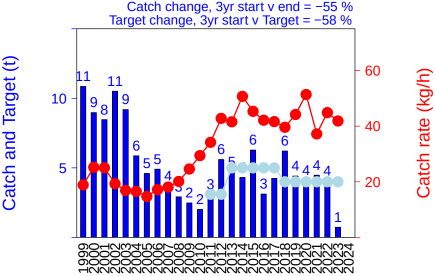
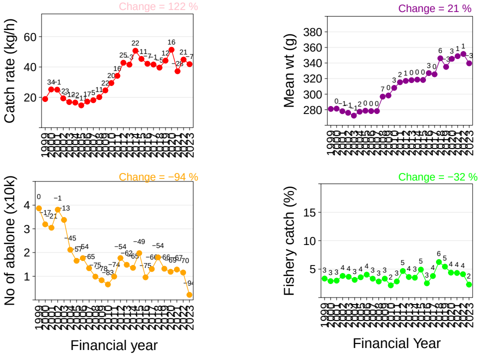
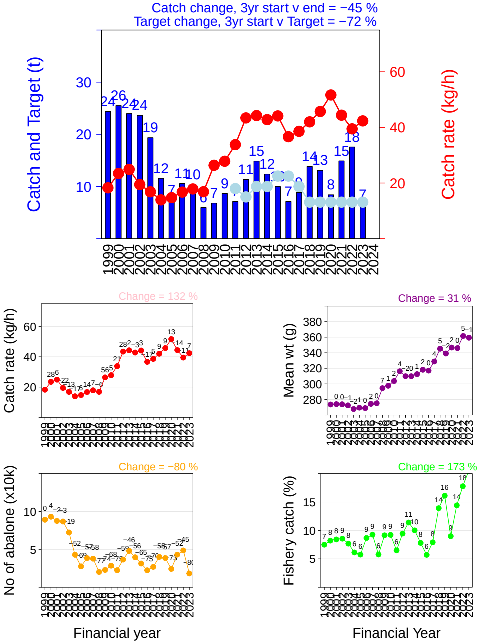


Area 13, Long Beach, X2





Area 14, Eden, Y11-21



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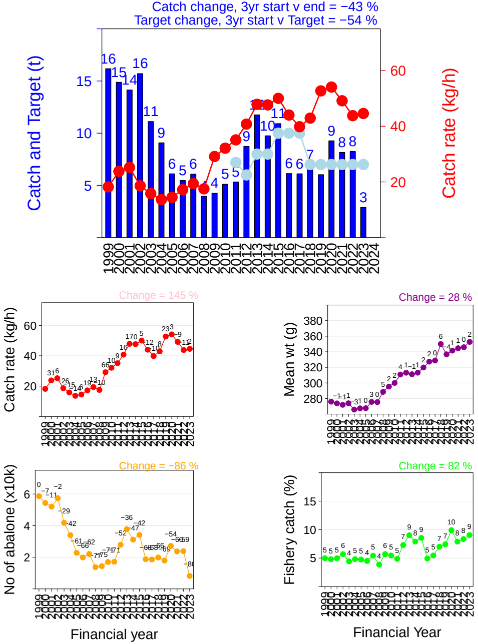

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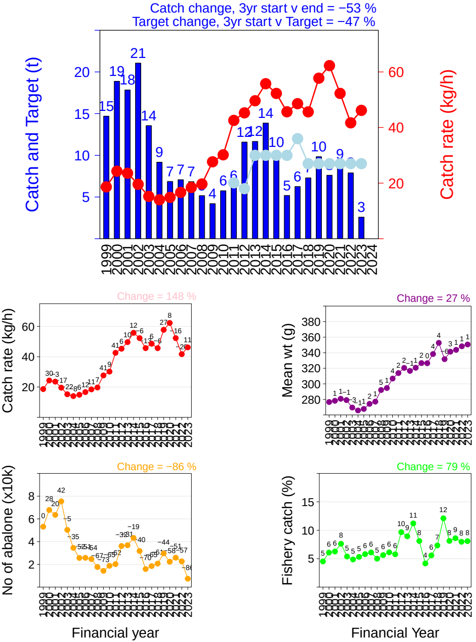

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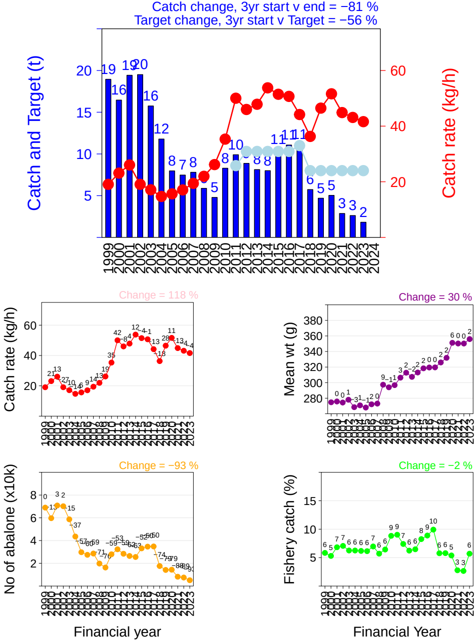
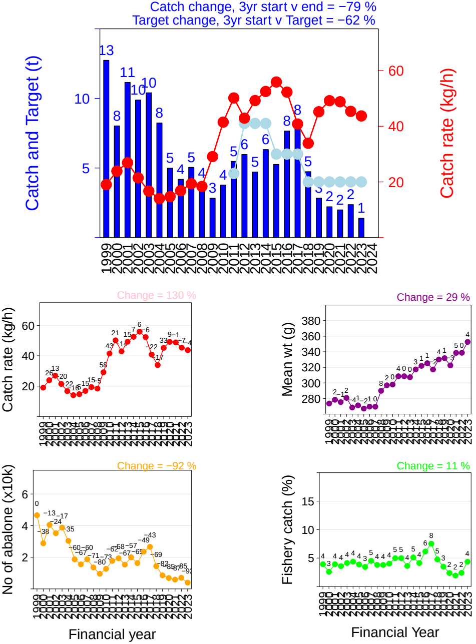
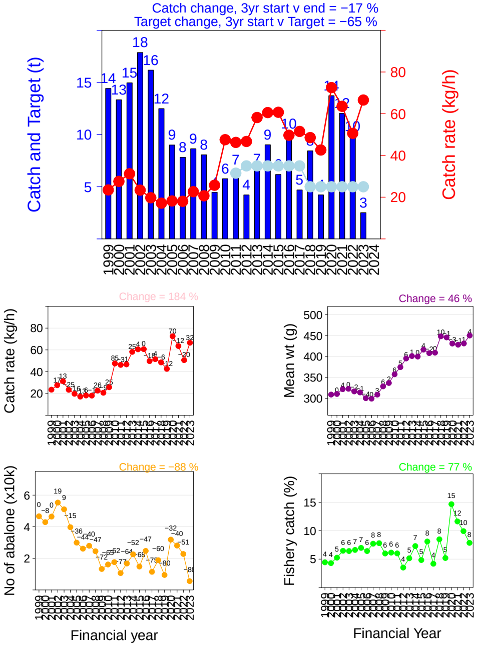


Area 18, City Rock, Y32



Area 19, Wonboyn, Z1-3



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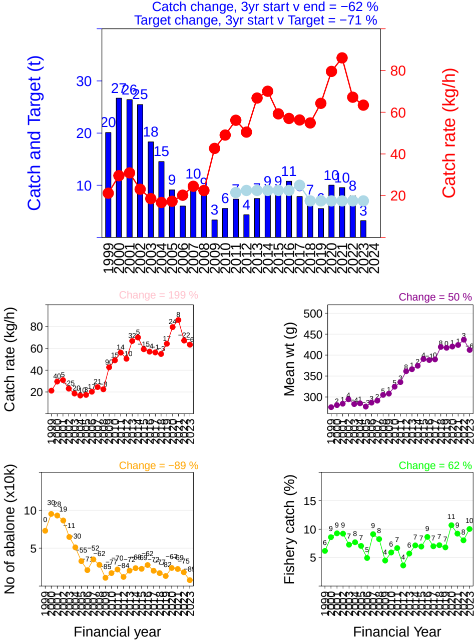
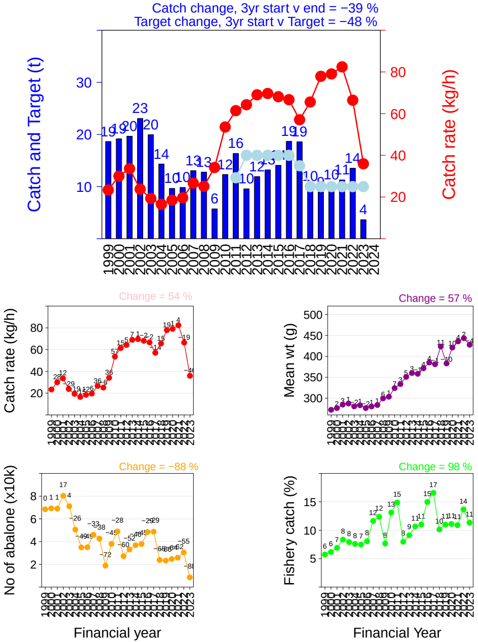


Area 21, Howe, Z5



NSW Abalone Fishery Logbook catch figures

Abalone Council of NSW

11 January, 2024

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Graph 1. Total catch (blue bars with 6 month centered moving average blue line, 24 month trailing average dark cyan line, and current year target cyan line) and catch rate per bin (box plot with median red circle, quartiles, 1.5IQR and outliers) with loess fit (red line). Standardised catch rates per bin are shown by loess fit to expected values for individual bins for the average diver (green line) and monthly effects (green squares). Values above graph show change of recent 3 or 6 mths to the same period 12 months earlier, with blue indicating total catch/total effort, red for loess fit to raw bin data, and green for loess fit to standardised expected bin values.

Graph 2. Total catch (blue bars with 6 month moving centered average blue line, and 24 month trailing average dark cyan line, and current year target cyan line) and mean weight of abalone per bin (box plot with median pink circle, quartiles, 1.5IQR and outliers) with loess fit (pink line). Standardised weights are shown by loess fit to expected values for individual bins for the average diver in a 60 abalone bin (green line) and monthly effects (green squares). Values above graph show change of recent 3 or 6 mths to the same period 12 months earlier, with blue indicating total catch/total number of abalone, red for loess fit to raw bin data, and green for loess fit to standardised expected bin values.

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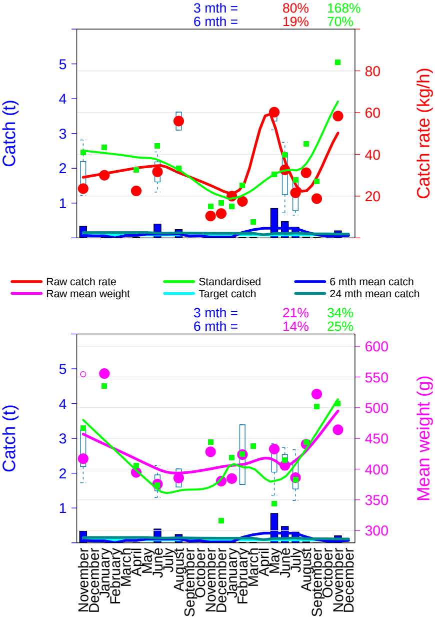

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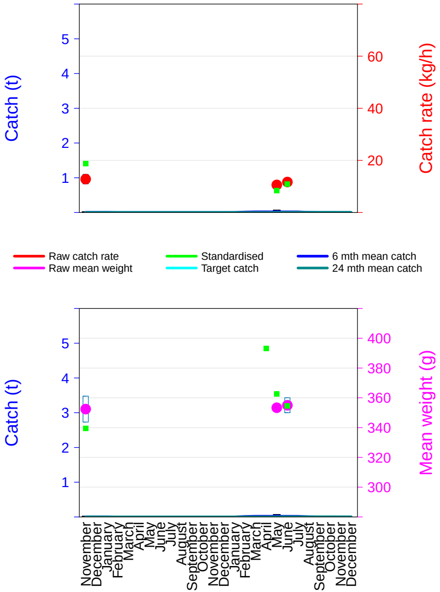
Area 2, Swansea, G-J



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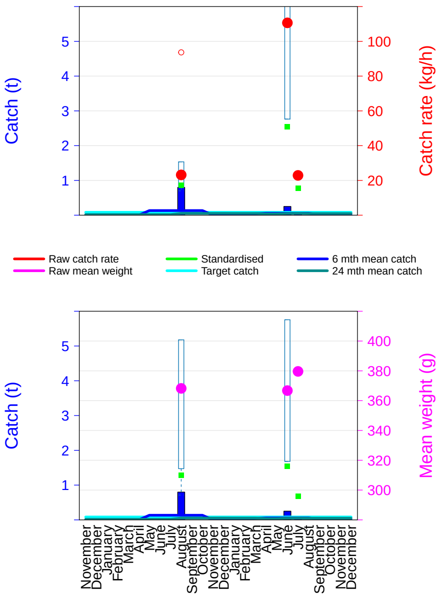
Area 3, Kiama, K-M



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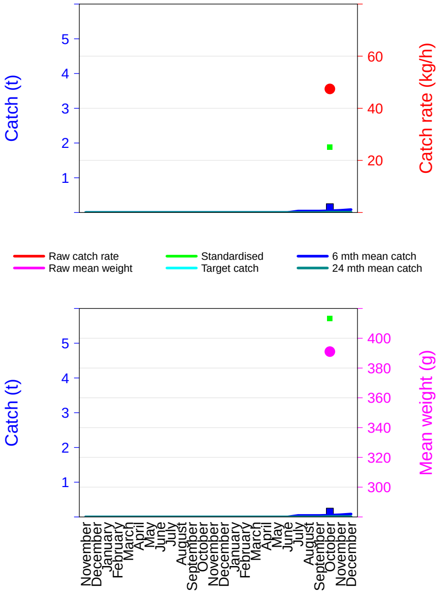

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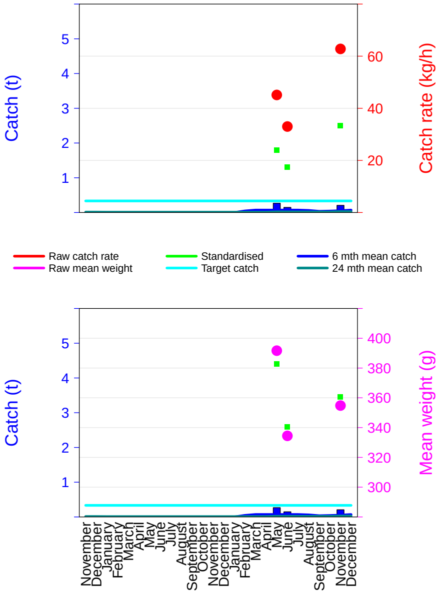
Area 5, South Brush, P



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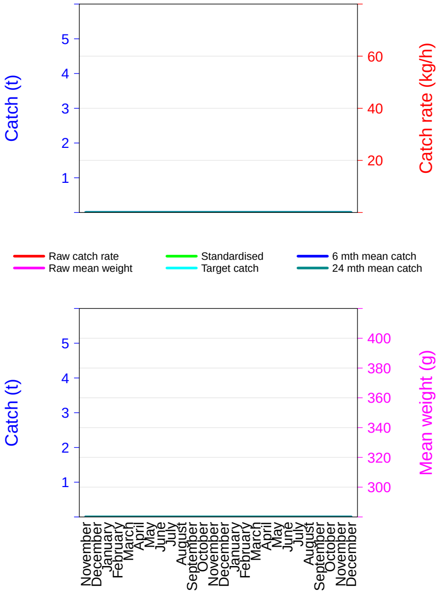
Area 6, Batemans, Q-R



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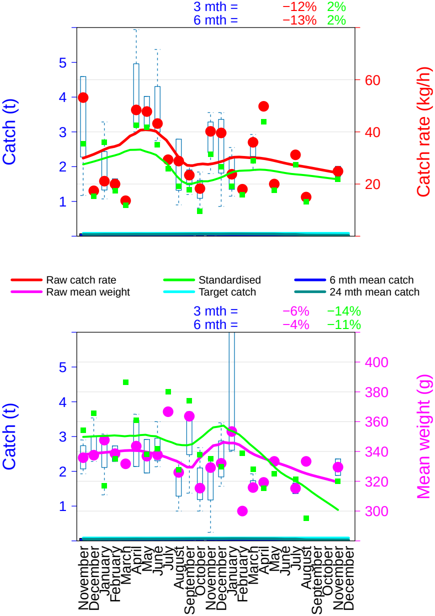
Area 7, Tuross, S



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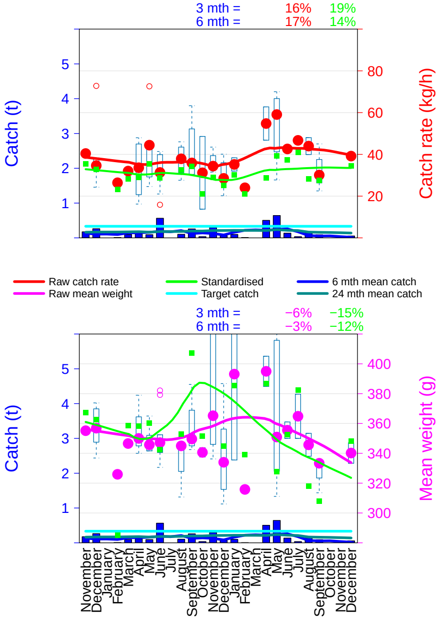
Area 8, Narooma, T



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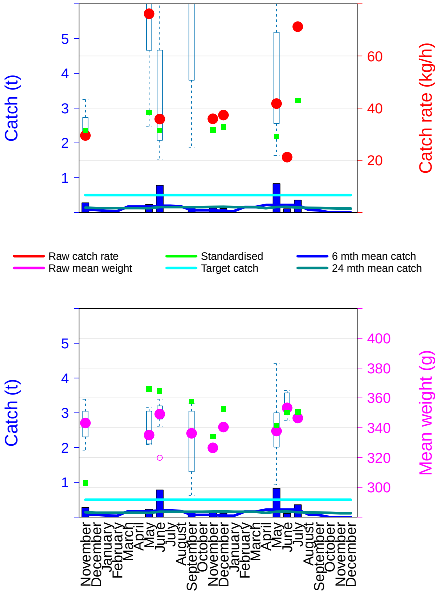
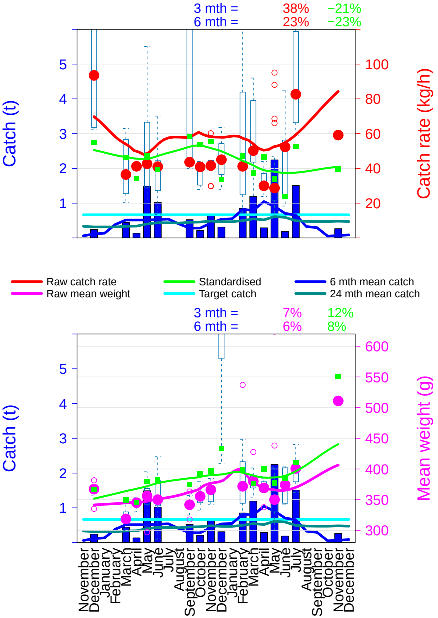
Area 9, Bermagui, U1-3



Area 10, Bunga, U4-V2



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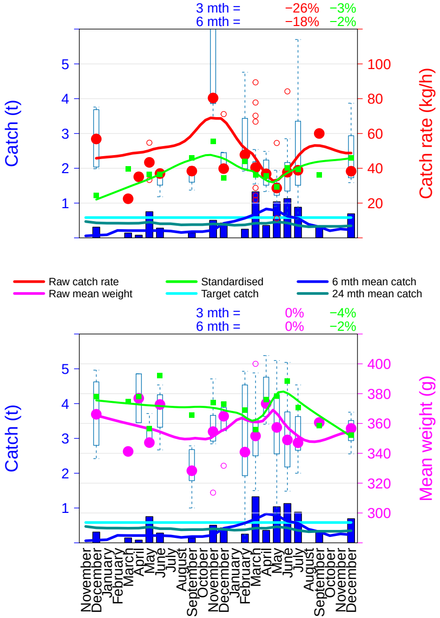
Area 11, Moon Bay, V3-W1



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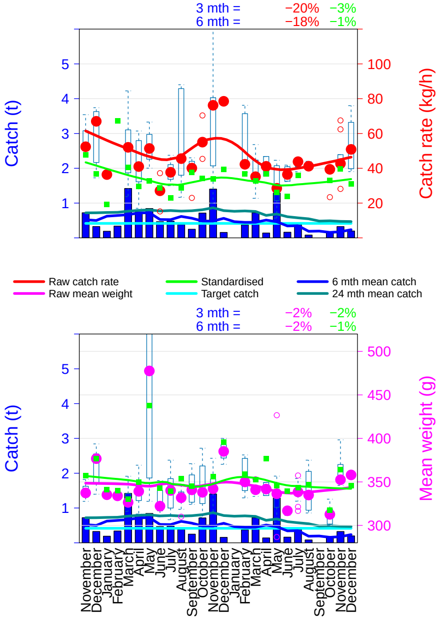
Area 12, Turingal, W2-X1



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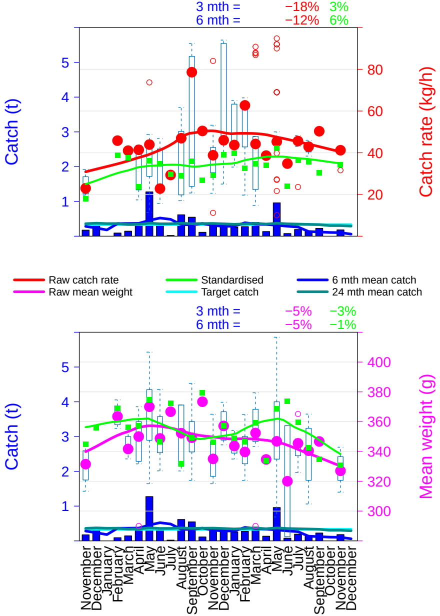
Area 13, Long Beach, X2



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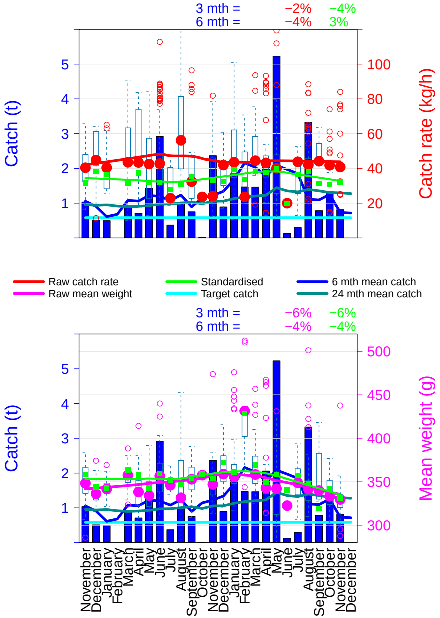
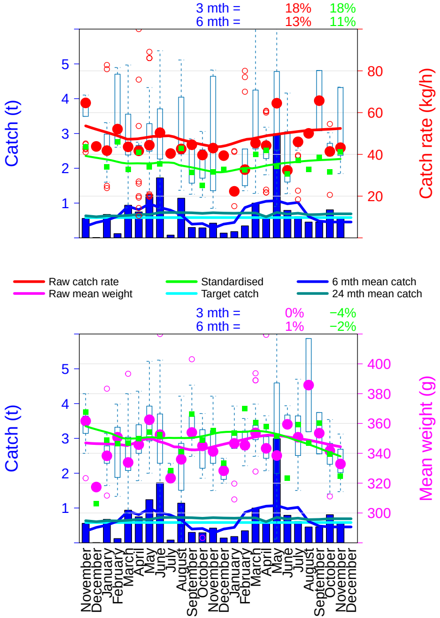
Area 14, Eden, Y11-21



Area 15, Saltwater, Y22-23



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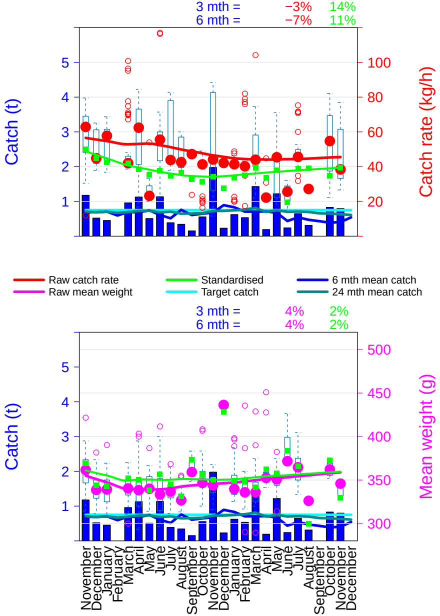
Area 16, Bittangabee, Y24



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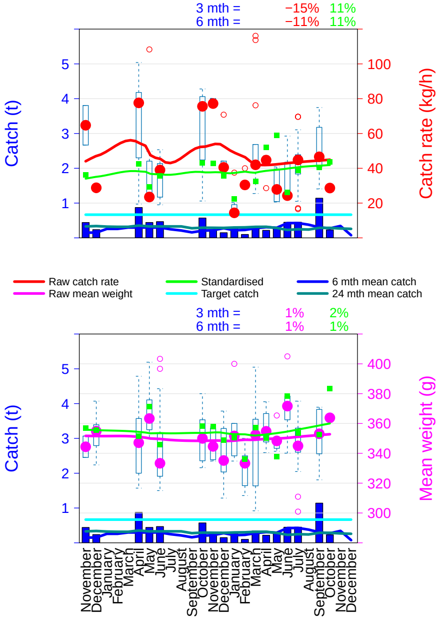
Area 17, Green Cape, Y31



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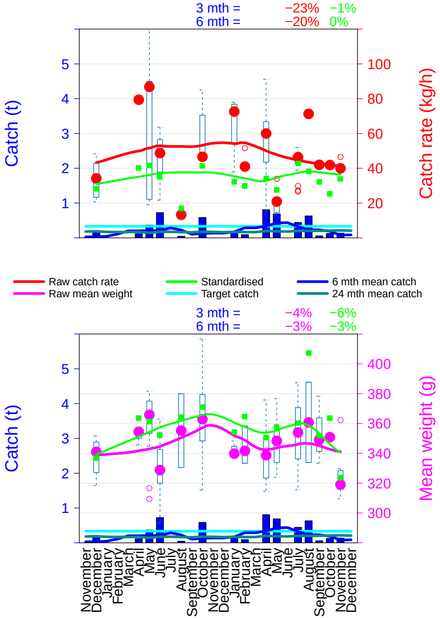
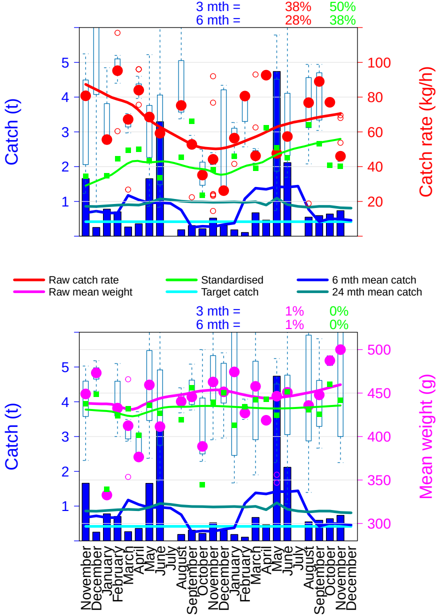
Area 18, City Rock, Y32



Area 19, Wonboyn, Z1-3



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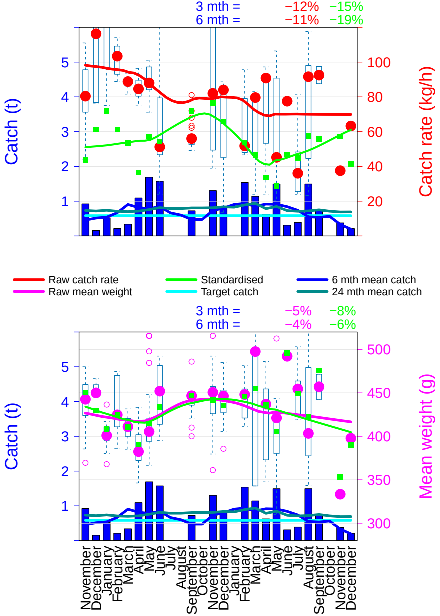
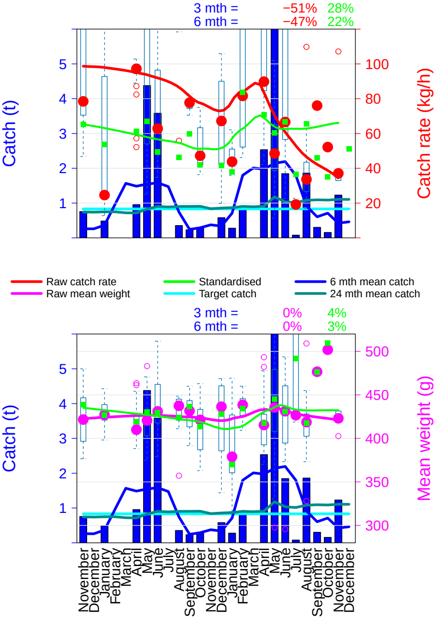
Area 20, Saltlake, Z4



Area 21, Howe, Z5



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