NSW Total Allowable Catch Setting and Review Committee

Report and Determination 2018

ABALONE FISHERY

22 November 2017

EXECUTIVE SUMMARY

Preamble

The NSW Total Allowable Catch Setting and Review Committee (the Committee) has responsibility under the NSW Fisheries Act (1994) for determining the annual Total Allowable Commercial Catch (TACC) of abalone by NSW commercial fishers. This determination is for the period 1 January 2018 to 31 December 2018. The determination is based on best available information about the status of the abalone stocks, reports from managers of the fishery and compliance enforcement officers, comment from fishers, and discussions at a public forum with the Committee on October 4th 2017.

Determination

The Committee has determined that the total allowable catch of abalone by NSW commercial fishers during the 2018 fishing period should not exceed 100 tonnes (t), a material reduction from the allowable catch in the 2015–2017 fishing periods. The determination is set given likely catches of abalone by non-commercial fishers of up to 10 t and illegal and unreported commercial catches of up to 50 t.

Recommendations

The Committee provides the following recommendations to the NSW Department of Primary Industries (the Department) and the abalone industry (Industry) towards improving performance of the fishery.

Recommendation 1: The Department and industry develop a harvest strategy for the fishery with specific biological and economic objectives linked to target reference points.

Recommendation 2: The Legal Minimum Length (LML) for abalone harvest in Areas 1–18 be increased to 120 mm, with Area-specific adjustments where recent biological information clearly demonstrates a lower LML is appropriate because of slower abalone growth.

Recommendation 3: The TACC be distributed amongst Spatial Management Units as recommended in Table 6.1, with regulatory or co-management measures to ensure that catch distribution.

Recommendation 4: The Department and Industry resolve robust and definite mechanisms for spatial-explicit management of the fishery, including an agreed set of spatial management units, spatially determined catch quotas and LMLs, efficient quota management methods, and rigorous spatially-explicit monitoring and assessment.

Recommendation 5: The Department develop a robust, spatially explicit bio-economic assessment model to support TACC determinations, LML settings, and strategic management of the fishery.

Recommendation 6: The Department and Industry develop a strategy for regular economic survey and analysis of the fishery to inform economic optimisation of the fishery.

Recommendation 7: The Department obtains more robust estimates of recreational catch and makes no change to recreational bag limits until rigorous recreational catch monitoring is implemented and sound stock status is secured.

Stock Status

There was substantial improvement in the state of the stock from about 2006 through to about 2014. The reductions in TAC and increased Legal Minimum Length (LML) since the mid-2000s succeeded in rebuilding stock abundance and size composition. This was demonstrated by substantial increases in catch rate, abalone density, abalone biomass, and mean weight of abalone for all SMUs over that period, and shows an about doubling of exploitable biomass between 2009 and about 2014.

This rebuilding has not persisted, however. All indicators in all the significantly fished Spatial Management Units have shown substantial decline during the last 3 years. This decline has been particularly strong in the last year. The catch rate and biomass indicators show that by 2017 the abalone stock abundance had decreased, beginning about 2014, to about the level last seen in 2012–13. The stock that was rebuilt since 2012–13 has now been removed, and most of it was removed in the 2016–17 year of fishing. This reduction has left about half of the biomass rebuilt since 2009–10. The stock decrease after 2014 mostly occurred at higher TACCs but similar harvest fractions to those that resulted in stock rebuilding during the period 2010–2014. The exception is 2017 when the harvest fraction in the SMU 4 increased substantially and there was also some increase in SMU 3.

Several possible causes of the recent deterioration in abalone stock status have been considered. They are not mutually exclusive. They are: increased illegal catch; impacts of extreme weather events; previous stock rebuilding being less substantial than was reflected in the indicators; natural fluctuation in productivity; inadequately managed spatial distribution of catch; and low Legal Minimum Length.

It is concluded that several of these possible causes may have contributed in part to the recent stock decline. The main causes, however, were likely to be a reduction in population productivity beginning about 2014, combined with only modest biomass increases during the rebuilding period 2010–2014 (despite large increases in indicators in that period), without compensating reductions in the recent TACCs. These circumstances have resulted in rapid deterioration of abalone stock status, particularly in the last 1–2 years, after a 2–3y period during which stock status indicators plateaued. These plateauing indicators were interpreted at the time as suggesting that most of the recent population productivity was being harvested, resulting in relatively stable stock abundance with limited scope for further rebuilding. That interpretation now appears to have been overly optimistic. Catches started to exceed net population productivity during 2014–16 and ultimately caused stock reduction. A reduction in area fished in the past two years as the stock declined is consistent with sequential spatial depletion, though other interpretations are possible.

Periods of low productivity have been observed previously in this fishery and they persisted for about 3–5 years. It is not known how long the current period of low productivity might persist. This situation means there is risk of further significant deterioration of the stock at current catch levels. The priority is to prevent further deterioration in stock condition and to protect the mature stock, then to recommence stock rebuilding. Reducing harvest rates from recent levels is a key step in that process.

Economic Considerations

The gross value of production (GVP) of the abalone fishery appears to have stabilised, with relatively little change in real gross value of production since 2011–12. The fishery GVP in 2017 is expected to be around $4m, slightly higher than previous years due to an increase in beach prices. Prices as of August 2017 were roughly 4% higher in 2017 than 2016 in real terms. Industry reports that beach prices have increased a further 10% this year, and expect these higher prices to be maintained into 2018.

Productivity, in terms of CPUE, in all areas has decreased in 2017 relative to 2016. The lower catch rates will result in an increase in the total number of days required to achieve the full quota. The increased fishing time required to take the catch will have a negative impact on the economic performance of the industry in 2017 relative to 2016.

Share trading declined substantially between 2015–16 and 2016–17, likely reflecting decreased short term profitability. Share trading prices (based on Industry information), however, increased slightly, suggesting continued optimism for the medium to longer term economic outlook for the fishery. The limited share trading appears to be linked mainly to individuals increasing shareholding to enable them to become endorsed to actively participate in the fishery (i.e. hold more than 70 shares) rather than existing endorsed fishers expanding their share in the fishery.

Quota transfers also were fewer than in previous years. Quota transfer price, an indicator of short term economic performance, is unavailable. Anecdote from Industry, however, suggests that quota transfer prices have increased in 2017, despite other indicators of a short term decline in economic performance.

Beach prices for abalone have increased in recent months, but market pressure from the increasing supply of cultured abalone nationally and internationally is likely to affect adversely prices for wild product in the medium to longer term. The current size of NSW product is largely within the size range produced through aquaculture. Chinese aquaculture production was reduced substantially in late 2016 due to a severe typhoon, resulting in a shortage of abalone on the Chinese market. This, and the reduction in import tariffs on abalone sold into the Chinese market has had a positive impact on prices in other states, and this is potentially also underlying (directly or indirectly) the improved prices received in NSW. Industry also suggests that increased competition among buyers and a stronger domestic market also contributed to recent beach price increases.

The Committee had little economic information to inform TACC setting other than that provided by Industry on a largely anecdotal basis. Reliable information is required on quota and share trading prices, abalone prices, and changes in fishing costs. The only economic performance study of the industry (i.e. costs and earnings) related to the 2011–12 financial year, and likely bares little relevance to the current economic performance. Industry has expressed a willingness to undertake a new economic survey to help support management decision making. This is especially important given the downward change in

the TACC. The Committee recommends that the Industry undertake an economic survey of the current season (2017) and again in 2018 to identify the impacts of the change on industry profitability. The Committee again recommends that Industry and the Department resolve an ongoing strategy for economic monitoring of the operating costs and product prices for the fishery, including share and quota trading. Absence of such information continues to constrain setting economically optimised TACCs.

The Committee again notes that current economic indicators and triggers for the fishery lack specificity or clear management responses. Economic data for the fishery relating to long-term profitability are required to inform operational objectives, performance indicators, and target reference levels in a harvest strategy for the fishery.

The current higher prices, if sustained, will offset to some extent effects of a lower quota on revenues, although the likely quota reduction is greater than the reported price increases on a proportional basis. Revenues in 2018 are expected to decrease accordingly, unless further increases in beach prices occur. Costs are also likely to decrease with the lower quota. The net effect of these changes on fishery profitability is uncertain, but available information suggests that change in profits is likely to be proportionally less than the change in TACC.

Management Considerations

The NSW abalone fishery has been in the early stages of rebuilding since 2009, following historical lows in the fishery and a TACC reduction to 75t in 2009. The Committee last year characterised the fishery as having "been on an improving trajectory, albeit with considerable uncertainty about the status of the stocks, their prognosis, and the ecologically and economically appropriate TACC". Specifically, key biological indicators have plateaued since 2013. The available indicators are crude indicators and difficult to interpret without better data and analysis than currently available, but the Committee nevertheless identified their plateauing as concerning. That view has been strengthened by declines in some indicators in the last year.

The Committee to date has taken a precautionary approach to TACC-setting and simultaneously made strong recommendations to improve the management of the fishery and reduce the uncertainty in understanding the performance of the fishery. Few of these recommendations have been given any serious attention and almost none have been implemented.

This approach has maintained the TACC at 125-130 tonnes since 2013. There now is increasing evidence, however, that the biological performance of the fishery may be worsening. Limitations in the available data and analyses still do not enable conclusions about exactly what is going on with the stock to be drawn with certainty, but there are enough worrying signs to indicate that the appropriately precautionary approach now is to reduce the TACC. Other aspects of the management of the fishery also reinforce the need for a conservative TACC. The lack of any management arrangements to spatially spread catch and the demonstrated inability of industry to do this voluntarily, for example, mean that there is no mechanism to mitigate serial depletion of stocks. Similarly, the recommended increases in size limit that have been outlined by the Committee for several years have not been fully implemented, and so TACC-setting remains the primary tool for managing harvest. This is the context for the reduction in TACC for 2018.

The Committee's experience in setting this TACC again has reinforced the need for a harvest strategy that outlines the objectives the fishery is working toward, how performance will be measured, how data will be collected and analysed to inform decision-making, and how decisions will be made. More consistency and transparency is required of the data monitoring and stock assessment program to build on recent improvements. The level of investment in these programs needs to be revisited as the fishery has reached the point where under-investment is compromising efficient TACC decisions.

Advice available to the Committee about non-commercial catch (Aboriginal, recreational, and illegal) suggests the range of estimates assumed in recent years remain appropriate, notwithstanding general concerns that illegal harvest may be increasing within that range. Estimates of illegal harvest remain difficult to ground-truth reliably. These activities require continued attention, however, to further reduce the associated uncertainties with the fishery. Compliance information presented to the Committee provides confidence that the quota system has integrity, and the information from it is reliable, but also indicates that there are major risks that need to be managed continually in the interests of ongoing improvement.

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1. INTRODUCTION

The Total Allowable Catch Setting and Review Committee (the Committee) is established by Division 4 (S26-34) of the *Fisheries Management Act 1994*. The committee in 2017 was:

- Dr Bruce Mapstone – Chair
- Ms Kelly Crosthwaite – fisheries management
- Dr Sean Pascoe – natural resources economics
- Dr Keith Sainsbury – fisheries science

The Committee is required to determine the Total Allowable Commercial Catch (TACC) for the commercial sector of the abalone fishery and, in doing so, give effect to the objectives of the *Fisheries Management Act 1994,* as amended where relevant by *Fisheries Management Amendment Acts (1997, 2004, 2006, 2010, 2015)*. The Committee is not subject to control or direction of the Minister but in reaching its decision is required to have regard to:

- All relevant scientific, industry, community, social and economic factors;
- The need to ensure that the abalone resources are exploited in a manner that will conserve stocks in the long term;
- The impact of fishing on other species and the environment; and
- The precautionary principle as set out in Section 30(2)(c) of the Act.

The Committee also may be consulted out of session on a range of management issues.

The Committee produces a stand-alone report each year in support of the TACC determination. The report also sometimes includes recommendations for management of the fishery related to setting TACCs, based on the experience and background of the Committee members and reports received by the Committee. Constructive dialogue between the Committee and the Department and Industry on a range of issues related to the fishery, including recommendations from the Committee, is an important and valuable part of the Committee's deliberations in reaching a TACC determination. It is important to note, however, that the Committee makes a determination on the TACC and, potentially, matters it is required to regard that affect directly that TACC. The degree to which the Committee's suggestions or recommendations beyond that scope are accepted is a matter entirely for the Department. The Committee holds the position, however, that the abalone Determination is linked inextricably to selectivity (size limits for harvest) and spatial dynamics considerations and that its recommendations regarding these intrinsic components of the TACC should not be discretionary.

The Committee must consider the full extent of abalone exploitation to meet its statutory obligations. Total removals from the NSW abalone stock are made up of:

- The quota allocated to commercial fishers;
- The total legal catch by recreational and Aboriginal fishers; and
- Catches by commercial, recreational, or Aboriginal fishers not sanctioned by the Regulations controlling the fishery and not recorded in catch statistics (illegal catches).

The legal and illegal components of the non-commercial fishery currently are estimated as a single figure based on historical evidence, compliance information, and judgements from the Department and Industry.

The Act defines, in Section 30(2)(c), how the Committee should apply the precautionary principle, specifically:

> *'… if there are threats of serious irreversible damage to fish stocks, lack of scientific certainty should not be used as a reason for postponing measures to prevent that damage.'*

The Committee interprets 'threat' in this context to mean an 'indication of probable harm to come'. The Committee therefore must respond to evidence before it that indicates probable future harm to the fishery or the stocks and not postpone action to prevent that harm occurring even if there is uncertainty surrounding such evidence. Similarly, the Committee should not take pre-emptive decisions on issues such as increasing the TACC when there is insufficient verifiable information on which to base such decisions. The abalone fishery is an instance were the Committee currently takes a precautionary approach.

2. PROCEDURES

2.1 Public Consultation by Committee

The Committee, through the Department, called for public submission on the appropriate total allowable commercial catch under the requirements of Section 31 Division 4 of the *Fisheries Management Act* 1994. Abalone fishers, relevant industry and community bodies, and the community were invited to make submissions on the total allowable commercial catch. The consultative process is set out in Appendix 1 and main points from submissions summarised in Appendix 2.

The Committee obtained input from participants in the Total Allowable Catch Committee Open Forum meeting in Sydney on October 4th 2017 and received written reports from:

- NSW Department Primary Industries (DPI) Fisheries Research and Abalone Council[1];
- NSW Department Primary Industries Commercial Fisheries Management;
- NSW Department Primary Industries Fisheries Compliance;
- The Abalone Association NSW; and
- Participants in the commercial abalone fishery.

Public submissions and presentations to the Committee were invited in the Open Forum meeting. Confidential submissions were not discussed publicly. The Committee also was able to call for *in-camera* discussions, where appropriate. No in-camera discussions were requested at the 2017 meeting.

2.2 Matters considered

The Committee considered the following matters before reaching its determination:

- Documentation available on the fishery and submissions received for this year;
- Management objectives set out in the management plan;
- The current state of the fishery;
- Advice on the status of management of the fishery provided by the Department;
- Advice on the economic status of the fishery by the Department and Industry representatives;
- Advice on compliance with regulations from the Department and Industry representatives;
- The data and assessment report for abalone stocks provided by the Abalone Council of NSW under contract to the Department;
- The spatial nature of the fishery; and
- Submissions, commentary, and presentations provided at the Open Forum.

The Committee notes that the timeliness of reports from the Department was improved this year, but emphasises again the importance of delivering reports to the Committee no later than 2 weeks prior to meetings to enable appropriate consideration of information by the committee.

2.3 Format of the Report

This report covers the three key areas affecting management of the fishery and setting the TACC:

- Status of the abalone stocks;
- Economic considerations; and
- Management considerations.

The key considerations for each of these areas are presented in the following sections 3, 4, and 5. Greater details, together with relevant historical context, for each topic are presented in Appendix 3 (Stock), Appendix 4 (Economics), and Appendix 5 (Management) for interested readers. General background information about the fishery is provided in Appendix 6.

The Committee has made several recommendations with the Determination to clarify the position of the Committee on a number of issues related to the TACC. The primary recommendations are included in the Executive Summary and all recommendations appear as relevant in sections 3, 4, and 5 and Appendices A3, A4, and A5.

The Determination of the Committee is to be published by the Minister. The Minister is required to review the regulations and any other instruments under the Act In the light of the Determination. The Determination is to be implemented in accordance with the Management Plan.

[1] The research report titled Assessment of abalone stocks in NSW was prepared by the Abalone Council of NSW under contract to the NSW Department of Primary Industries and submitted to the Committee as a Department-endorsed (draft) report.

3. STATE OF THE STOCKS

3.1 Introduction

The state of the NSW abalone stock is determined from two primary sources of information: (1) logbook and related information from commercial fishing (including catch, dive time, catch rate, and mean weight of individuals in the catch) aggregated spatially at various scales; and (2) fine-scale GPS data-logger information on the location of divers during fishing events that can be linked to the logbook records of catch by dive-bins as they are filled and for the total dive.

Several performance indicators are calculated from this information and used to interpret trends in stock status. Key indicators used are:

- Total catch (t);
- Total fishing effort (h);
- Catch rate (Kg/h);
- Size of abalone in the catch catch (Kg and mm);
- Area fished (Ha);
- Catch density (Kg/Ha searched);
- Search speed (Ha/h);
- Percentage of short dives;
- Biomass (t); and
- Harvest fraction (catch/biomass).

The last six of these indicators are calculated from the GPS-logger data. The last four are developmental and experience with their reliability and interpretation is limited; absolute values are considered less reliable than relative trends.

Indicator trends are examined at several spatial scales, including the four Spatial Management Units (SMUs) in the fishery. There is very little fishing in SMU 1 and the information available from it is not considered representative of the stock there. Examination of stock status consequently is focused on the more fished, southern SMUs 2, 3, and 4.

These indicators are all fishery dependent and so are influenced variously by changes in fishing operations, including targeting of different areas and abalone sizes. They also are all 'trailing indicators' that reflect past conditions; there are no 'leading indicators' of likely future conditions (such as of undersized abalone that will soon recruit to the fishery). This inevitably causes a delay in detecting changed stock conditions, and limits anticipation of changing conditions. Further, the indicators are all examined individually and there is no integrating analysis, such as population assessment modelling, to objectively identify common trends and interpretations and to highlight inconsistent trends. These limitations place various constraints on assessment of state of the stock.

3.2 Stock status and trends

There was a substantial improvement in the state of the stock, starting in about 2006 but particularly since about 2009, through to 2014 or 2015. The reductions in TAC and increased Legal Minimum Length (LML) since the mid-2000s, when those management interventions began, succeeded in rebuilding stock abundance and size composition. This was demonstrated by the substantial increases in catch rate, abalone density, abalone biomass and mean weight of abalone for all SMUs over that period, which shows an about doubling of exploitable biomass between 2009 and about 2014.

This rebuilding has not persisted recently, however. All indicators in all the significantly fished SMUs (i.e. SMUs 2, 3 and 4) have shown substantial decline over the last 3 years. This decline has been particularly strong in the last year (2016–17).

Recent changes in the primary indicators are provided in Table 3.1.

The catch rate and biomass indicators show that by 2017 the abalone stock abundance had decreased to about the level last seen in 2012–13. The decrease began in about 2014. The stock that was rebuilt since 2012–13 has now been removed, and most of it was removed in the 2016–17 year of fishing. This reduction has left about half of the biomass rebuilt since 2009–10.

Table 3.1: Changes in primary indicators of stock status (catch rates, size of abalone caught) and index of harvestable biomass (stock density) in each Spatial Management Unit (SMU) over the last 1 year (top) and 3 years (bottom).

	SMU 1	SMU 2	SMU 3	SMU 4
Annual change in last year				
Standardised catch rate	+3.5%	-9.9%	-13.7%	-9.3%
Standardised abalone weight	+1.0%	-3.7%	-4.1%	-2.9%
Index of biomass (i.e. logger-based density)	-	-11.2%	-32.0%	-21.5%
Annual change over last 3 years (i.e. 2014/15, 2015/16, 2016/17)				
Standardised catch rate	-2.6%	-6.7%	-7.7%	-9.3%
Standardised abalone weight	-0.8%	-1.2%	-1.8%	-1.5%
Index of biomass (i.e. logger-based density)	-	-6.7%	-12.3%	-2.7%
Implied cumulative change over 3 years				
Standardised catch rate	-7.8%	-20.1%	-23.1%	-27.9%
Standardised abalone weight	-2.4%	-3.6%	-5.4%	-4.5%
Index of biomass (i.e. logger-based density)	-	-20.1%	-36.9%	-8.1%

The area fished has decreased since about 2012, and there have been particularly strong reductions in the area fished across all SMUs in the last 2 years**.** The area fished in SMUs 2, 3, and 4 combined in the last 3 years is 70% of the area fished in all years since 2009–10, and in SMU 4 the fished area decreased by 10–20% in the last 2 years compared to 3 years ago. The reduction in area fished in the past two years as stock reduction occurred is consistent with sequential spatial depletion. It also is consistent with other interpretations and so is treated as a warning here.

The stock decrease after about 2014 occurred at higher TACCs but similar harvest fractions to those that resulted in stock rebuilding during the period 2010 to about 2014. The information available is consistent with the stock having a higher net productivity in the earlier period, and productivity being lower since about 2014, perhaps even zero or negative in 2016–17, and with productivity in SMU 3 being lower than that in SMUs 2 and 4.

Several possible causes of the recent deterioration in the abalone stock status since about 2014 have been identified, including at the TACC Committee public meeting, and considered in this determination. The possible causes are not mutually exclusive and include: increased illegal catch; effects of extreme weather events; previous stock rebuilding having been less substantial than was reflected in the indicators; natural fluctuation in productivity; inadequately managed spatial distribution of catch; and low Legal Minimum Length.

3.3 Conclusions

It is concluded that increased illegal catch was not the primary contributing factor to the recent stock decline, and that while weather factors may have contributed they also were not the major driver. It is concluded the main causes of the recent decline in abalone stocks were a reduction in population productivity beginning about 2014, combined with an only modest biomass increase during the rebuilding period 2010–2014 (despite large increases in indicators during this rebuilding period), and without compensating reductions in recent TACCs. This combination of factors has resulted in rapid deterioration of abalone stock status, particularly in the last 1–2 years, after a brief (variously 2–3 year) period of plateauing stock status indicators. These plateauing indicators were interpreted at the time by the Committee as suggesting that most of the recent population productivity was being harvested, resulting in relatively stable stock abundances with limited scope for further rebuilding. That interpretation now appears to have been overly optimistic, and catches started to exceed net population productivity during 2014–16, ultimately causing stock reduction. The reduction in area fished in the past two years as this stock decline occurred is consistent with sequential spatial depletion, though other interpretations are possible.

Periods of low productivity have been observed previously in this fishery and they persisted for about 3–5 years. It is not known how long the current period of low productivity might persist. In this situation

there is risk of further significant deterioration of the stock at current catch levels. The priority therefore is to prevent further deterioration in stock condition and to protect the mature stock, then to recommence stock rebuilding.

The recent significant reduction in abalone stock condition is the culmination of several inadequacies in the stock assessment information and management regime that the Committee has identified repeatedly over many years. It is a stark illustration of the consequences of these inadequacies.

The Committee has concluded that the TACC for 2018 should be reduced to 100t. This is a significant reduction that is intended to protect the biomass remaining from the previous years of rebuilding and to prevent further stock deterioration. It is not clear whether this reduction will be sufficient to achieve these intentions. There are interpretations of the current information under which it is likely not to be sufficient, including that: observations from reduced fishing areas are not representative of the fishery; estimates of the recent productive area reflect a 'down side risk scenario'; low, possibly zero or negative, estimates of net production could persist for some years; and biomass trends in SMU 4 are being more accurately reflected in catch rates than density estimates. The previous period of recovery started with TACCs less than 100t and it is possible that similarly low TACCs may be required to again allow rebuilding. Conversely, it also is possible that conditions for increased biological productivity and more spatially distributed fishing may return quickly, perhaps even in 2018, in which case the recommended TACC is expected to allow some recovery of the recently lost stock biomass.

The Committee recommends that the catches in 2018 be distributed among SMUs approximately as shown in Table A3.5. This is intended to reduce catches in each SMU to below levels that have underpinned recent depletions, and particularly to reduce the fishing in SMU 3 where productivity appears to have been particularly low recently and in SMU 4 where harvest fractions have increased substantially.

Table 3.2: Recommended catch targets by SMU for the 2018 fishing year.

SMU	Recommended 2018 SMU catch (t)
1	10
2	40
3	25
4	25
Total	**100**

4. ECONOMIC CONSIDERATIONS

4.1 Introduction

Economic information available to consider economic implications of different quota alternatives included estimates of gross value of production from the fishery, estimated beach prices, and estimated share trading prices. Indirect productivity measures were available in the form of average catch rates for the fishery as a whole as well as by fishing area.

The absence of contemporary data on fishing costs means it is not possible to make a complete analysis of economic performance of the NSW abalone industry. Using gross returns alone means that the economic implications of alternative quota scenarios cannot be assessed fully. The constraints of limited economic information have been highlighted in previous reports and are discussed further below.

4.2 Gross value of the fishery and abalone prices

The gross value of production (GVP) of the fishery was relatively stable over the period 2011–12 to 2016, with a value in real terms[2] of $3.85m. Estimated fishery GVP in 2017 is $4.05m based on processor prices up to August 2017 and expectations that the 130 tonne TACC will be taken. This is slightly higher than previous years due mainly to increased beach prices recently.

Average prices to August 2017 were estimated to be $31.17/kg, roughly 4% higher than in 2016 in real terms ($29.85/kg). Industry reports that beach prices have increased a further 10% this year to around $34/kg, and industry expect these higher prices to be maintained into 2018. Abalone prices remain low relative to historical levels, however, prices in 2017 being around one third of their 2000 level in real terms. This substantial decrease largely corresponds with the expansion of farmed abalone both within Australia and globally. Production of Australian farmed abalone more than doubled over 2010–2015 from 456 t to 965 t. Farmed abalone production increased globally from 8,700 t in 2002 to 130,000 t in 2015, while wild caught product declined from 10,000 t to 6,500 t over the same period.

Pressure from the increasing supply of cultured abalone is likely to continue to affect adversely prices for wild product in coming years. Previous studies of the Japanese market, a main destination for NSW abalone, found that consumers do not differentiate abalone based on their origin, so “wild caught” may not be sufficient alone to attract a price premium if the animals are of similar size to cultured abalone. NSW fisher comments, however, suggest that wild-harvest abalone may be preferred in the contemporary Japanese market. The current size of NSW product remains within the size range produced through aquaculture despite recent increases in NSW LMLs, meaning that NSW product is competing directly with cultured product rather than targeting alternative markets with preferred size.

Increases in demand for abalone in China have helped increase abalone prices globally. Chinese aquaculture production was reduced substantially in late 2016 due to a severe typhoon, with some estimates suggesting a 40%–50% reduction. This has resulted in a shortage of abalone on the Chinese market, putting upward pressure on prices across global markets. This, and the reduction in import tariffs on abalone sold into the Chinese market, has had a positive impact on prices in other states, and potentially is contributing (directly or indirectly) to the improved prices received in NSW in 2017.

The dominance of China as an abalone aquaculture producer, however, may mean that these prices might not be sustainable longer term as Chinese domestic aquaculture production recovers, nor that wild abalone premiums will be substantial for smaller animals. Price increases in NSW appear substantially less than those in states that supply larger abalone, such as Tasmania, where prices in excess of $60/kg have been reported, around 50% higher than the price in 2014–15.

There is an economic argument to increase the LML to differentiate NSW abalone from cultured product and potentially receive higher prices by targeting markets with preference for larger product. Industry notes that new overseas markets, particularly in China, are being explored with the expectation that supplying new markets will lead to higher prices. “Wild abalone” premiums may not be substantial for smaller animals in China, however, given the dominance of China as an abalone aquaculture producer.

Industry representatives also suggested that the Australian domestic market has improved over recent years, both through increased demand by local restaurants and increased competition among buyers.

[2] Nominal values are the actual or ‘raw’ transaction values recorded at given times, without any adjustment for inflation from previous or later times. Real values are the transaction values at each time adjusted for inflation between the time of transactions and some standard reference period. Comparison of real values over time are more sensible because the effects of inflation have been removed. The Consumer Price Index (CPI) often is applied for this adjustment since it reflects changes in the costs of living, and so inflation, over time.

The latter may be related indirectly to the increased demand on the Chinese market and subsequent higher export prices. The Committee suggested in previous determinations that Industry undertake a marketing study of size preferences for abalone on the domestic and overseas markets and size–price relationships for abalone. This could be proposed as a national research priority given it is an issue affecting abalone marketing from all States.

4.3 Fishery economic performance and quota trading prices

Information on actual economic performance of the fishery is unavailable, but an indication of changes in performance can be inferred by considering changes in productivity and quota trading prices.

Productivity, in terms of CPUE (kg/hr), increased by roughly 25% between 2011–12 and 2016, although has declined by around 12% since based on year-to-date indicators. Average nominal weight of abalone across the fishery increased only marginally (around 1%). The lower catch rates would mean that the total numbers of days fished to take full quota would have to increase, suggesting that the cost per unit of catch would have increased. The higher prices received in 2017 may have offset this cost increase to some degree, although the net effect on fishery profitability is highly uncertain.

Share trading prices reflect expectations of longer term profitability of the fishery. Share trading prices were not available for the current year but anecdotal information suggested that they have increased by up to 10% since 2015–16. The quantity of shares traded, however, was very small. Quota trading price, a good indicator of short term economic performance, also is unavailable, but Industry suggested that quota trading prices also have increased. These indicators suggest a strengthening of profitability in the fishery despite the reduced productivity, which may be due to the higher prices noted above.

4.4 Economic targets for the fishery

The Committee noted that there is no formal (or informal) economic objective for the fishery, nor an economically-based target level of biomass and catch. Industry representatives expressed a desire for an objective of maximum economic yield during the 2017 open forum and noted the substantial investment in shares by many fishers, the value of which can be maintained only by improving profitability in the fishery. Industry indicated a willingness to incur short term reduction in quota if it results in longer term, sustainable improvements in profitability. There is a trade-off between current (short term) and future profitability, but insufficient information available to determine the optimal level of each.

Economic performance of the fishery may be enhanced longer term through a higher Legal Minimum Length (LML) for harvest, as well as through improved biomass, particularly if a larger LML is sufficient to differentiate the wild caught from farmed product in the marketplace. There is a trade-off, however, between average size of the abalone (and its subsequent price) and the quantity that can be removed on a sustainable basis. There is also a trade-off in terms of how rapidly any increase in LML is implemented; a gradual increase may result in greater lost profitability over time during the adjustment phase than a larger size increase over a shorter period.

The Committee suggests that Industry and managers consider developing a bio-economic model of the fishery to allow such trade-off analyses be done to help inform future TACC determinations. This will require additional investment in the science and monitoring for the fishery, and possibly the development of a funding bid for targeted research.

4.5 Future economic information needs

The Committee had little economic information to inform TACC setting. The only economic performance study of the industry, including costs and earnings, related to fishing in the 2011–12 financial year and likely bares little relevance to current economic performance. Quota trading prices also are unavailable. Absence of such information increasingly will constrain the setting of economically optimal TACCs.

The Committee again notes that current economic indicators and triggers for the fishery lack specificity or clear management responses. Economic data for the fishery relating to long-term profitability are required to inform operational objectives, performance indicators and target reference levels in a harvest strategy for the fishery.

Industry indicated that they would be prepared to run a survey of fishers to help inform next year's assessment. Ideally, this would be developed as a regular process in the data collection for the fishery.

*The Committee again **recommends** that Industry and the Department resolve a strategy for economic monitoring of the operating costs and product prices for the fishery, including for share and quota trading.*

5. MANAGEMENT CONSIDERATIONS

5.1 Decision-making framework

This fishery has sound fundamental management systems in place to manage abalone – individual transferable quotas, size limits, and an independent TACC-setting process. A critical management tool for optimum management of abalone stocks that is missing, however, is a mechanism for spatially spreading catch and managing stocks at a finer spatial scale. Nevertheless, the existing system has been implemented over the last ten to fifteen years to rebuild the fishery from an over-fished condition and low TACC of 75 tonnes (t) to 130 t through annual review of TACCs and adjusting size limits, though the latter not to the full extent recommended by the Committee.

A harvest strategy is required to enable optimisation of the fishery. This has been highlighted in Determination reports as a priority for some years now, with some initial progress by the Department in early 2015 which has since stalled. A harvest strategy would provide a decision-making framework to articulate the objectives of the fishery, identify the information necessary to inform management, guide TACC-setting through decision rules, and guide other management interventions. The absence of a robust harvest strategy, and in particular the setting of standards for the collection and analysis of appropriate data, and how decisions will respond to those data, demonstrably and materially is affecting the management of the fishery.

The reduction in TACC by the Committee for 2018 is in response to the biological performance indicators that are available for the fishery. It is difficult to isolate the reasons for the observed plateauing and reduction in some performance indicators given the quality of the data and analysis available, as described in stock status section of this report, but the combined signals demand a precautionary response. The process of developing a harvest strategy would address some of the deficiencies in the decision-making framework and lead to better and more certain decisions.

5.2 Spatial management

Some prerequisites of a finer-scale spatial management regime for the fishery have been implemented over the last six years, with the collection of data from loggers and associated reporting and analysis at the finer "Area" scale. The recommended Area catch limits that have informed TACC-setting have not been adhered to, however, and it is clear now that voluntary approaches are not delivering appropriate spatial management. .

Previous TACC increases have been predicated on the Committee's expectation that more formal or effective spatial management arrangements will be put in place to ensure that Committee recommendations were implemented and enforced, either by regulation or voluntary actions by Industry. The Committee in the past has stated that the TACC increases have been intended to be spread across the fishery and that increased catches should not be concentrated on Areas in the south that have higher catch rates, are easily accessible, and are closer to wholesale buyers. No management arrangements have been put in place, however, and increased catches have been taken in the south of the fishery despite the Committee's recommendations. The Committee therefore has not recommended catch limits for each Area in this Determination. The revised TACC for the whole fishery is not based on Area-specific limits, though catch limits for the larger Spatial Management Units (SMUs) are recommended.

The absence of Area-specific catch recommendations should not be interpreted to indicate that that spatial management has become less important. Conversely, the current stock status and uncertainty of assessment increases the importance of active spatial distribution of the catch, preferably at Area scale but alternatively at SMU scale. Several mechanisms for implementing spatially-explicit management arrangements were discussed at the TACC meeting including zoned quotas, cap and close of spatial units, differential quota allocation rates for different zones, the relaxation of limitations on 'hanging' of abalone to enable exploration of new parts of the fishery; and sharing logger data in real-time within the fishery to enable fishers to make informed decisions about which reefs to target or avoid. The data sharing option in particular is considered to have a lot of potential and the Committee encourages industry to continue exploring this with the Department. The absence of any functional or effective spatial management tools reinforces the need for a conservative, precautionary TACC to diminish the risk of serial depletion of the stock, for which there now is emerging evidenced.

*The Committee **recommends** that the Department implement a system to improve the spatial spread of catch to reduce the likelihood of serial depletion of reefs.*

5.3. Legal Minimum Length

Previous reports have discussed at length the close relationship between Legal Minimum Lengths for harvest (LMLs) and catch limits in managing abalone fisheries and have recommended increases in LMLs in the NSW fishery. The Committee reiterates its advice that LMLs in the fishery should be reviewed in light of more spatially-specific information about stock dynamics and the need to develop a harvest strategy to optimise the fishery economically and biologically. An overall increase in LML, for all sectors, is expected to improve production from the fishery, provide consistency that will improve compliance, and underpin market differentiation of wild caught product from smaller aquaculture product in international markets.

The Committee is of the view that increasing the LML at a time of reduced TACC is in the best interests of the fishery and will assist in rebuilding to sustainable increased TACCs in the long term.

*The Committee **recommends** again that the underlying LML for all of the fishery be set at 120 mm with specific variations for Areas 19, 20 and 21 south of Wonboyn (123 mm) and other Areas where recent biological information demonstrates a lower LML is appropriate to productivity in those areas.*

5.4 Compliance

The compliance performance of the fishery is important to TAC-setting as it provides the confidence that catch limits are being adhered to, and that the information on which decisions are based is accurate and reliable. The current management plan for the fishery establishes basic benchmarks about 'compliance rate' but this can be misleading because improvements in the targeting of compliance effort can lead to more offences being detected, which can appear as higher levels of non-compliance when reported statistically together with other data. Use of an intelligence-led and risk-based approach should lead to a higher rate of detections and therefore the appearance of lower rates of compliance, at least initially. It is difficult to draw conclusions from crude 'compliance rate' information, therefore, without supporting explanations and the Department continues to adjust its reporting. The Committee encourages the Department to continuously improve the reporting of its activities to distinguish clearly improved targeted enforcement from declining compliance. The focus of revised reporting should be to provide insights about the efficiency of targeted compliance activity *versus* actual changes in illegal activity.

There was considerable discussion at the TACC meeting about illegal fishing by Aboriginal fishers and the availability of a native title defence to prosecutions. This discussion distinguished between legitimate Aboriginal cultural fishing, under the relevant bag and possession limits or cultural fishing permits, and illegal, unlicensed commercial fishing. The industry perceives that native title is being misused in defence of illegal unlicensed commercial fishing and that the Government has been slow and non-committal in dealing with these matters, to the detriment of the fishery and the community. It therefore was timely that two offenders had been found guilty, despite presenting a native title defence, just days before the meeting and the Department were able to report on these two successful prosecutions. The Department were also able to outline the whole-of-government approach to prosecutions which provides the appropriate rigour and balance in decision-making on prosecution matters in general, and those involving native title specifically.

These discussions clarified that for the purposes of setting the TACC:

- the estimates of illegal catch of 20–40t that have been used in recent years is still relevant although advice from industry and fisheries officers is that it may be creeping up towards the upper end of this ange, rather than the lower end referred to last year; and
- the Department are actively targetting organised illegal activity and are having an impact, resulting in detection and prosecution.

The Committee therefore continues to have confidence in the overall integrity of the quota system and other regulatory restrictions on catch, but notes that high-end offending through syndicates remains a risk that continues to require resources for targeted enforcement.

Other issues also were discussed, including:

- scope for considerable improviement in the traceabilty arrangements in the fishery which would further reduce risk and increase efficiency in monitoring and compliance;
- the need to consider alternative deterrence mechanisms such as prohibition orders on restaurant owners; convicted of receiving illegally harvested abalone; and
- improved education campaigns to complement enforcement actions, for example an education campaign in the Chinese community in relation to the impact of illegal fishing and how toensure the abalone they buy come from legitmate sources.

The Committee recommends that a compliance strategy be developed for the abalone fishery. The strategy would not need to be complex, but should identify the compliance objectives of the fishery, the risks to achieving those risks, the range of compliance strategies that will be applied including education and enforcement, and how success will be measured. Such a strategy would inform future cost recovery discussions.

5.5 Fees

The Committee is of the view, consistent with previous years, that investment is required in several areas of the abalone fishery to secure the sustainability and optimise the benefits from the fishery. Fisheries management expertise and legal clarity is required to implement the recommended spatial management arrangements. Analysis of optimum size limits is required to inform optimal harvest settings. A harvest strategy set within a clear policy framework is required to guide future TACC Determinations and any review of recreational harvest. Targeted investment in science is required to collect and analyse commercial and recreational harvest data at relevant spatial scales and implement an appropriate assessment model to inform strategic and tactical decision-making. Sustained investment in compliance monitoring and enforcement is required to ensure illegal harvest declines, for which development of an abalone fishery compliance strategy would help.

There are obvious gaps in the existing funding structure, particularly in the short term, for fisheries management expertise to implement a robust framework for the ongoing management of the fishery.

*The Committee **recommends** that consideration be given to revising investments in research and management for the fishery and that relevant strategic issues be considered in cost recovery discussions between the Department and Industry, which might include consideration of direct investment by Industry in the fishery's monitoring and management.*

6. CONCLUSION

6.1 Summary

The abalone stock and fishery metrics have shown significant improvement over the last decade but now are showing signs of stock decline in most areas. This is a worrying position given stock and fishery gains realised over recent years and not a condition on which to base further increases in harvest.

The Committee was impressed by the positive engagement of shareholders attending the public forum and notes industry's advice that shareholders favour a cautious approach to quota setting, with an emphasis on securing stock status and future rebuilding. Persistent uncertainties about the true status of stocks in the context of a legislative requirement for a precautionary approach also mean caution is required to protect improvements over recent years and avoid reversion to previous conditions of poor stocks and low catches.

The Committee continues to be concerned about the low level of research and monitoring investment in the fishery, the absence of a sufficient assessment model to inform tactical or strategic decisions, and the lack of a well-developed harvest strategy with clear resource and economic objectives. There also are basic economic data needed to inform future TACC setting if quotas are to be set for economically as well as biologically optimal results, especially under continued instability in stock status. Recreational harvest continues to be very uncertain and the Committee recommends no increases to recreational bag limits until more robust information about recreational harvest and stock status are available and signals of stock decline have reversed.

*The Committee **recommends** that no changes to recreational bag limits be considered without robust monitoring to quantify recreational harvest and the consequences of any change to bag limit.*

Abalone life history renders them extremely vulnerable to serial depletion despite seemingly stable fishery metrics and there now are signals that serial depletion of the stocks may be re-occurring. The scarcity of monitoring and biological assessment information makes it difficult to detect serial depletion with certainty, notwithstanding provision of detailed diver and catch logging data. Absence of effective management to implement spatially-explicit allowable catches and size limits also means the fishery remains vulnerable to serial localised stock depletion such as apparently depleted the stock historically.

A revised management plan with specific fishery objectives and a formal harvest strategy are needed urgently to facilitate further development of this fishery. Such a strategy should include formal limits and targets that incorporate economic as well as biological considerations to guide future setting of TACCs and review of LMLs, which should be determined together. The lack of such a harvest framework, and robust monitoring and assessment information to support it, potentially has contributed materially to the lag in recognising what now appears to be emerging stock decline and continue to constrain TACC Determinations given the requirement to act within a precautionary approach.

6.2 Total Allowable Commercial Catch for 2018

The Committee was presented with a detailed Research Report provided by the Abalone Council of NSW under contract to the Department that summarised available fishery-dependant information. The Committee interprets the report to be a joint report from Industry and the Department. Management and compliance reports also were provided.

The key factors in arriving at the Total Allowable Commercial Catch for 2018 were:

- Catch rates of abalone, whilst strong, have plateaued in recent years and now be appear to be declining in most Areas;
- Sizes of abalone landed also appear to have declined recently, though there is some ambiguity in this conclusion related to the metrics used;
- Indicators of abalone stock biomass suggest recent reduction in biomass in most areas to levels present in 2012–13, representing approximately half of the biomass build since 2009–10;
- There are clear circumstantial signals of localised depletion in some Areas, changes in fisher behavious, and concerning changes in catch to stock biomass ratios;
- There remains an absence of clear objectives or a coherent harvest strategy to which TACC settings can be referred;
- There continues to be insufficient biological or economic monitoring data or any robust bio-economic assessment information to imform tactical or strategic TACC settngs for the fishery or, in particular, assess the true status of stocks or their prognosis;

- Curent management arrangements are not sufficient to implement effectively spacially distributed catches recommended by either the Industry or the Committee;
- Consistent advice is that compliance in the fishery is improving, notwithstanding the (potentially misleading) statistics from successful targeted enformcement activities and suspected recent increases in illegal harvest for sale; and
- Industry opinion favours a cautious approach to TACC setting to protect stock status whilst the status of abalone stock remains uncertain.

The Committee has decided that the TACC should 100 tonnes for the 2018 quota year on this basis.

The Committee acknowledges that this is a material reduction in quota from that allowed in recent years but considers it a necessary step given evidence that the abalone stock may have entered a period of diminished productivity and declining status. The Committee has reached this conclusion after taking into account diverse submissions from shareholders and informative discussion at the 2017 public forum, in conjunction with the information provided in Departmental reports to the Committee, including the research report. The still nascent use of high-resolution logger data has provided useful information about the likely status of stocks but ongoing uncertainty about the true status of the stock in the absence of any credible formal stock assessment, and uncertainty that any spatially specified catch limits can or will be implemented, mean that a demonstrably precautionary setting of the TACC is prudent. The Committee has taken such a precautionary approach in the interests of preserving at least some of the improvements in the fishery from the last decade of rebuilding and, hopefully, avoiding reversion of the stock, and fishery, to previously depleted levels.

The Committee's determination is influenced heavily by persistent uncertainties in many aspects of the fishery that could be improved by strategic reinvestment in robust bio-economic assessment and development of a credible harvest strategy.

6.3 The Determination

The Total Allowable Catch Setting and Review Committee, pursuant to Division 4 of Part 2 of the Fisheries Management Act 1994, determines that the Total Allowable Commercial Catch of abalone that may be taken in the NSW Abalone Fishery during the period 1 January 2018 to 31 December 2018 should be **100 tonnes.**

The Committee also ***recommends*** a spatial distribution of that catch by Spatial Management Unit per Table 6.1 and increases in Minimum Legal Lengths for harvest to 120mm in Areas 1–18[3] for all sectors of the fishery.

The Committee expects that the Department, in consultation with industry, will manage the fishery to achieve the recommended spatial distribution of catch in support of the above Determination.

Table 6.1: Recommended catch targets by SMU for 2018.

SMU	Recommended 2018 SMU catch (t)
1	10
2	40
3	25
4	25
Total	**100**

Bruce Mapstone, Chair

Kelly Crosthwaite, Fisheries Management

Sean Pascoe, Natural Resource Economist

Keith Sainsbury, Fisheries Scientist

[3] Subject to review where recent biological information *demonstrates* a lower LML is appropriate to particular Areas with unusually slow growth and small maximum sizes of abalone.

APPENDIX 1. DETAILS OF PUBLIC CONSULTATION

Public consultation steps taken by the Committee, with support from the Department, are summarised in the table below. These steps effected the consultation requirements stipulated in the *Fisheries Management Act 1994, Division 4 S31.*

Date	Fisheries Management Act Reference	Consultation Stages
28.08.2017	Section 31(1)	Committee called for public submissions on the appropriate level of the annual TACC for Abalone for 2018 fishing period.
28.08.2017	Section 284 (1b)	Individual calls for submissions sent to particular interest groups who the Committee considered might wish to provide collective submissions either due to their direct involvement in the abalone fishery or their interest in related issues. These groups included: ■ NSW Abalone Shareholders; ■ NSW Abalone Fishery Nominated Divers; ■ Abalone Association NSW ■ NSW Recreational Fishing Advisory Committee ■ NSW Aboriginal Fishing Advisory Committee ■ Professional Fishermen's Association.
06.09.2017	Section 284 (1b)	Advertisement calling for public submissions placed in the Sydney Morning Herald and the Daily Telegraph.
20 – 26.09.2017	Section 31 (2)	The Committee received the following collated submissions: ■ NSW DPI – Commercial Fisheries Management Report; ■ NSW DPI & Abalone Council NSW Research Report; ■ NSW DPI Compliance Report; ■ The Abalone Association of NSW; and ■ 5 NSW abalone fishery shareholders*.
04.10.2017		The Committee considered submissions and heard formal presentations and opinions at the Total Allowable Catch Committee Open Forum meeting in Sydney on 04 October 2017. The following made presentations or provided information to the Committee: ■ Dr. D. Worthington (Abalone Council of NSW, contracted provider of stock status report to DPI); ■ The Abalone Association of NSW (presented by Mr Greg Ryzy); ■ Mr Mick Arentz ■ Mr Stephen Bunney; ■ Mr Greg Finn; ■ Mr Ryan Morris; ■ Mr Gunther Pfrengle ■ Mr Greg Ryzy ■ Mr David McPherson, NSW DPI (Group Director) ■ Ms Fiona McKinnon, NSW DPI (Management); ■ Dr Rowan Chick, NSW DPI (Research); ■ Mr Nick Schroder, NSW DPI (Compliance); ■ Mr Drew Egan, NSW DPI (Compliance).

These submissions were considered 'Confidential'. Identification of the authors has been withheld from the Report and Determination.

APPENDIX 2. SUMMARY OF SUBMISSIONS

Submission from	Issue(s) Raised
Abalone Association of NSW (AANSW)	The submission provided background information about the AANSW and made several comments about the fishery. ➢ Expressed concern about illegal (commercial) fishing, especially by aboriginal fishers claiming to be engaged in cultural fishing. ➢ Concerned that aboriginal people caught with commercial quantities of abalone appear not be being prosecuted. ➢ Concerned that illegal (commercial) harvests threaten sustainability of stocks and create reputation (health) risks in the domestic marketplace. ➢ Recommended reduction in possession limits for cultural fishing to the same level as recreational possession limits. ➢ "The members of AANSW are frustrated and concerned DPI's inaction on a range of issues raised by industry at workshops and at TAC meetings …", including: • "A review of all data relevant to the size of abalone in view of the TAC Committee's recommendations for an increased size limit for some areas of the fishery; • An abalone fishery harvest strategy; • Cultural fishing as a "front" for illegal fishing and selling of abalone (see above)." ➢ Recomended no change in size limits or quota until above issues addressed. ➢ Provided several member comments consistent with above. ➢ Varied reports from divers about recent status of stocks. ➢ Provided comment on price and market conditions, noting solid demand for NSW abalone and increased beach prices.
Shareholder 1*	➢ Provided background about experience, quota, & business. ➢ Recommended increase in TAC given increasing catch rates for experienced divers. ➢ Noted several new participants in fishery lower overall averge catch rates. ➢ Provided copies of daily catch records as evidence of high catch rates. ➢ Recommended no change in size limits for most areas but reduction to 110 mm MLS for some (unspecified) areas. ➢ Contended hihger size limits result in concentration of effort in areas with faster growing abalone.
Shareholder 2*	➢ Recommended increase in Legal Minimum Size Limits from 117 mm to 120 mm north of Wonboyn. ➢ Provided arguments from experience for increase in LML. ➢ Recommended reduction in TAC by 10–13 t for 2018. ➢ Recommended allocating quota and reporting catch by number of abalone rather than weight, with sale by weight. ➢ Recommended mandatory use of data loggers. ➢ Recommended mandatory prosecution for possession of specified amount over specific recreational or cultural limits. ➢ Requested additional mitigation or rehabilitation work for abalone, including urchin culls, kelp habitat rehabilitation, & abalone translocation.
Shareholder 3*	➢ Provided background on experience in fishery and business.. ➢ Recommended reduced TAC for 2018, by "approx 10%", whilst noting static TAC probably OK but "…better to be safe than sorry". ➢ Argued strongly for no increase in LML. ➢ Contended hihger size limits result in concentration of effort in areas with faster growing abalone.
Shareholder 4*	➢ Recommended increase in LML to 120 mm where current LML is 117 mm. ➢ Provided raw length from catches over recent years to support case for increased LML.

**** These submissions were considered confidential. Identification of the authors has been withheld from the Report and Determination.***

APPENDIX 3. STATE OF THE STOCKS — DETAILS

A3.1 Introduction

The stock assessment report was produced by the Abalone Council of NSW and was endorsed by both NSW DPI and the Abalone Association of NSW. The stock assessment report was prepared by Dr Duncan Worthington, Executive Officer of the Abalone Council of NSW, under contract to the Department and was co-badged by the NSW DPI and the Abalone Association of NSW. It would be preferable for the DPI scientific assessment to be provided separately to the Committee.

Timeliness of report delivery to the Committee this year was good, being received by the Committee two weeks before the public forum, and consistency of the assessment report between years continues to improve. It was notable, however, that the report was not sent by the Department to Industry representatives until the day before the forum, effectively precluding pre-consideration by Industry.

There is still inconsistency in the way key stock indicators are calculated between years, however, and the descriptions of the methods used are not always clear or adequate. These issues made it difficult to understand the apparent trends in both of the primary indicators (catch rate and mean weight), the effects of standardisation, and the logger-based estimates of biomass and harvest fraction, and necessitated repeated requests from the Committee for clarifying additional information.

Evolution of indicators and methods is to be expected and encouraged but both previous and new versions of methods or indicators must be reported in parallel during transition when changes are made. This is necessary for transparency and comprehension of the effects of changing methods on inferences about changes in stock status. It is usual in fishery assessment processes that in such transitions the previous and new methods are reviewed before fully adopting a change and no longer reporting the previous approach. A process of this kind should be applied to the abalone assessment. This process should be between the contracted analyst and the Department with explanation to the Committee, but it could also involve the Committee as appropriate.

Consistency between the assessment and management reports also has improved, but there remain significant differences that confuse interpretation and communication.

- The spatial units in the fishery are now described in both reports but there remain some differences in definitions. Subzones K1 and K2 are allocated to Area 3 in the assessment report and to Area 2 in the management report. This affects analysis and interpretation for these Areas but it does not affect analysis at the SMU scale. The spatial units used in the fishery, however, remain unnecessarily duplicative, complex and confusing. Two different spatial structures (Regions, Zones, and Sub-Zones vs Spatial Management Units and Areas) are used currently for various purposes, and the boundary between SMU 1 and SMU 2 divides Area 7 which complicates some compaisons. The spatial reporting and management units should be rationalised and applied consistently.
- Both reports provide catch rate and mean weight, but they calculate them differently, being standardised in the assessment report and nominal in the management report. The differences between these are now significant in both absolute value and trend, which is confusing and potentially misleading (especially to a reader of just one report). The analysis, interpretation, and reporting should be harmonised and reconciled by the Department before presentation to the Committee.
- The graphical presentations in the management report of catch, effort, catch rate, mean weight by SMU, and year (and usefully from 1999, rather than the more truncated period shown in the assessment report) are particularly informative and should be maintained. The Area vs year 'bubble plot' of catch in the management report could usefully be extended to show catch rate, whilst also ensureing that the assessment report and the management report use the same measures of catch rate and mean weight.
- Both the asessment and management reports provide a draft harvest strategy and use that to help focus on particular indicators and interpretations. Those draft harvest strategies are different, however, and so the guidance they provide is somewhat different and at times inconsistent. Recent developments in the fishery highlight the need for additional technical analysis and testing of indicator and reference point options specifically in the NSW context before they are formally adopted in a management strategy, rather than continued use just of the current indicators and benchmarks. The Committee again emphasises the need to develop and finalise a single harvest strategy, and agree on the indicators that will be used in the assessment and management reports as the interim strategy is developed.

The Committee considers the current and likely future status of the stocks in making its determination. There are two main features that provide a background and context for this year's consideration – previous conclusions about the status of stocks and changes in information available for assessment.

A3.2 Background and context

A3.2.1 Previous conclusions about the status of the stocks

Previous inferences about the status of the stocks provide a key context for the current interpretations and recommendations. Several specific previous findings remain highly relevant to this year's assessment – especially the multi-year periods of high and low productivity demonstrated in earlier assessments, the causes of historical overfishing that need to be avoided now, and the status of stocks in northern NSW.

The NSW abalone stocks historically suffered from significant over-fishing and over-depletion. The actions of the Committee since the early 2000s were a response to that, with the aim of rebuilding the stocks and preventing repetition of the previous over-exploitation.

The stocks showed significant evidence of over-depletion in the 1990s and early 2000s including:

- Serial depletion starting in the north of NSW in Region 1, exacerbated in the north by mortality from a severe outbreak of the disease *Perkinsus* in the late 1990s, and progressing south;
- Recruitment overfishing (i.e., breeding stocks depleted sufficiently to reduce the number of young produced) in Region 2 from the early to mid-1990s;
- Onset of recruitment overfishing in Regions 3 and 4 starting in about the 1990s;
- All the well monitored Regions (2-6) showed increasingly 'spiky' patterns in catch rates and estimated recruitment, indicating multi-year periods of high and low productivity, with progressively lower lows between the spikes with briefer and (in most Regions) progressively lower highs (Figure A3.1); and
- The fishery harvest became highly dependent on abalone that grew over the Legal Minimum Length (LML) each year.

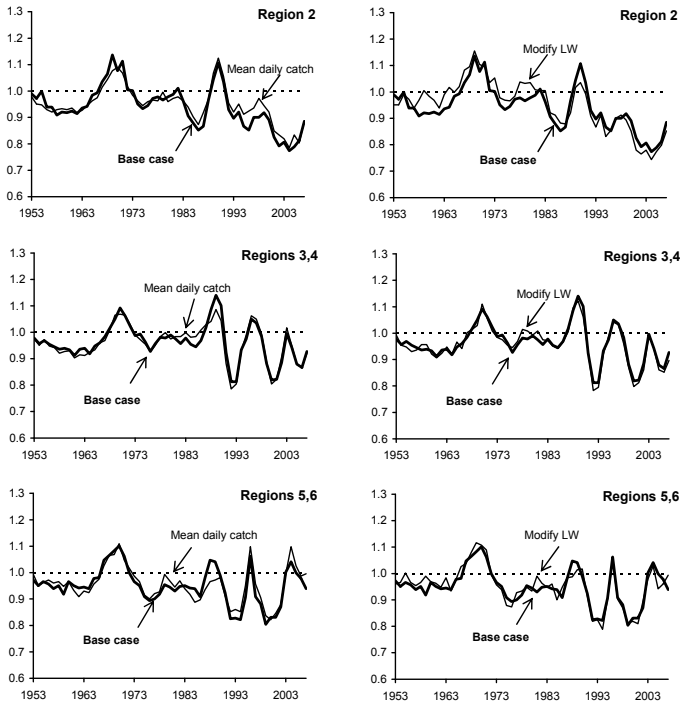


Figure A3.1. The pattern of recruitment estimated from the fitted population model in 2008, the last year of its application. Multi-year periods of high and low recruitment are evident, with high periods in about 1979, 1980, 1990, the mid-1990s and the mid-2000s. Average recruitment since about 1990 in Regions 3, 4 and 5 and 6 was lower than in the earlier period, with an increasingly 'spiky' pattern of recruitment in which different Regions showed different combinations of lower, and more persistent, lows and briefer highs. Decreased recruitment in Region 2 started in about 1990.

The population modelling shows multi-year periods of high and low recruitment, but these are more appropriately interpreted as multi-year periods of high and low productivity. Changes in the rates of spat settlement, emergence from crypsis, growth, and natural mortality would all be interpreted through the model as changes in estimated recruitment. This information overall indicated sequential depletion with a very high fishing mortality on abalone above the LML, a population that had lost most of its age structure and resilience, and a population with greatly reduced breeding potential because the high fishing mortality was applied with a LML that was relatively close to the size at reproductive maturity.

There also have been additional issues relating to the status of stocks in the northern part of NSW (i.e., Regions 1 and 2, which were later aggregated to form SMU 1).

Region 1 North *(north of Port Stephens, Zones A-E or Area 1)*

There was very little information available to assess the status of stocks in Region 1 north of Port Stephens. There was no Fishery Independent Survey in this area and there has been very little commercial fishing at any time since 1987, even when there were no regulatory restrictions on fishing there. It is not known whether, or to what extent, the stocks there were affected by the *Perkinsus* that significantly reduced stocks in the southern portion of Region 1. Commercially targeted fishing was stopped in Region 1 North in 2002 but special catch allocations were made to allow structured collection of data to determine the extent of *Perkinsus* impacts, to support an initial assessment of the stocks, and to estimate a sustainable catch. Region 1 North was re-opened to targeted commercial fishing in 2010.

Region 1 South *(south of Port Stephens, Zones F-L or Area 2 plus the northern part of Area 3)*

This area suffered a severe outbreak of *Perkinsus* in the late 1990s. There were relatively few Fishery Independent Survey sites in the southern portion of Region 1 but they all showed the death of 50-75% of abalone of all sizes. Some areas were closed to commercial fishing in 1996 and the whole of Region 1 South was closed in 2002. The Fishery Independent Surveys after total closure showed continued low abundance and no recovery of the small or medium sized abalone. They showed an accumulation over time of increasingly large abalone, interpreted to be the survivors of the outbreak augmented by low recruitment. Fishery Independent Survey sites in Region 1 South were clustered in three southern areas - Port Stephens, Sydney, and Kiama (Zones F, J and K), so there was concern about how representative these sites were of the whole region.

Trial fishing in Region 1 South during 2004 showed that it was possible to take large abalone at high catch rates from targeted sites, as was expected from the Fishery Independent Surveys. Information from that fishing, however, did not help assess the status of the stock or the extent of any recovery.

A more structured program of trial fishing was conducted in 2007 to test the change in status of the stock at pre-identified sites that had been productive historically. This program allowed comparison of the proportion of previously productive sites that remained productive, of the change in catch rate at those sites compared to catch rates in 1994, 1987 and 1982-85, and of the current catch rates at historically productive sites compared to sites chosen by divers in 2007 as being productive contemporarily. The general conclusions were:

i) About 36% of historically productive sites were still as productive as they were previously;
ii) 70-80% of historically productive sites had catch rates that were lower than those recorded at the same sites in 1994 or 1987;
iii) The northern Zones, between Pt Stephens and Sydney (Zones F, G and H) had very low abalone abundance and a major loss of historically productive sites;
iv) The southern Zones, between Sydney and Wreck Bay (Zones J, K and L) had considerably higher abalone abundance and had lost fewer historically productive sites than the northern Zones, and slightly more than half of all sites fished in these southern Zones had catch rates greater than was recorded at the same sties in 1994;
v) The median length of abalone taken was greater than 120mm for almost all sites; and
vi) The diver selected sites provided slightly higher catch rates than the pre-identified historically productive sites but did not materially change the overall results or conclusions.

These conclusions were consistent with the Fishery Independent Survey data in indicating that Region 1 South in the late 2000s supported some dense aggregations of large abalone, but that many historically productive sites still did not support dense abalone aggregations or significant numbers of small abalone despite several years of protection from fishing. The stock of legal sized abalone in the northern Zones (F, G and H) remained very depleted in 2007, while the stock of legal sized abalone in the more southern Zones (J, K and L) had recovered to 1994 levels at more than half of the sites fished.

The south Zones (Sydney to Wreck Bay) were re-opened to commercial fishing in 2010 and the northern Zones (Pt Stephens to Sydney) were reopened in 2012.

Region 2

Region 2 was closed to commercial fishing in 2006 because of evidence of recruitment overfishing (Fig. A3.1). Average recruitment in Region 2 started decreasing in about 1995, including a decrease in the strength of recruitment in the 'pulse years'. The 1995–96 and 2001–02 pulses of increased recruitment and productivity were estimated to be very much weaker in Region 2 than in the more southern regions in those years and were considerably weaker than was seen in Region 2 in the 1988–89 pulse. Special catch allocations were made each year following the closure of Region 2 to allow collection of data that would support an improved assessment of the stocks there, especially in relation to interpretation of recruitment overfishing. Region 2 was re-opened to commercial fishing in 2010.

3.2.2 The information available for recent assessments

The information available to assess the status of stocks has changed considerably in the past decade.

- The fishery assessments until 2008 were based on: (i) Fishery Independent Surveys of the relative abundance of different size categories of abalone, including abalone smaller than the LML for the fishery that provided a 'leading indicator' of recruitment to the fishery; (ii) catch rate and weight composition from commercial fishing; (iii) integrated analysis of this information through a length-based population model to estimate population size and recruitment; and (iv) prediction of the expected future trends in the status of the stocks under different levels of harvest.
- Fishery assessments between 2009 and 2017, inclusive, have included no formal scientific stock assessment or prediction of future stock condition. Rather, they have relied primarily upon interpreting a small number of fishery dependent indicators.
- Collection of fine scale data on fishing effort and catch, through the use of GPS-linked data loggers, started in 2008. Coverage of the fishery has increased as more, and more reliable, data loggers were provided to divers. Logger data allows estimates of catch per unit area searched, which is an indicator of relative population density that can be used to test the consistency of catch rates derived from logbooks. Logger data also allows estimation of the exploitable biomass and harvest fraction, and these are used as additional indicators for fishery assessment. The performance and appropriate interpretation of these estimates has not been scientifically evaluated, however, for either relative or absolute interpretations, and reference points corresponding to desired or undesired outcomes for the fishery have not been developed or tested.

The information available to assess the status of stocks since about 2008 has been in a very slow transition from the previous methods based on Fishery Independent Surveys, coarse scale data from commercial fishing, and population modelling to new methods that are hoped to be cheaper, and potentially better. The new approach was based strongly on monitoring commercial catch rate from log-book returns and the mean weight of abalone in the catch, but also used fishery dependent fine scale data reporting through the GPS loggers. The previous methods were stopped, however, before the new methods were developed and shown to be adequate. Rather, methods were developed and variously applied through the annual assessment reports in an empirical 'learn by doing' approach. This resulted in increased uncertainty about the state of the stock, increased uncertainty about the consequences of different catch levels, ongoing uncertainty about the implications of constantly changing assessment methods, and the need for precautionary TACCs. Robust and meaningful indicators of stock status or fishery performance using the logger data have not been tested formally, despite their use in fishery assessments and TACC setting, and this is both inefficient and carries risk, though understanding of, and confidence in, the logger indicators and their interpretation is slowly increasing.

There now is heavy reliance on commercial catch information of trends in commercial catch rate and the average weight of abalone in the catch. This reliance on commercial catch data has well-known problems, especially for abalone which have localised population aggregations that can be selectively targeted by fishing. Specific issues in this fishery are:

- The intent of the individually tradable quota management is for industry to innovate and change fishing practices to optimise economic returns in their dynamic external environment. These innovations and changed fishing practices can be expected to affect the indicators used for assessment, including the catch rate and mean weight of abalone caught.
- Commercial catch rate, particularly for aggregated areas and times, is notoriously 'hyper-stable' for abalone fisheries. High catch rates can be maintained for a time by targeting concentrations of abalone in known patches of preferred habitat or by searching faster even if the overall population is declining. Hyper-stable catch rates have been seen in the NSW

abalone fishery at both Region and Sub-Region scales. Logger-based estimates of catch density (catch per unit area searched) can account for some operational changes that result in hyperstable catch rates (e.g., faster swims, short dives in unproductive areas), but not all.

- Catch rates and mean abalone weight in the catch are 'trailing indicators' that reflect what has happened, rather than 'leading indicators' of what will happen. They contain no information about numbers of sub-legal sized abalone that provide the future harvestable stocks.
- The mean abalone weight in the catch is an ambiguous indicator. Increasing mean weight can be associated with balanced rebuilding of population size structure (a positive interpretation) or with reduced recruitment and fishing on the remaining large animals as they grow (a very negative interpretation). Conversely, decreasing mean weight can be associated with truncating size composition caused by high fishing mortality (a negative interpretation) or with recently increased recruitment giving many small animals in the population (a positive interpretation). The combination of mean weight with size-aggregated commercial catch rate, the main two indicators available in this fishery, are similarly ambiguous without additional information or judgements.

The current lack of size or age-based population analysis also precludes scientific examination of the LML that both optimises catch and provides adequate protection of the breeding stock. Consequently, this is being tested empirically in the fishery by applying small changes in allowable catch or LML and monitoring the results over subsequent years. This is inefficient because it does not make use of well-established scientific methods of prediction, slow because monitoring and measuring the consequences of each change before the next change can confidently be made takes time (years), and risky because mistakes are recognised only after their effects have occurred and become measurable.

A key issue in managing stock recovery, and preventing repeated overfishing, is understanding and addressing what was wrong with the previous management settings. The Committee considers three issues are very important to achieving this goal, in addition to setting an appropriate TAC for the fishery.

i) *Finer-scale management*. Use of finer scale monitoring, assessment, and management to better address the risk of sequential localised depletion. There are ongoing and broadly successful efforts to gather finer scale data from the fishery using GPS-linked data loggers. The analysis and interpretation of these data for stock assessment continues to improve and allow interpretations at finer spatial scales. Attempts to limit catch at finer spatial scales (e.g., at SMU and Area scales), however, have had very limited success. This remains an important challenge to sustainable recovery of the fishery.

ii) *Minimum Legal Lengths.* The Committee and many in industry have questioned the appropriateness of the LMLs used in the fishery. The fishery has a history of a relatively small LMLs compared to those used in other fisheries on the same species. The LML in NSW was 100mm in the 1970s, 108mm for most of the 1980s, 115mm for the 1990s and most of the 2000s, and 117mm from 2008. The LML for the most southern areas of Region 6 was increased to 120mm in 2010 and then to 123mm in 2012. Some shareholders have voluntarily and successfully also fished to a 120mm size limit in more northern areas in recent years.

   The Committee has recommended for several years that a larger size limit be applied to the overall fishery in NSW, complemented with various locally specific arrangements applied to those areas where abalone growth appears unusually higher or lower. There are several advantages of a higher 'default LML' which can be altered selectively as appropriate, rather than low LMLs everywhere. It protects against localised overfishing of abalone sub-populations that grow quickly, have a large size at first maturity, and reach large maximum size. Such fast-growing abalone are highly productive if managed appropriately but are vulnerable to overfishing if fished at too low a LML.

   An argument against increase in the overall LML has been the view that NSW has many areas of abalone with stunted growth, which was supported by some early research results. Responses of the fishery to changes in LMLs, however, made it clear by 2010 that the population is not dominated by stunted stocks and that the earlier research results were not representative of the majority overall stock or the current situation. The observed rapid increase in the individual weight of abalone caught following increases in LML would simply be impossible if the population was dominated by stunted stocks.

iii) *Management Objectives.* The Committee has commented often that the benchmarks and reference levels used in the Share Management Plan and the Fishery Management Strategy were set at levels that did not adequately protect sustainability or achieve maximum productivity. Revision of these benchmarks and reference levels is necessary and should be grounded in scientific assessment of the biological productivity of the stocks.

Previous reports have identified serious weakness in the current management situation. These include uncertainties about the robustness of the recent stock improvements, the limited ability to detect any faltering in recovery, the lack of benchmarks for current indicators relating to overfishing and optimal fishing, and unknown management settings for optimal fishing (including spatial management of LML and catch caps). It is not appropriate or possible with the limited information available for management measures to be based on detecting detailed nuances of population change. Rather, precautionary management measures, as required by the Act, must be simple, robust and conservative.

A3.3 Information and analysis available for the current 2017 assessment

There are two primary sources of information available: (1) logbook and related information from commercial fishing (including catch, catch rate, and mean weight of individuals in the catch) aggregated variously by Regions, Zones, Sub-Zones, Areas or Spatial Management Units (SMUs); and (2) fine-scale GPS data-logger information.

A3.3.1 Aggregate catches, catch rates, and mean weight and length

The annual commercial catch and catch rate (CPUE in Kg/h) from logbook returns is shown for each SMU in Figure A3.2.

Catch rate is standardised in Figure A3.2 across the last 3 years only because the draft harvest strategy refers to 3y rolling averages and trends. This is a very limited use of standardisation, however. The standardisation as provided has a material effect on the trends over the 3y for which it is shown, especially the most recent year. Consequently, longer-term comparisons (e.g. comparison between any of the past 3 years and earlier years) are difficult from the information provided. Such comparison is made even more difficult because the three standardised values provided are calibrated so that the standardised and nominal catch rates match in the first year. It would be more usual and informative to standardise and use the full catch rate time series, with trend analysis applied to the last 3 years for that focus, and that should be done in future assessments.

A further complication to interpretation of recent trends in catch rate is that the area fished has contracted considerably in the most recent about 2 years (2015–16 and 2016–17, see Table A3.2), particularly in SMU 2 but also in SMUs 3 and 4. Contraction in the area fished can indicate sequential depletion but also operational constraints, and the causes are not clear from the information available. Such large contraction in the area fished also raises uncertainty about the representativeness of the fishery catch rate to represent the whole stock, including stock in areas not recently fished. The same issues arise in relation to estimation of biomass from logger density observations, and they are discussed in some detail later in that context. Effectively it is not known whether the observed catch rate reasonably reflects the whole stock, including in areas recently unfished, or whether the recently unfished areas have lower abalone densities so that the recent trend in catch rate over-estimate abundance of the whole stock. This is not resolvable with the information available and remains as an uncertainty that applies to interpreting the catch rate recently, and particularly in the past about 2 years.

There has been very little catch from SMU 1 during the last several years, including in the most recent year. Catch rate trends there likely reflect a few targeted areas rather than the SMU as a whole.

The trends in catch rate for the other SMUs are all very similar. All showed steady increases from 2010, followed by plateauing during about 2014-2015, and then marked decreases by 2017.

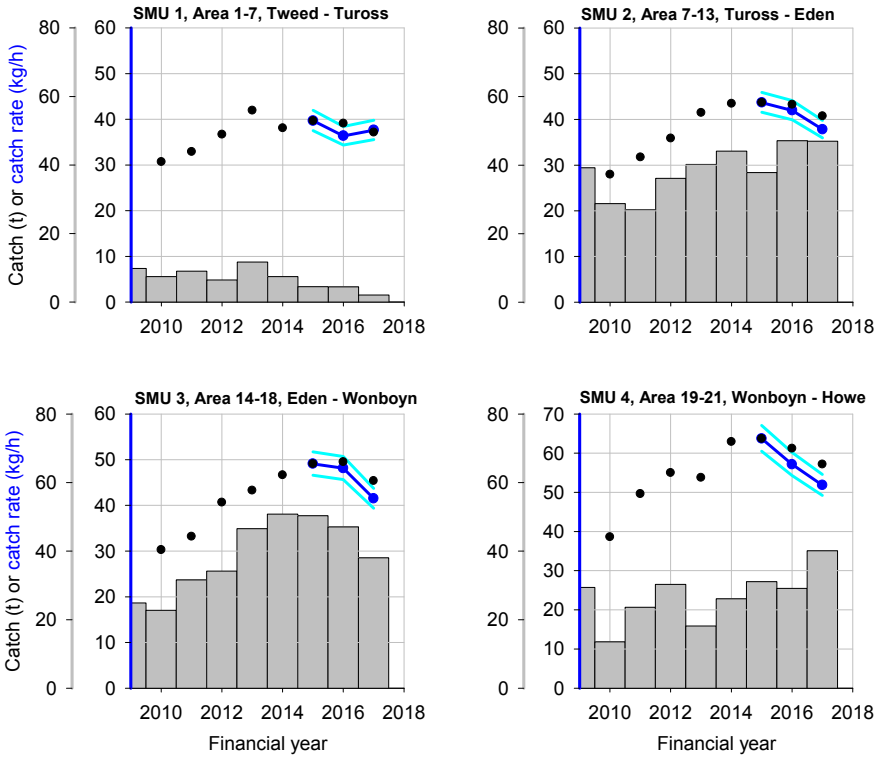


Figure A3.2. Annual catch (histograms) and nominal catch rate (black dots) for each Spatial Management Unit (SMU) as given in the assessment report. The dark-blue line shows the mean catch rate (+/- 1 standard error shown in light blue) standardised over the past 3 years and calibrated to the first of the three years.

Figure A3.3 shows recent trends in mean weight for each SMU. The mean weights in Fig A3.3 are standardised across the last 3 years only, as were the catch rates in Fig A3.2. This creates the same problems for mean weight interpretation and comparison as described for the standardisation of catch rate. The problems for mean weight interpretation are greater, however, because the standardisation has greater effect, particularly in the most recent year. The standardisation of the last 3 years of mean weights changes a small increasing trend in nominal mean weights (in the Management Report) to a decreasing trend in the standardised mean weights that is driven by a particularly strong decrease in the last year. The size of the change may appear small but mean weight is not a highly responsive indicator and this difference is important. In general, and for reasonably constant fishery selectivity:

- Decreasing catch rate combined with increasing mean weight (the pattern in nominal weights in this fishery, especially SMU 4) is a symptom of significant recruitment decline, including from recruitment overfishing, environmental variability, or both, and so has a negative implication for stock status.
- Decreasing catch rate combined with decreasing mean weight (the pattern from standardised weights) is a symptom of a generally declining stock, and so also a negative implication for stock status, though not necessarily as urgent or severe.

The initial description of the standardisation method suggested that the cause of discrepancy between trends in standardised and nominal mean weights was changed balance in the number of weight observations across months, areas, bins, or divers. The Committee was informed during discussion at the public forum, however, that the likely cause was a changed balance of observations across different weight measuring programs that contain different conversion factors intended to make them compatible. The ultimate cause of the discrepancy remains unclear from the available information, meaning that it is not clear what relative credibility to place on the standardised versus the nominal mean weight trends. The standardised values should be more reliable, in principle, so they are given preference here, but this unexplained discrepancy, with such different implications, increases uncertainty in assessment of stock status.

Mean weight is one of only a few primary indicators available in this fishery and it is of serious concern that its measurement and interpretation is in such doubt. The importance of this issue means it should have been recognised and resolved internally by the Department or its contractor and then explained consistently to the Committee.

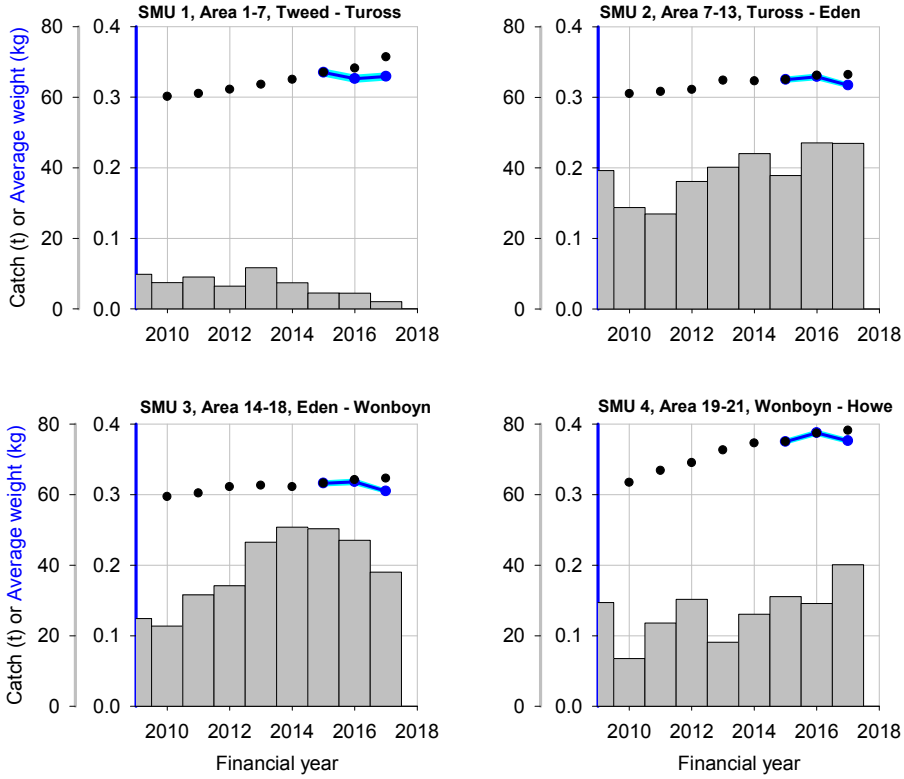


Figure A3.3. Recent trends in mean weight of caught abalone by SMU. Black dots are the nominal mean weight and the dark-blue lines show the standardised mean weights (+/- 1 standard error in light blue) for each of the past 3 years. The LML was increased from 115mm to 117mm in late 2008. The LML was further increased in SMU 4 from 117mm to 120mm in late 2010, and then to 123mm in late 2012.

The changes in catch rate and mean weight are summarised in Table A3.1 below.

Table A3.1: Changes in primary indicators of stock status in each Spatial Management Unit (SMU) over the last 1 year (top), per year over the past 3 years (middle), and cumulative over 3 years (bottom).

	SMU 1	SMU 2	SMU 3	SMU 4
Annual change in last year				
Standardised catch rate	+3.5%	-9.9%	-13.7%	-9.3%
Standardised abalone weight	+1.0%	-3.7%	-4.1%	-2.9%
Annual change over 3 years				
Standardised catch rate	-2.6%	-6.7%	-7.7%	-9.3%
Standardised abalone weight	-0.8%	-1.2%	-1.8%	-1.5%
Implied cumulative change over 3 years				
Standardised catch rate	-7.8%	-20.1%	-23.1%	-27.9%
Standardised abalone weight	-2.4%	-3.6%	-5.4%	-4.5%

SMU 1 has received very little fishing and the fishery dependent data are not considered to be representative of the whole stock there. SMU 1 in effect is not reliably assessable with the information available, though that information suggests that there has been no major change in stock status despite many years of low fishing effort and catches (see Section A3.2.1 for earlier assessments of stock status, and note that SMU 1 combines Regions 1 and 2 and diverse stock situations).

There are consistent patterns across the significantly fished SMUs 2, 3, and 4.

- Annual catch rates increased rapidly from about 2008 through to a plateau in about 2014–2015, after which they decreased. The decrease in the last year (2017) has been substantial.
- The cumulative reductions in catch rate over the past 3y are very substantial; about 20% or more. The 2017 catch rates for all these SMUs are about the same as they were in 2012, though interpretation is made difficult by the mixture of standardised and nominal information provided. These general patterns are repeated at the Area spatial scale.
- Mean weights of landed abalone in SMUs 2, 3, and 4 steadily increased from about 2008 through to about 2016, after which they decreased. These patterns also are apparent, though variable, at the Area spatial scale.

Patterns in catch rate and mean weight have been described in the past few years by the Committee as 'plateauing', at both SMU and Area scales. The addition of the 2017 information, however, indicates these measures had reached a maximum that has been followed by decline. Overall these indicators suggest a substantial deterioration in stock density and size composition since about 2014, and a return to stock conditions approximately as they were in about 2012.

Arrangements to implement Area-based catch targets and limits, intended to spread the catch spatially and avoid localised depletion, are an important aspect of management to avoid repetition of localised and sequential depletions that depleted the fishery historically. Catch targets and limits have been identified by Area previously, but it is apparent from comparison of the targets and actual catches that management of catches within the intended area-specific ranges has not been successful. Considerably more catch than intended has been taken persistently from some Areas, while persistently less has been taken from others. A larger than intended catch was taken from some Areas in SMU 2, one area in SMU3, and all Areas in SMU 4 in 2016 and the first half of 2017, while considerably less catch than intended has been taken from most Areas in SMU 1, some Areas in SMU 2 and most Areas in SMU 3. A response from Industry has been to change the targets rather than better control catches.

Inability to control fishing effort and catch at local scales is not expected to have major stock consequences at low TACCs, but as TACCs increase poor spatial management is increasingly likely to cause sequential spatial overfishing, and it is possible this has occurred in the years following increase of the TACC to 130t in 2015. These recent catches resulted in stock decline and large spatial contraction of the fishery – with the implication that local areas could be vulnerable to rapid depletion if catch was concentrated on them. Confidence in the ability to control catches at this finer scale is a key consideration in management of the stock in this circumstance and, accordingly, when setting precautionary TACCs. There are proposals for a catch allocation specifically to SMU 1 though the details of this are still being developed. Such SMU-specific catch allocations, if they resulted in catch reductions in recently 'over-subscribed' Areas further south, could be an effective part of the spatial management of the fishery to avoid (further) sequential depletion.

A3.3.2. Fine scale data and interpretations

All divers in the fishery have access to GPS data-loggers though not all divers operate them on all fishing days and there are occasional equipment failures. The GPS data analysed for the 2017 assessment covered 51% of logbook diver days. The coverage in both the 2015 and 2016 assessments was reported to be 50-60% of logbook diver days. There was reasonable coverage in 2009 and 2010, as the logger program was being established, and good coverage subsequently. The data-logger information is increasingly critical to assessment, and the continuation and further improvement of the data-logger program is strongly supported by the Committee.

The logger data were used to calculate abalone density (Kg/Ha), the area of productive reef fished (Ha), biomass (t) and harvest fraction (catch/biomass). They were also used to calculate several indicators related to diving operations, including searching rate (Ha/h), the area covered per dive, the frequency of short dives, dives per day, and spatial overlap of dives. The use of logger data for these estimations is a new and evolving methodology. It is a very promising development but its reliability is not yet objectively demonstrated, and it should be tested further against proven scientific survey methods. Relative trends from logger analysis, particularly the biomass and harvest fraction estimates, are likely to be more reliable than the absolute values.

Abalone density (Kg/Ha) was calculated from the logger data for all SMUs and for most Areas for the period 2010-17. This density is proportional to biomass under the assumptions of representative observations and constant habitat area. Two methods of standardising the density estimates were used; one standardised to the average (or 50%) diver and the other to an above average diver in the 70th percentile of performance (70% diver). Standardising to the 70% diver is considered the most

appropriate because this gave results very similar to the density measured by fishery independent surveys in the southern reefs in 2013. Both time series of standardised density estimates were then calibrated to the fishery independent surveys.

The 'base case' abalone density estimates used the 70% diver standardisation and are shown by SMU in Figure A3.4.

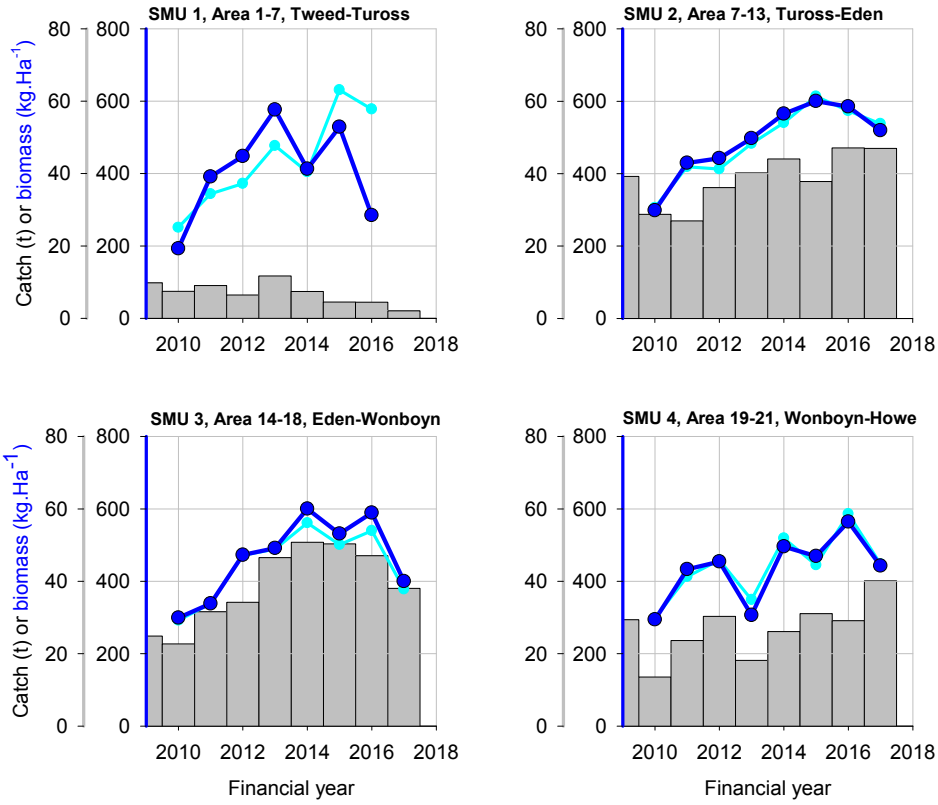


Figure A3.4. The density of legal sized abalone (Kg/Ha) for each SMU calculated from the GPS logger data using the 70% diver standardisation and calibrated to the scientific surveys conducted in some southern reefs in 2013. The pale blue line is as calculated for last year's (2016) assessment. The dark blue line incorporates additional fine scale analysis and is the 'base case' in this year's assessment.

The density indicators for all SMUs show a recent and very substantial decrease in stock abundance - of about 15-20% between the year of each individual SMU peak to 2017.

Comparison of the time series of commercial catch rate (Kg/h, Figure A3.2) and logger-based density estimates (Kg/Ha, Figure A3.5) by SMU indicates these two indicators of abalone density show substantially the same patterns. This increases confidence in both indicators, though as both are fishery dependent they both reflect only where fishing occurred, and the area fished decreased substantially from 2015. Both indicators show increasing stock abundance in all SMUs from 2010 to 2014–15. Both indicators then show substantial decreases in SMUs 2 and 3, but the recent behaviours of the indicators differ in SMU 4; the catch rate there shows substantial decrease after 2015 but the density estimate remains high until a decrease in 2017, and that decrease is less pronounced than in the other SMUs.

Comparing logbook catch rate with logger density estimates allows detection of hyperstability in commercial catch rate caused by some operational changes (e.g. in search speed). It cannot detect other causes of hyperstability, however, such as spatial effort selection or size selection which are not detectable through fishery-dependent observations. The similar patterns in commercial catch rate and logger-based density estimates throughout the time series for SMUs 2 and 3 indicates no detectable hyperstability at the SMU level there. SMU 4, however, shows sharply decreasing catch rate with variable but not strongly trending estimates of density since about 2015. This is the opposite of hyperstability (i.e. hyperdepletion) in commercial catch rate. The cause of this is not clear, and consequently it's interpretation and which indicator should have most credibility is also not clear. Analysis of the fine scale logger data would help with interpretation, but such analysis is not available and so interpretation of stock trends in SMU 4 from these indicators is uncertain. It ranges from

substantial decline since 2015 (the catch rate indicator) to some decline in the most recent year that is just below the range of variability seen in the last 4 years (the density indicator). The latter interpretation is used in estimating biomass and harvest fraction from the logger data, and this uncertainty is relevant in interpreting those estimates.

The catch rate, mean weight, and density indicators all show that significant change occurred in the stock during about 2014–2016. Some further indication about the timing of changed abalone abundance can be obtained from the dive event indicators that are calculated from the logger data. The searching rate (Ha/h) of divers increased and the proportion of very short dives (reflecting dives on sites that are quickly recognised as having unacceptably low abalone density) increased in most SMUs from about 2014; perhaps earlier in SMU 3 and later in SMU 4. There is limited experience with interpreting these indicators, but they suggest that changes in operational diving practice of the kind expected with declining stock abundance started in about 2014.

This widespread plateauing of commercial catch rate and logger-based density from about 2014–16 was interpreted at the time by the Committee as indicating that most of the recent population productivity was being harvested, resulting in relative stable stock abundance with very limited scope for further rebuilding. The lower commercial catch rate and logger density observed since then shows that the previous interpretation was over-optimistic, and catches started to exceed net population productivity during 2014–16 and ultimately caused stock reduction. Clarity in retrospect is an expected feature of trailing indicators.

The logger-derived estimates of density, productive area and biomass are given in Table A3.2, where the values relating to 'base case' in this year's assessment report are shown in red.

The biomass in this analysis is estimated by applying a constant productive area to the time series of density for each SMU, and so does not include the possibility of change in the productive area through time). Differences in the productive area assumption for an SMU change the absolute values of estimated biomass (and harvest fraction) but not the temporal pattern of relative change. The temporal pattern of estimated biomass consequently is the same as shown for estimated density (Figure A3.4). There was an about doubling of the exploitable biomass in each of the SMUs between 2010 and about 2014, and plateauing followed by decrease since then, with the biomass in 2017 reduced to about the level last seen in 2012 or 2013.

This year's base case interpretation for biomass and harvest fraction differs from last year's base case because different assumptions are made about the productive area of abalone habitat. The productive area was estimated last year for all SMUs as the cumulative area fished in the previous 3 years (i.e. 2013–14 to 2015–16). The productive area estimated in this year's base case used the same approach as last year for SMUs 1 and 2 and was estimated as the cumulative area fished in the last 3 years (i.e. 2014–15 to 2016–17), but productive area for SMUs 3 and 4 was estimated as the cumulative area fished since 2009–10 (i.e. the 'all years' estimate in Table A3.2).

The productive area estimate is intended to reflect the area over which it is reasonable to extrapolate the current density to give an estimate of total biomass. Two extreme assumptions are (1) that the current density applies only to the area currently fished, and (2) the current density applies to all areas ever fished. The same two assumptions also arise in interpreting commercial catch rate data as an index of abundance if the fished area changes (when these assumptions are called the 'variable squares' and 'constant squares' interpretations respectively), and they are relevant to the interpretations of recent catch rates in the NSW abalone fishery.

The area fished in the most recent few years is much smaller than the cumulative area fished since 2009–10 for all SMUs. The area fished in SMUs 2, 3, and 4 combined in the last 3 years is 70% of the area fished in all years since 2009–10. The reduction is particularly large in SMU 1, where cumulative area fished in the last 3y is 29% of that fished in all years, but is also large in SMU 2 (65%), SMU 3 (74%), and SMU 4 (75%). There have been particularly strong reductions in the area fished across all SMUs in the last 2y (Table A3.2) and for SMU 4 the fished area decreased by 10-20% in the last 2 years compared to just 3 years ago; 396 Ha in 2015, 349 Ha in 2016, and 325 Ha in 2017).

Table A3.2. The biomass of legal sized abalone estimated from logger data each year since 2009–10. Density (Kg/Ha) estimates are provided for two standardisations, the left one in each cell standardised to the average '50% diver', the right standardised to the 70% diver. Five estimates of the productive area are provided: the cumulative area fished in 2009-17; the cumulative area fished in the last 3 years (2014–15 to 2016–17); the cumulative area fished in the previous 3 years as used in last year's (2016) assessment report (2013–14 to 2015–16); and the areas fished in each of the last two years. Estimates of biomass are given for a range of combinations of the density standardisation and productive area estimation method. The 'base case' used in this year's assessment is shown in red text. Application of the same productive area as in last year's base case, (i.e. the 'previous years' area fished that was fished during 2013–14 to 2015–16) is regarded as most appropriate for this assessment. Density and biomass were not calculated for SMU1 in 2017 because of the very low fishing effort there.

Year	SMU 1	SMU 2	SMU 3	SMU 4
	Density (kg/Ha): standardized to 50% diver, standardized to 70% diver			
2009–10	156, 193	241, 298	242, 299	238, 294
2010–11	316, 391	347, 430	273, 338	350, 433
2011–12	362, 448	358, 443	382, 473	367, 454
2012–13	466, 576	402, 498	397, 491	248, 306
2013–14	333, 413	457, 565	485, 600	401, 496
2014–15	427, 529	485, 600	429, 531	379, 469
2015–16	230, 285	473, 585	476, 589	456, 565
2016–17	NA	420, 519	323, 400	358, 443
	Area (Ha)			
All years	779	1280	742	435
Last 3 years (2014–15 to 2016–17)	225	837	552	325
Previous 3 years (2013–14 to 2015–16)	461	873	654	349
2015–16	102	525	325	163
2016–17	13	575	360	216
	Biomass (t): 70% std & 'All years' area (70% std & 'last 3 years' area, 50% std & 'all years' area, 70% std & 'previous 3 years' area)**			
2009–10	150 (43 , 121 , 89)	382 (250 , 308 , 260)	222 (165 , 179 , 196)	128 (96 , 103 , 103)
2010–11	305 (88 , 246 , 180)	550 (360 , 444 , 375)	251 (187 , 203 , 221)	188 (141 , 152 , 151)
2011–12	349 (101 , 282 , 206)	567 (370 , 458 , 386)	351 (261 , 283 , 309)	198 (148 , 160 , 159)
2012–13	449 (130 , 363 , 266)	637 (416 , 514 , 434)	365 (271 , 295 , 321)	133 (100 , 108 , 107)
2013–14	321 (93 , 260 , 190)	724 (473 , 584 , 493)	445 (331 , 360 , 392)	216 (161 , 174 , 173)
2014–15	412 (119 , 333 , 244)	768 (502 , 621 , 524)	394 (293 , 319 , 348)	204 (153 , 165 , 164)
2015–16	222 (64 , 179 , 131)	749 (490 , 605 , 511)	437 (325 , 353 , 385)	246 (183 , 198 , 197)
2016–17	NA	665 (435 , 537 , 454)	297 (221 , 240 , 262)	193 (144 , 156 , 154)

** Note that metrics for the 'base case' presented in the 2017 assessment report used the last 3 years areas fished for SMUs 1 and 2 but the areas fished over all years for SMUs 3 and 4.

Major changes in area fished occurred starting in about 2014–15, in addition to the longer-term slow decrease since about 2012, including the following.

- The reduction in area fished in SMU 1 is thought to be primarily due to operational constraints.
- There are some operational constrains in the other SMUs but none were specifically identified as being sufficient to cause the large and widespread fishery contractions seen in the last 2 years. One suggestion was that weather conditions in the last couple of years, and specifically

a large storm in southern NSW in June 2016, prevented fishing in prime abalone habitat on the exposed parts of the coast. This suggestion potentially could explain the observed patterns, and may have contributed to it in part. There would have had to be significant disruption in all southern SMUs (2, 3 and 4) over a long period (since about 2014–15), however, for this to be a full explaination. Fishing disruption on this scale has not been reported, and appears unlikely. This would be examinable through analysis of the fine scale logger data, potentially including structured fishing sites that have been mentioned over several years in the assessment reports, but no such analysis has been provided.

- It has been suggested that reduced estimates of fished area in SMUs 2, 3, and 4 are due to reduced logger coverage in recent years, and also specifically that some 2017 logger records from divers active in SMU 3 were not available for inclusion. The recent decrease in area fished has occurred across all SMUs, however, and in both of the past 2 years, while the fraction of logbook fishing days covered by the logger observations is reported to have been in the 50-60% range throughout the past 3 years. Variation in logger coverage therefore is not considered to be a sufficient explanation for the recent large reduction in area fished, and while operational constraints may have contributed to the reduction they are not considered sufficient to explain the size and spatial scale of the reduction.

Abalone fisheries are expected to show rotational harvest at some time and space scale, in which an area may be fished relatively intensively for a time then fished less intensively or not at all for a period to allow recovery. Lower density is expected, on average, in areas that are not currently fished during harvest rotation. There are circumstances in which this would not apply (e.g. productive areas that are forgotten or not fished for operational reasons) but these are not expected to be common. Unproductive areas might be fished during exploration or occasionally checked, and these also would be expected to have lower than average density. The large contraction in the fished area during the past 2 years is not inconsistent with expectations from a declining stock or sequential depletion, both of which imply lower abalone density in areas not recently fished.

The above means that applying the average current density from areas recently being fished to the cumulative area fished over a longer period is likely to give an over-optimistic estimate of biomass and it is not considered appropriate for a base-case interpretation. The cumulative area fished in the most recent 3 years is a reasonable compromise, in principle, to estimate current productive area while accounting for rotational harvesting patterns. This approach was used as the base case in last year's assessment and it remains appropriate. This approach might be overly pessimistic when applied to the most recent 3y period (2014–15 to 2016–17), however, because, although not well demonstrated, operational constraints, such as effects of severe weather, may have limited the spatial extent of the fishery to some extent recently. It is reasonable under these circumstances to apply the same productive area used in previous year's (2016) analysis (i.e., the cumulative area fished in the 3 years 2013–14 to 2015–16), and this is used here as the most appropriate guide to interpretation (shown in light blue in Figure A3.2). The productive area estimates based on the most recent 3y period (2014–15 to 2016–17) are also regarded here as possible, however, and these give more pessimistic outcomes for SMUs 3 and 4. .

The estimated biomass and harvest fractions for the assessment base case plus what is regarded as the most appropriate interpretation are shown in Figure A3.5.

The estimated Harvest Fractions in Figure A3.5 show a consistent gradient of low to high harvest fractions from north to south SMUs. Estimated harvest fractions have differed among SMUs and varied year-to-year but have been reasonably consistent on average over the long-term for each SMU until the most recent year (2017). There was a small increase in harvest fraction in the most recent year in SMU 3 and a large increase in SMU 4. These increases for SMU 3 and SMU 4 are larger under the productive area estimates from the most recent 3y period (2014–15 to 2016–17).

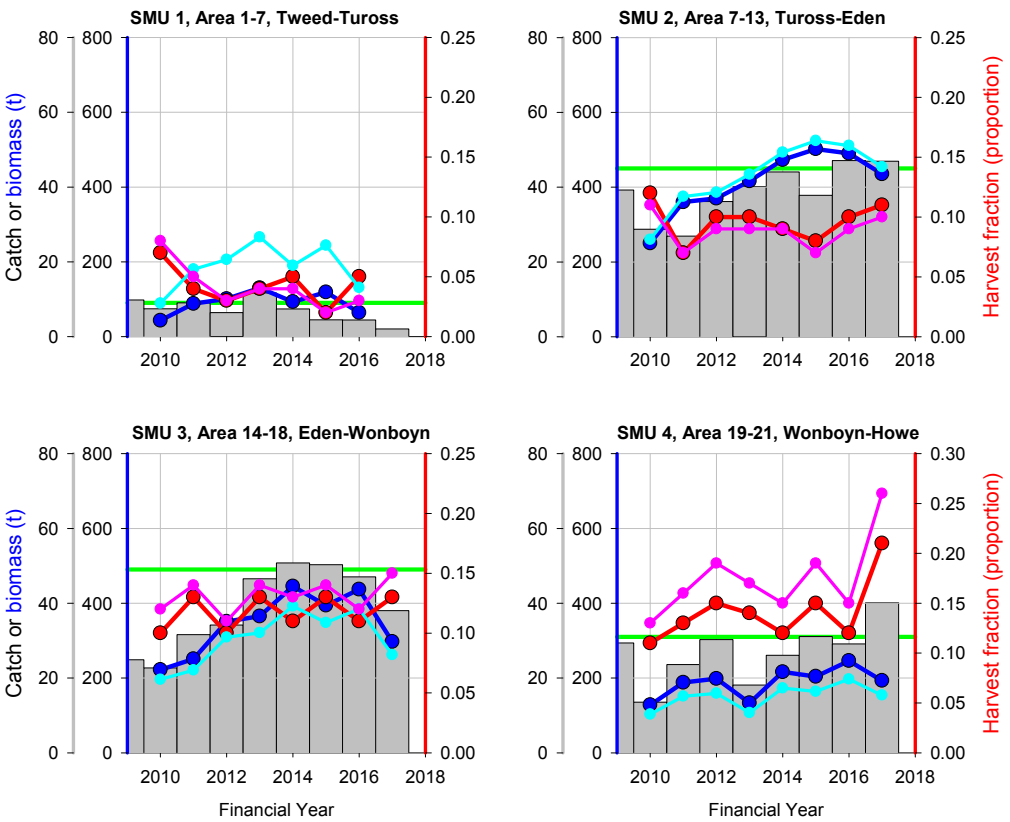


Figure A3.5. The biomass and harvest fraction (catch divided by biomass) estimated from logger data year since 2009–10. The base case from the 2017 assessment is shown in dark blue (biomass) and red (harvest fraction), based on the areas fished in the last 3 years for SMUs 1 and 2 but the total areas fished over all years for SMUs 3 and 4. The interpretation regarded here as most appropriate, which estimates the productive area from that fished in the 3 years 2013–14 to 2015–16), is shown in light blue (biomass) and pink (harvest fraction. The 2016–17 harvest fractions using the last 3 years (2014–15 to 2016–17) to estimate productive area for SMUs 3 and 4 (not plotted) show a more pessimistic scenario for those SMUs, with values of 0.17 for SMU 3 and 0.28 for SMU 4.

The harvest fractions and stock responses differ among SMUs.

- The estimates in SMU 1 are considered to be unreliable, because they are based on very small catches of questionable representativeness, but nonetheless show a consistently low harvest fraction that is considered to be reasonable. Future analysis in SMU 1 should relate the spatial coverage and densities from the data loggers with the earlier scientific monitoring locations and the experimental fishing sites in Region 1 (south) in 2007, to examine any recovery and determine harvest potential there.
- The harvest fraction in SMU 2 has been about 10% since 2010, with an increasing trend in the most recent 3 years from a year of low catches in 2015. Analysis of Victorian blacklip abalone populations have indicated that this harvest fraction should allow substantial ongoing stock rebuilding. The biomass in SMU 2 was rebuilding between 2010 and about 2014 under this harvest fraction but since then stock rebuilding has slowed and then reversed, under about the same harvest fraction.
- The harvest fraction in SMU 3 has varied from about 10–15% since 2010, with a small increase in the last year. Stock rebuilding occurred until about 2014, there was little or no rebuilding from 2014 to 2016, and then a substantial stock decrease in the last year under a harvest fraction of about 15%.
- The harvest fraction in SMU 4 has varied from about 15–20% between 2011 and 2016, and was then substantially increased in 2017. Stock rebuilding occurred until about 2015. The logbook and logger derived indicators are contradictory about trends in 2016, but by 2017 there was stock decrease and a substantially increased harvest fraction.

There was a pattern of stock rebuilding from 2010 to about 2014 across all the substantially fished SMUs, then plateauing and subsequent decline during the last about 3 years, particularly in 2016 and 2017. Harvest fractions increased somewhat in the last 3 years but the increases were relatively small except for the large increase in SMU 4 in 2017. The cessation of stock recovery and the onset of decline occurred under estimated harvest fractions very similar to those previously associated with recovery.

Comparisons of the estimated biomass in 2016–17 with the 2015–16 estimate minus the 2016–17 catch give an estimate of net population production that year. These are shown in Table A3.3 for SMUs 2, 3 and 4 in 2017 for both the base case assumptions about productive area and the assumptions regarded here as most appropriate. Both these productive area estimates give similar results and are equally feasible by this comparison. The estimated net production in 2016–17 is low for all SMUs, with absolute values close to zero or negative. Similar comparisons for years between 2010 and 2013 give considerably higher relative net production and positive absolute values. This reflects the stock rebuilding that occurred during the earlier periods under similar harvest fractions that caused stock decline in more recent years.

Table A3.3. Comparison of estimated biomass in 2016–17 (Table A3.2) with the 2015–16 estimate minus 2016–17 catch. The difference gives the surplus production in the year. The base case from the 2017 assessment is shown in red and the interpretation regarded as most appropriate is shown in blue.

	SMU 2	SMU 3	SMU 4
2016–17 Catch	47.0	38.1	40.1
2015–16 biomass (Table A.3.2)	490 – 511	437 – 385	146 – 197
2015–16 biomass minus 2016–17 catch	443 – 464	399 – 347	206 – 157
2016–17 estimated biomass (Table A.3.2)	435 – 454	297 – 262	193 – 154
Difference (surplus production, t)	-8 – -10	-102 – -85	-13 – -3

The primary conclusion about stock productivity is that it was relatively high during the earlier period of stock recovery and has been low in recent years of stock decline under similar harvest fractions. The additional information available confirms and extends the conclusions of the Committee last year that "*… there has been significantly lower stock productivity after about 2014 compared to the period 2010–2014*". The interpretations of absolute value are by necessity more uncertain, but for SMU 2 and SMU 4 they are consistent with surplus production being close to zero in 2016–17 and this is at least possible. The absolute value in SMU 3, however, shows a large negative surplus production in 2016–17. There have been no reports consistent with the implied mechanisms for this (e.g. high natural mortality, length-weight shrinkage, or large reduction in abundance of abalone growing over the size limit) and so this estimate is considered likely to be overly pessimistic. The biomass of abalone in SMU 3 in 2016–17 may be under-estimated by both assumptions of productive area, but the possibility that recent productivity in SMU 3 has been more compromised than that in SMUs 2 and 4 cannot be eliminated.

The stocks in SMUs 2, 3, and 4 all have decreased substantially in the recent 2-3 years under harvest fractions similar to those associated with stock rebuilding in earlier years, when stock productivity was higher. Continuing to apply the harvest fractions seen in the past 3 years in this context is of concern, despite the harvest fractions being much lower in some SMUs than others, because all already have resulted in stock decrease; including the modest values in SMU 2, the more substantial values in SMU 3, and the large recent increase in SMU 4. There currently is no method to predict likely future productivity for the stocks, and continued high or increasing harvest fractions applied while stock productivity is low is likely to cause rapid deterioration of stock biomass. The biomass rebuilt since about 2012–13 appears to have been lost already, mostly during the past 1–2 years.

The harvest fraction for common fishery management objectives (e.g., maximum sustainable yield, MSY) has not been calculated for NSW abalone. Victorian experience suggests harvest fractions of about 10–15% are likely to allow rebuilding after stock depletion but NSW observations indicate that the situation in this fishery is more complex because of significant periodic changes in stock productivity. These variations in productivity were known from earlier assessments (e.g., Figure A3.1) and one of the Committee's explicit intentions in setting precautionary catch levels was to prevent stock depletion during periods of low productivity, but recent decreases in productivity seem greater than anticipated.

It should be recognised that here the biomass and harvest fraction estimates mostly are being used as an empirical and relative measure. For example, the harvest fraction values that cause rebuilding or decline, or the catch and biomass values that give high or low net productivity, can be identified

empirically from the time series of harvest fraction and biomass indicators (i.e. catch rate and density). The absolute harvest fraction and biomass values themselves are immaterial in that use — so long as they are consistently related to the true values. The harvest fraction and biomass estimates are being used in an absolute sense, however, in estimating the size of net productivity or comparing the NSW values against threshold values from modelling done elsewhere.

This analysis illustrates the value of the fine scale data and its analysis. The analytic methods are not yet well developed, tested, or standardised from year to year, but they already are allowing cross-comparison with more standard indicators (e.g., logbook catch rate and mean weight) and exploration of some of the key questions of stock recovery and sustainability. The estimation of biomass from logger data is promising but the approach needs further development and testing, and especially testing against direct surveys of biomass.

The Committee strongly supports use of finer-scale information for assessment and management of the fishery and further development of verified, robust indicators for routine, and consistent, application.

A3.3.4. Illegal, unreported, and non-commercial fishing catches

The level of illegal, unreported and non-commercial (recreational and Aboriginal) catch, and trends during the history of the fishery, remain very uncertain. The Committee was informed that recent recreational catch was likely to be unchanged and less than 10 t. An aggregate catch for Aboriginal fishing was not provided specifically but the Committee was advised that legal harvest by Aboriginal fishers was estimated to be very low and consistent with permitted catch. The recent implementation of Aboriginal cultural fishing permits is not considered to have caused a significant increase in Aboriginal legal catch.

The illegal and unreported catch in previous years has been assumed to be 40% of the legal and reported catch in 1987, equating to 102t from Regions 2-6. General impressions from compliance officers and Industry are that the illegal catch probably was about 100t per year in the past, that it was likely to have been below 100t but above 50t by 2008, and to have been about 20-40t per year from about 2010. It is considered to have been trending down and in the lower part of that range between 2010 and 2013, and to have been trending up and in the upper part of the range since then. There are no precise or reliable data available to test these impressions, but they indicate that the illegal catch has been in the range 20-40t since about 2010.

It is recognised that there is likely to have been some increase in illegal catch in recent years within the 20-40t range but this is unlikely to have impacted materially stock sustainability. A recent change in illegal fishing practice was raised during the public meeting of the Committee, however, that could have stock sustainability implications: very high fishing mortality across all sized abalone applied in locally focused areas. Abalone have very low dispersal and are very slow to recolonise and recover from near total removal from an area, as illustrated by the disease impacts in northern NSW and in parts of Victoria. This fishing practice, while very damaging, would not be expected to quickly compromise the overall stock and fishery at the level of illegal catch currently considered likely in NSW. The practice of extremely high rates of removal from specific sites could give rise to cumulative sequential depletion, however, if it persisted or expanded.

A3.4 Conclusions

There was a substantial improvement in the state of the stock, starting in about 2006 but particularly since about 2009, through to 2014 or 2015. The reductions in TAC and increased LML since the mid-2000s, when those management interventions began, succeeded in that stock rebuilding. This is demonstrated by the substantial increases in catch rate, abalone density, abalone biomass, and mean weight of abalone for all SMUs over that period, which shows an about doubling of exploitable biomass between 2009 and about 2014.

Rebuilding has not persisted recently, however. All indicators in all the significantly fished SMUs (SMUs 2, 3, and 4) have plateaued and then substantially declined in the last 3 years, since about 2014, with particularly strong declines in the last year (2016–17, Table A3.4).

The timing and extent of decrease differed somewhat between SMUs but all show a very similar pattern. The catch rate and biomass density indicators show a decrease in stock abundance of 20-30% between the individual SMU maxima and 2017. The reduction from 2014 in the catch rate and biomass indicators for SMU 2 are about 20%, with reductions in the last year accounting for about half of the 3-year changes. Catch and biomass reductions from 2014 in SMU3 were over 20% and 30% respectively, also mostly during the last year, whilst catch and biomass declines in SMU4 since 2014 were around 8% and over 20% respectively, again mainly in the last year (Table A3.4).

These interpretations from logbook catch rate, mean abalone weight, and logger-based density are supported by other indicators of fishery status and operation.

- Logger-based indicators of diving operations showed changes since about 2014 of the kind expected with declining stock abundance or productivity.
- Areas of habitat fished contracted substantially starting in about 2014, and remained low in 2015 and 2016, in patterns that also are consistent with general stock reduction, sequential depletion, or both.

Table A3.4: Changes in primary indicators of stock status (catch rates, size of abalone caught) and index of harvestable biomass (stock density) in each Spatial Management Unit (SMU) over the last 1 year (top) and 3 years (bottom).

	SMU 1	SMU 2	SMU 3	SMU 4
Annual change in last year				
Standardised catch rate	+3.5%	-9.9%	-13.7%	-9.3%
Standardised abalone weight	+1.0%	-3.7%	-4.1%	-2.9%
Index of biomass (i.e. logger-based density)	-	-11.2%	-32.0%	-21.5%
Annual change over last 3 years (i.e. 2014/15, 2015/16, 2016/17)				
Standardised catch rate	-2.6%	-6.7%	-7.7%	-9.3%
Standardised abalone weight	-0.8%	-1.2%	-1.8%	-1.5%
Index of biomass (i.e. logger-based density)	-	-6.7%	-12.3%	-2.7%
Implied cumulative change over 3 years				
Standardised catch rate	-7.8%	-20.1%	-23.1%	-27.9%
Standardised abalone weight	-2.4%	-3.6%	-5.4%	-4.5%
Index of biomass (i.e. logger-based density)	-	-20.1%	-36.9%	-8.1%

Catch rate and biomass indicators show that by 2017 the abalone stock had decreased to about the level last seen in 2012–13, at about half of the biomass rebuilt since 2009–10. The stock that was rebuilt since 2012–13 now has been removed, and most of it was removed in the 2016–17 year of fishing. These declines have occurred at the highest TACCs since 2006–07 and estimated harvest fractions that previously were associated with stock rebuilding, suggesting that stocks may have entered a period of low productivity. Continuation of these harvest conditions would be expected to cause further rapid decline if the stock productivity remains low.

Several possible causes of the recent deterioration in the abalone stock status have been identified, including at the TACC Committee public forum, and considered.

1. *Increased illegal catch*. This is not regarded as a likely main cause because the illegal catch is reported to have been consistently in the range 20-40t since about 2010.
2. *Storm impact, particularly from a major storm in southern NSW in June 2016*. The June 2016 storm may have affected fishing in the 2016–17 year but no analysis was provided to demonstrate this and inspection of the aggregate catch rates in the likely affected Areas does not indicate a strong or attriutable sustained effect. The stocks appear to have deteriorated across SMUs 2, 3, and 4 beginning about 2014 or 2015, so that particular storm is not regarded as the major cause of the change in stock indicators, notwithstanding that there likely was some localised, short-term disruption to fishing, catch rates, or both. The possibility that weather patterns more generally disrupted fishing or the stock on the space scale, time scale and to the extent shown in the fishery indicators is more difficult to evaluate but, o the information available, it is considered unlikely that that could explain fully the extent and magnitude of the recent trends in abalone stock indicators. Weather conditions could be a partial and contributing cause, however, and this was taken into consideration in interpreting changes in the area fished and estimating abalone productive area.
3. *Stock rebuilding in the period 2010 to about 2013–2014 was not as substantial as suggested by the indicators, and the TACC was increased too quickly in recent years*. Catch rate, density, and mean weight indicators all showed clear and substantial evidence of increases during the 2010–

2014 period. The recently observed decreases in catch rate and estimated biomass under relatively modest total catches imply that the biomass increases achieved during the rebuilding period were relatively modest - notwithstanding the substantial increases in the catch rate and other indicators through that time. The recent changes in stock status are highly undesirable but they have provided an ability to very crudely calibrate the catch rate, logger density, and biomass indicators[4]. This is effectively what a stock assessment population model would do in a more structured and qantitative way. Both the catch rate and biomass 'calibrations' give similar results and suggest that the biomass rebuild from 2012 to 2014, then lost, was about 200t and no larger than about 400t. This is relatively small compared to recent TAC levels, and so could provide little buffer against stock decline in conditions of lower productivity. The expecation of continued rebuilding, and even stock stability, under the recent TAC levels made strong assumptions that stock productivity would remain similar to that in during 2010–2014. The crude calibrations across indicators also suggests that about 200t of the stock rebuilt since 2009–10 remains, so the stock is still improved compared to the 2009–10 benchmark. The past few years have demonstrated, however, that this rebuilt stock can be depleted quickly with relatively modest TACCs.

4. *A period of low productivity in recent years*. Episodic periods of high and low productivity are known to have occurred in the NSW abalone populations in the past, and to occur in many marine populations in SE Australia. Two elements support the interpretation that recent low productivity significantly contributed to the recent abalone population decline. The first is that the decline occurred with harvest fractions very similar to those that had previously given stock rebuilding. The second is that comparison of biomass and catch information suggests that recent surplus production was lower than it was during the period of stock rebuilding, and although the absolute estimates are very uncertain recent surplus production may have been very low in SMUs 2 and 4 and even lower in SMU3. Such a reduction in recent productivity without compensating reductions in the recent TACC would be expected to give rapid deterioration in abalone stock status.
5. *Inadequately managed spatial distribution of catch leading to sequential depletion*. The attempts to distribute catch spatially to better match productivity have not been sucessful. There have been mismatches between recommended and actual catches at both SMU and Area levels in the past several years, with some locations providing more catch than intended and others less. There now are patterns in the fishery that are consistent with sequential depletion, though there also are other possible interpretations of those patterns. Sequential depletion, if occuring, can become well advanced in the time it takes to clearly demonstrate and acknowledge its presence. It is not clear to what extent the inability to manage spatial distribution of the catch has contributed to the current deterioration of stock status, but the risk of sequential depletion is present, especially when the stock is relatively reduced and less productive, and several warning signs are evident.
6. *Relatively low Legal Minimum Length (LML).* Arguments have been made previously that increasing the LML ultimately would improve yields and protect the breeding potential of the population. Those arguments continue to apply, but in the current context of recent stock depletion and a period of lower productivity the main benefit is protection of the breeding potential of the stock. A low LML results in any stock reductions also affecting most of the breeding stock while a larger LML gives greater protection to breeding sized individuals. A low LML also allows the most productive abalone stocks, that grow quickly to large maximum size and that typically have large size at maturity and fecundity, to be overfished in both growth and egg production senses. The role of the low LML in the recent stock reductions is unclear and would take specific analysis to identify, but in principle a low LML makes a decreasing population more vulnerable to decline in egg production and ultimately to recruitment overfishing. Increasing the LML during a period of low productivity is expected to result in a slower transition of catch rate and mean size than if the same change was made during a period of high productivity, but the need to protect egg production is also greater.

[4] The recent stock reductions, in which indicators reverted to about their 2012 level, occurred over the 3 years 2015–2017 with a cumulative catch of 390t, and mostly in 2017 with a catch of 130t. If it is assumed that the stock was about constant in 2015 and 2016, with catches about equal to production, consistent with the plateauing of indicators at that time, followed by very low production in 2017, then it would be concluded that a biomass of about 130t had accumulated from 2012 to 2014 and then been removed in 2017. Assuming higher and more uniform population productivity in the entire 2015–2017 entire period implies an initially accumulated biomass less than the cumulative catch in that 2015-2017 period; accumulated biomass of perhaps about 200–300t, but no more than about 400t. The same question about the size of the recovery gained then lost can be examined using the logger-based estimates of biomass. The resulting increase in biomass between 2012 to 2014 is estimated to be about 179-206t (for the productive area assumptions of the assessment base case and the most appropriate assumptions respectively) and the estimated loss of biomass from 2013–14 to 2017 to be about 173–188t.

It is concluded that the main causes of the recent declines in abalone stocks were a reduction in population productivity beginning about 2014, combined with only a modest biomass rebuilt during the period 2010–2014, without compensating reductions in the recent TACCs. These circumstances have resulted in rapid deterioration of abalone stock status, particularly in the last 1–2 years, after a brief (variously 2–3 years) period of plateauing stock status indicators. It was noted previously by the Committee that "… *recent catches in SMUs 2, 3, and 4 have been taking most of the surplus production, leaving relatively little to contribute to further stock rebuilding*". That interpretation now appears overly optimistic and instead catches were beginning to exceed surplus production, leading to stock reduction. The reduction in area fished in the past two years as this stock reduction occurred is consistent with sequential spatial depletion, though other interpretations are possible.

Periods of low productivity have been observed previously in this fishery and they persisted for about 3–5 years. It is not known how long the current period of low productivity may persist. In this situation there is risk of further significant deterioration of the stock at current catch levels. The priority is to prevent such further deterioration and to protect the mature stock, then to recommence stock rebuilding.

The recent significant reduction in abalone stock condition is the culmination of several inadequacies in the stock assessment information and management regime that the Committee has repeatedly identified over many years. It is a stark illustration of the consequences of these inadequacies.

- The assessment information available is dominated by trailing indicators that inform about what has happened but not what is likely to happen. These can give clarity in retrospect, but there is an inevitable lag in confident interpretation during which inappropriate interpretations and management measures may be applied - as has now happened in this fishery. The logger-based data have been essential to the current interpretations by providing indicators that have allowed both cross-checks of the more traditional indicators and insights into aspects of the fishery that previously were only weakly inferrable (e.g. operational fishing changes and trends in biomass and harvest fraction). Development and testing of reliable methods of analysis and interpretation, however, has occurred very slowly since inception of the program in about 2008, and the methods being applied still have little formal scientific testing or ground-truth calibration. This fishery has been handicapped for many years by insufficient monitoring and an absence of robust, formal stock assessemtn modelling and interpretive analysis.
- Leading indicators in this fishery could (and should) include both new observations (e.g. structured surveys of sub-legal abalone abundance) and interpretations through integrated population modelling. Such requirments have been recommended repeatedly, iunclduing at least one proposal from Industry (see 2014 submission from the Abalone Council of NSW), but not implemented since 2008. The absence of data continue to constrain severely the setting of TACCs.
- The Committee has identified the weak control of the spatial distribution of catch and the low size limits as likely contributors to the historical overfishing and sequential depletion of NSW abalone stocks. The Committee has noted recently that "*The inability to manage effectively the spatial distribution of the catch risks sequential localised depletion and that risk increases as the overall TAC increases because large catches could be taken from unintendedly small areas. This is a significant impediment to confident recovery of the fishery.*" These issues remain; the fishery has taken increasing TAC from smaller areas In the past few years.

The above issues and the undesirable decline in stock status should trigger revision of the monitoring and assessment program and key aspects of the management arrangements for the NSW abalone fishery. Some recommended actions for this revision include the following, all of which have been recommended previously by the Committee:

- Develop a robust, spatially explicit assessment model to support TACC determinations and strategic management of the fishery;
- Develop and test robust indicators from the GPS data loggers that inform detection of hyperstability, hyperdepletion, and sequential depletion and estimation of density, biomass, harvest fraction, and surplus production;
- Develop and implement arrangements between industry and government to improve management of the spatial distribution of the TACC, including local catch targets and limits that provide reasonable operational flexibility whilst protecting local and overall stocks;
- Increase the overall LML to 120mm, with exceptional arrangements to allow harvest in designated areas with demonstrated and verified low maximum abalone lengths;

- Develop a harvest strategy that identifies the high level and operational management objectives, plus the monitoring information (including monitoring sub-legal abalone), assessment, indicators and reference points based on scientific analysis of all data from the NSW abalone fishery.

The Committee has concluded that the TACC for 2018 should be reduced to 100t. This is a significant reduction that is intended to protect the biomass remaining from previous years of rebuilding and to prevent further stock deterioration. It is not clear whether this reduction will be sufficient to achieve these intentions. The previous period of successful rebuilding started with TACCs less than 100t and there are interpretations of the current information under which a 100t TACC is too high. Conversely, it also is possible that conditions for increased productivity and more spatially distributed fishing may return quickly, perhaps even in 2018, in which case the recommended TACC is expected to allow some recovery of the stock biomass recently lost.

The Committee recommends that the catches in 2018 be distributed among SMUs approximately as shown in Table A3.5. This is intended to reduce catches in each SMU to below levels associated with recent depletions, and particularly to reduce the fishing in SMU 3 where productivity appears to have been particularly low and in SMU 4 where harvest fractions have substantially increased recently.

Table A3.5: Recommended catch targets by SMU for 2018.

SMU	Recommended 2018 SMU catch (t)
1	10
2	40
3	25
4	25
Total	**100**

APPENDIX 4. ECONOMIC CONSIDERATIONS — DETAILS

A4.1 Introduction

The economic status of the NSW abalone industry is described in this section, consistent with the requirement that the Committee have regard to economic and social issues in making its determination.

Discussion is provided of the data affecting the economic performance of the abalone fishery, including gross revenue, export prices, and catch per unit effort. Much of the information provided in this section is derived from the Management Report provided by NSW Department of Primary Industries (McKinnon 2017)[5] and is reproduced in this report for completeness. This section also follows a similar format to economic background information sections in previous determination reports, for consistency.

A4.2 Volume and value of production

The volume of reported catch of abalone in 2016 was 129.8 tonne (t) and catch is expected to come close to the 130 t TACC for 2017. Data to 31 August 2017 has the reported catch at 69% of the TACC, slightly lower than the proportion of the TACC at the same time in 2016 (73%). The proportion of TACC caught by the end of the season has remained above 97% since 2005–06 and has been over 99% of the TACC since 2008–09 (Figure A4.1).

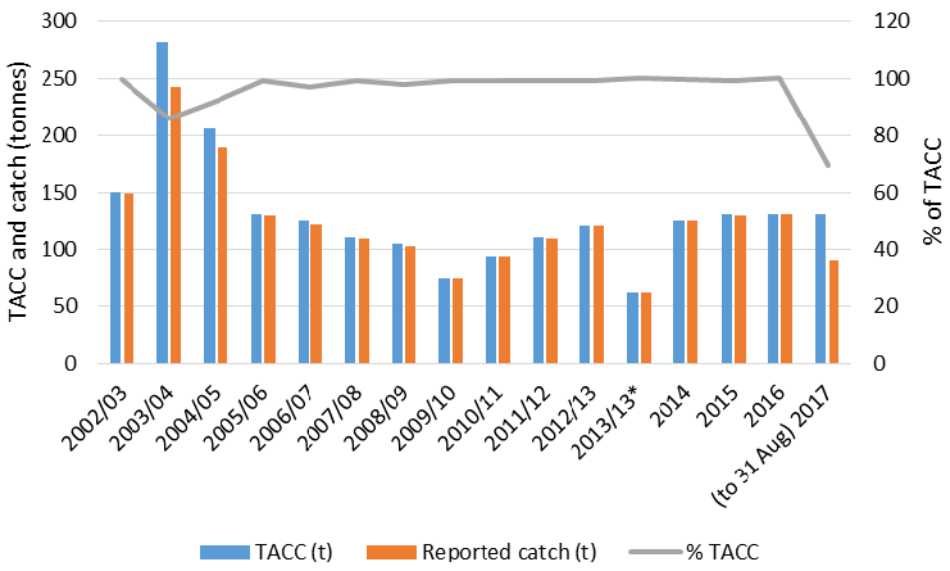
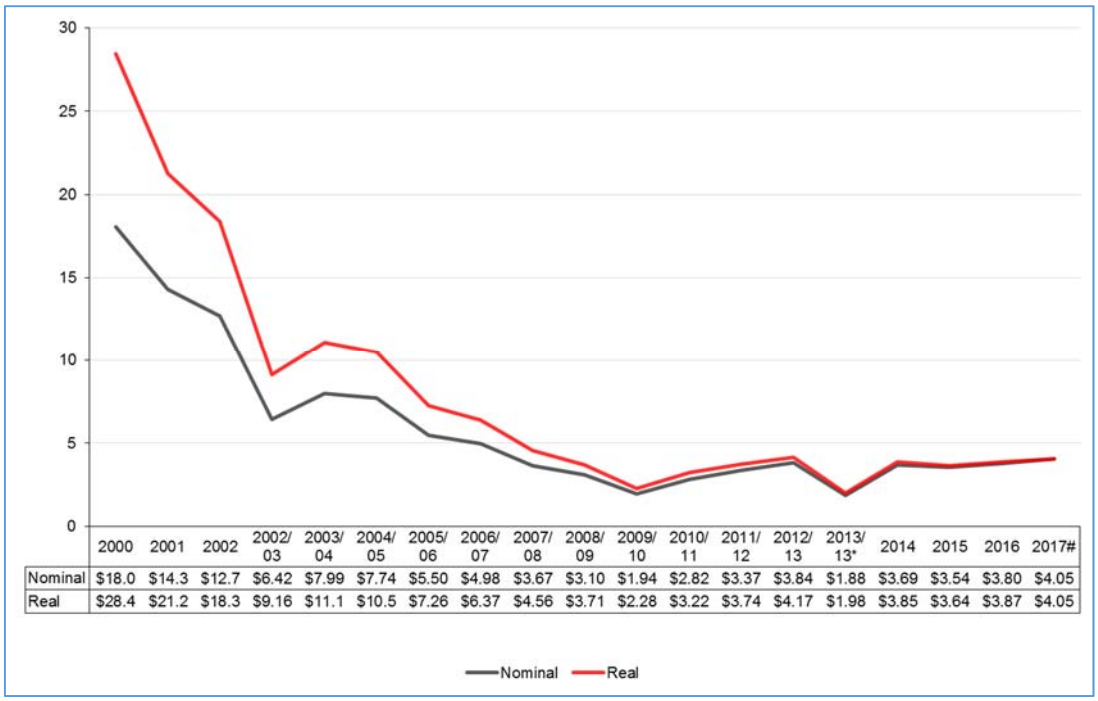


Figure A4.1. TACC (t), total reported commercial catch (t), and proportion of TACC caught (%) for each fishing period from 2002–03 to end August 2017 (* 6 month fishing period 2013).

The gross value of reported catch of abalone has remained relatively constant since 2011–12 in real terms despite the changes in TACCs over this period. Real values are CPI adjusted values using RBA "all groups" CPI data up to 2017. The 2017 gross value of production (GVP) is expected to be $4.05 million, assuming the TACC is reached (Figure A4.2). Current values are low compared to those in 2000 when the gross value of the fishery was $28.4 million in real terms due to both higher catches and higher prices. It is noted, however, that that the high levels of catch at that time were not biologically sustainable and that the price of abalone was unusually high.

[5] McKinnon, F. (2017). Management Report – NSW Abalone Fishery, Report to the TAC Committee for the 2018 Fishing Period, *OUT17/37401*. NSW Department of Primary Industries, Sydney.



	2000	2001	2002	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/13*	2014	2015	2016	2017#
Nominal	$18.0	$14.3	$12.7	$6.42	$7.99	$7.74	$5.50	$4.98	$3.67	$3.10	$1.94	$2.82	$3.37	$3.84	$1.88	$3.69	$3.54	$3.80	$4.05
Real	$28.4	$21.2	$18.3	$9.16	$11.1	$10.5	$7.26	$6.37	$4.56	$3.71	$2.28	$3.22	$3.74	$4.17	$1.98	$3.85	$3.64	$3.87	$4.05

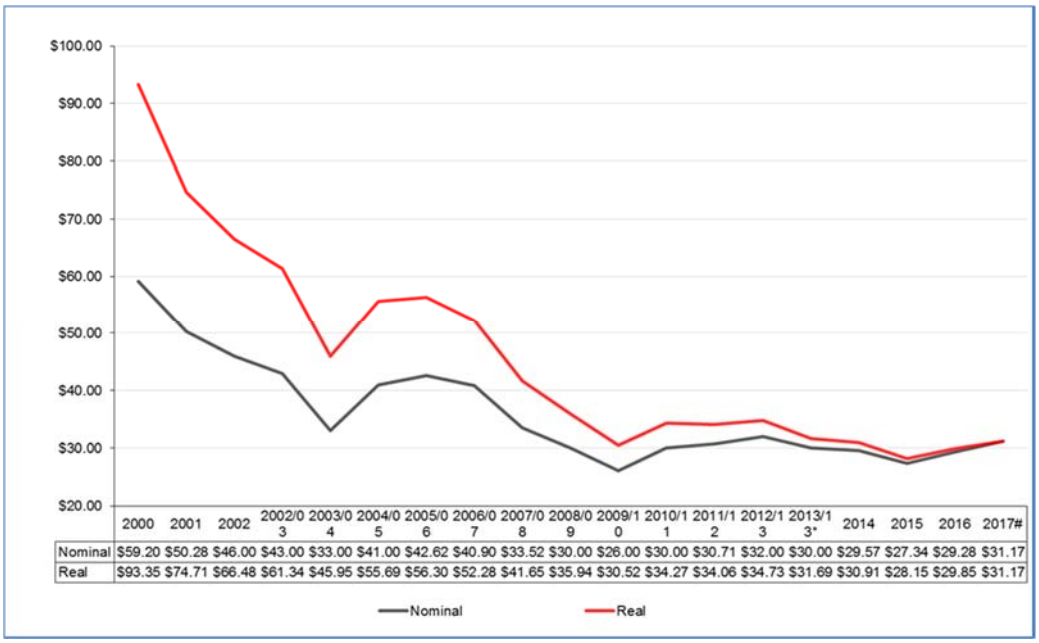
Figure A4.2. Estimated nominal and real gross value of production in the fishery ($m) for each fishing period from 2000 to the end of August 2017. * 2013–13 catch figures applied to a six-month adjusted reporting period. # 2017 value assumes the 130 t TACC is reached.

A4.3 Abalone markets and prices

The NSW abalone industry is predominantly export-oriented. Prices received for NSW abalone therefore are subject to economic conditions and exchange rate fluctuations in the main export markets, and competition from exports from other abalone exporters. Another significant factor affecting prices is increasing competition from cultured product.

The main export markets for Australian abalone are China, Hong Kong, and Japan. The main market for NSW abalone in 2016 was Japan, for which the main product was live abalone. China is seen as a potential new market for NSW abalone, with industry reporting high prices on the market for Tasmanian abalone in particular.

Beach prices for abalone are estimated from data provided to the Department by abalone processors. Real terms prices declined rapidly from around $93.35/kg in 2000 to $30.52/kg in 2009–10 (Figure A4.3). Prices have continued to decline since then but at a slower rate. Prices have declined gradually recently from $34.06/kg in 2012–13 to $31.17/kg in real terms over the first eight months of 2017 (Figure A4.3). Industry report that prices have since improved, suggesting that the price for the remainder of the season is likely to be around $34/kg.



	2000	2001	2002	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/13*	2014	2015	2016	2017#
Nominal	$59.20	$50.28	$46.00	$43.00	$33.00	$41.00	$42.62	$40.90	$33.52	$30.00	$26.00	$30.00	$30.71	$32.00	$30.00	$29.57	$27.34	$29.28	$31.17
Real	$93.35	$74.71	$66.48	$61.34	$45.95	$55.69	$56.30	$52.28	$41.65	$35.94	$30.52	$34.27	$34.06	$34.73	$31.69	$30.91	$28.15	$29.85	$31.17

Figure A4.3. Estimated nominal and real beach prices ($/kg) for each fishing period from 2000 to the end of August 2017.

Part of earlier declines in prices may be related to increasing strength of the Australian dollar against the Japanese Yen and US dollar. Beach prices have continued to fall despite a depreciating Australian dollar in recent years, however, which instead should have resulted in higher prices to Australian producers. The Australian dollar depreciated roughly 20% against the Yen and 25% against the Hong Kong Dollar during 2013–2017 (Figure A4.4), but has since appreciated against both currencies.

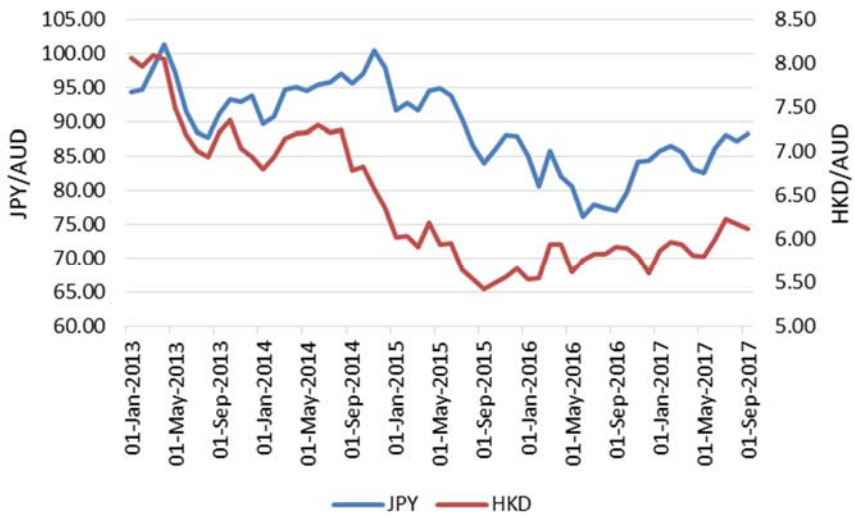


Figure A4.4. Exchange rates JP¥:AUD and HK$:AUD 2013 to 1 September 2017 (source: RBA).

The decrease in prices over recent years largely corresponds with the expansion of farmed abalone both within Australia and globally. Australian farmed abalone has more than doubled between 2010 and 2015 from 456 t to 965 t (Cook 2014[6]). Farmed abalone has increased globally from 8,700 t in 2002 to 130,000 t in 2015, while wild caught product has declined from 10,000 t to 6,500 t over the same period (Cook 2016[7]). China and Korea are the two largest producers of farmed abalone with production levels in 2015 of 115,397 and 9,400 t respectively (Cook 2016). Costs associated with producing cultured abalone are continuing to fall both in Australia and, more significantly, China and Korea. This is resulting in lower prices for cultured abalone, undercutting those for wild caught, particularly of smaller, product.

[6] Cook, P.A. (2014). The worldwide abalone industry, *Modern Economy* 5, 1181.
[7] Cook, P.A. (2016). Recent Trends in Worldwide Abalone Production, *Journal of Shellfish Research* 35, 581-583.

The challenges from decreasing prices facing NSW abalone producers also are being felt by other Australian abalone producers. Beach prices for NSW and Victorian abalone have been close to prices of farmed product over recent years, while prices for Tasmanian, Western Australian, and South Australian product have been higher (Figure A4.5). These States have variable LMLs with many areas subject to LMLs >130mm. Anecdotal evidence from Industry suggests Tasmanian prices have increased in recent years particularly for larger abalone with a premium on the international markets (particularly China). A decline in Chinese domestic aquaculture production due to a typhoon in late 2016 has resulted in a shortage on the Chinese market and a substantial price increase for Australian product exported to China. Tasmanian prices are reported to have reached $60/kg during 2017 as a result of this shortage.

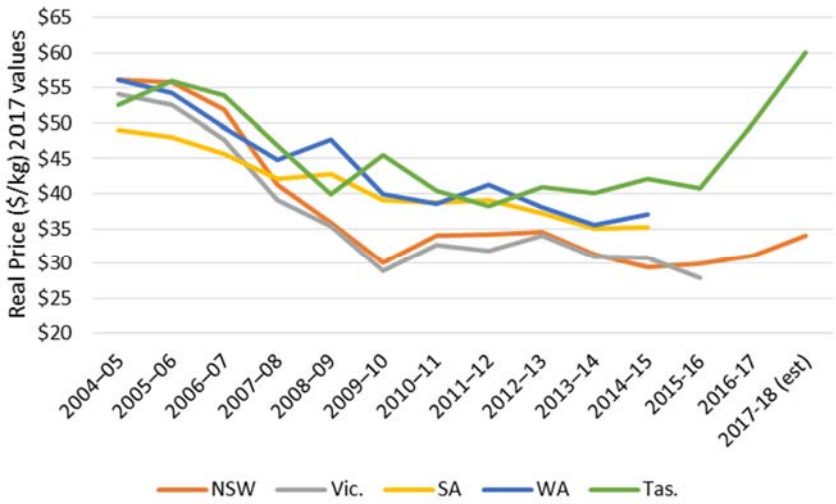


Figure A4.5. Estimated beach prices ($/kg) by State, 2010–11 to 2017–18 (real values). Data for 2015–16 and 2016–17 for NSW prices were taken from the Management Report (McKinnon 2017). Prices for 2017–18 are based on current reported prices. Prices for other years and States were derived from ABARES (2016[8]).

NSW abalone is sold through registered fish receivers, two main processing plants along the NSW coast, and a processing plant in Mallacoota, Victoria. The capacity of the two main NSW processing plants to take abalone was identified as a key constraint by many divers interviewed through a previous survey of the fishery. This also was raised by an industry representative at the TACC Committee meeting in 2016, who noted that trip limits often were imposed on fishers supplying to the processors. Preferences expressed by processing plants affected significantly decisions on days to fish, where to fish, and the size of abalone to target, aside from effects of weather or availability of quota.

The relatively small size of the NSW industry and irregularity in demand from overseas were identified in 2016 as key reasons for the processors' caps on abalone intake. Shareholders and divers continue to sell increasing shares of abalone through 'AFCOL' in Mallacoota. The absence of daily catch limits to abalone landed at Mallacoota and willingness from that processor to travel as far north as Tathra to collect product means there is likely to be increasing interest in landing NSW catch through Mallacoota, possibly accompanied by movement of effort toward the southern boundary of the NSW fishery. The location of processors to a large extent dictates where divers fish, as processors are not willing to travel long distances to pick up from a single diver. This may be particularly relevant to the northern areas of the fishery that have been fished below their recommended level in recent years and also contribute to the increasing harvest from southern areas. The Department should continue to keep a watching brief on movement in fishing effort towards the southern Areas of the fishery.

One Victorian processor indicated that size preference for abalone sold through AFCOL in Mallacoota differs from NSW processors. AFCOL cans or freezes abalone and is happy to buy a range of sizes of abalone. The strongest demand, and highest prices, elsewhere in Victoria, however, is for smaller sized (250g in the shell) live abalone, which the NSW industry can supply. A NSW shareholder, in contrast, maintained that the main processor in NSW, Pacific Shoji, preferred larger abalone to supply live to Japan. The strongest demand, and highest price, was for abalone over 130mm. The other main supplier of live abalone, Southern Ocean Seafood, sells a range of sizes, with a preference for larger animals.

[8] ABARES (2016). Australian fisheries and aquaculture statistics 2015. ABARES, Canberra.

Evidence provided to the Committee previously indicated that tastes and preferences in overseas markets were changing away from product that can be supplied easily by NSW abalone fishers. It was stated that the niche market that NSW abalone previously held in Japan in particular was shrinking due to competition from cultured product and that a separate Japanese market was emerging for larger size abalone due to a recent change in consumer preferences. Hoshino et al. (2015[9]) found that Japanese consumers did not differentiate between wild and farmed abalone on the market, and that any "wild premium" instead would result through size based differentiation in which a preference for larger abalone would be met by wild-caught product but not by farmed product, given the costs associated with the additional time it would take to grow farmed abalone to larger sizes. NSW fisher comments in 2017, however, suggest that wild-harvest abalone of all sizes may be preferred in the contemporary Japanese market. Shortage of abalone in Chinese markets also may have affected other Asian markets through increased competition for the product, with higher prices in turn being paid for NSW abalone in 2017.

The indicators above, including strong demand for abalone within current NSW LML for canning and potentially strong demand for live product larger than NSW can supply currently, indicate that it is more important than ever to investigate tastes and preferences for abalone on overseas markets, and size–price relationships for abalone. An appropriate TACC and LML for maximum economic yield can be assessed only with such information and a well-founded harvest strategy with specific economic goals.

The Committee again suggests that Industry investigate size preferences for abalone on overseas markets and size–price relationships for abalone on those markets.

A4.4 Catch per unit effort and average size

The fishery has been in a rebuilding stage over the last decade with TACCs reduced to help rebuild stock abundance. There are well known risks in relying on overall catch per unit effort (CPUE) as an indicator of stock abundance of abalone but it does provide an indication of changes in the availability of abalone to the fishery. It also reflects changes in the cost of catching the quota (discussed later).

CPUE has doubled since 2008–09 from 19.6 kg/hr to an average of 48.6 kg/hr in 2016, although decreased between 2016 and 2017 (as at 31 August 2017) to 42.6 kg/hr. These earlier increases most likely resulted from stock growth under lower TACCs and higher size limits. Higher size limits and significantly reduced numbers of fish being taken than earlier in the decade continue to put the fishery in a much better position to improve productivity and consolidate recruitment events. Industry reports that a substantial storm in mid-2016 adversely affected parts of the fishery, with fishing effort transferring out of these affected areas into the southern area of the fishery. The reduced productivity in the affected areas and the substantial increase of fishing effort in the southern region contributed to the lower catch rates observed in 2017. The estimated biomass across the fishing regions in 2016–17 also decreased by an estimated 19% overall (figure A4.6).

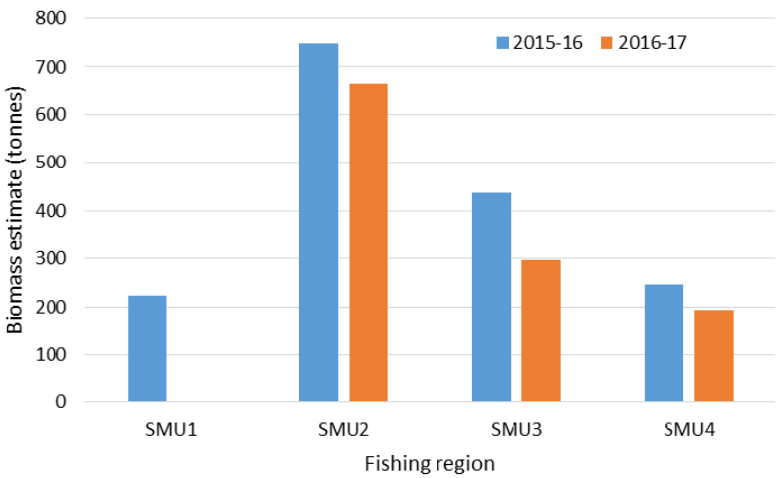


Figure A4.6. Estimated abalone biomass in each fishing region, 2015–16 and 2016–17. Source: 2017 report to the TACC on assessment of abalone stocks in NSW.

[9] Hoshino, E., Gardner, C., Jennings, S. and Hartmann, K. (2015). Examining the Long-Run Relationship between the Prices of Imported Abalone in Japan, *Marine Resource Economics* 30, 179-192

The average size of abalone in the fishery catch has risen continuously from 280g in 2005–06 to 346.9g in the first eight months of 2017. The average weight in the different areas in the first eight months of 2017 ranged from 314g–409g (Figure A4.7). The current premium market grades[10], in contrast, appear to be in the range 340g–450g, which corresponds to average lengths of 130mm–140mm. This is currently above the size range being harvested from most of the fishery but the fact that five of the areas averaged within this range suggests that it is not beyond what the fishery can achieve.

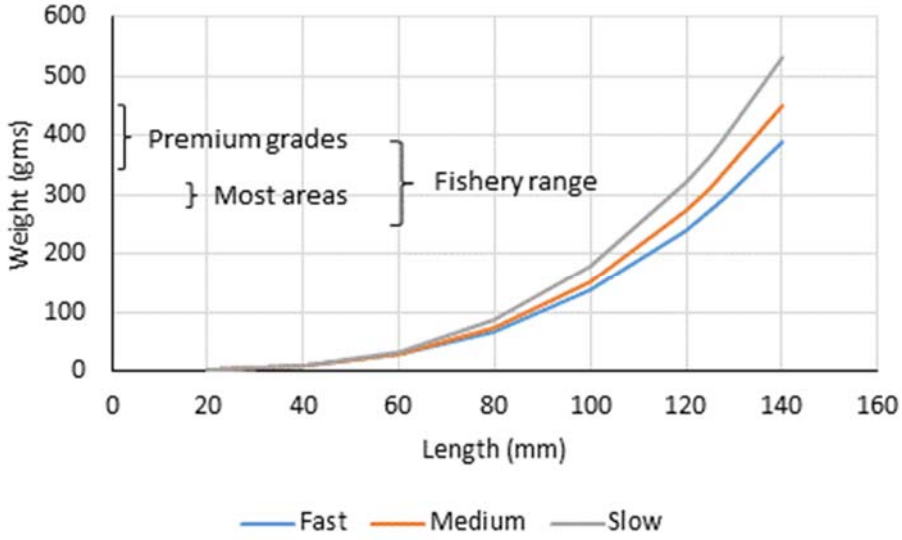


Figure A4.7. Relationship between length and weight of NSW abalone, premium market grades and performance of the fishery in 2016. Length-Weight derived from Worthington and Andrew (1998)[11]. 'Fast' refers to animals showing rapid growth in length; 'Slow' refers to animals with relatively slow growth in length.

It remains the opinion of the Committee therefore that a further increase in LML in many areas of the fishery may be appropriate and economically advantageous. There is a trade-off, however, between LML and allowable catch, and the benefits of increasing LML to achieve higher prices need to be assessed against the potential overall reduction in catch. Building the stock further to increase the proportion of larger animals also will take time and there are trade-offs between the speed at which it rebuilds and the longer term benefits against the short term costs to the industry. Previous increases in LML, however, indicate that reductions in catch have been relatively short-lived (less than 1 year) compared to the long-term improvement in CPUE and, likely, economic efficiency.

*The Committee **recommends** that bio-economic modelling analysis be undertaken to assess short-term vs long-term harvest and economic trade-offs associated with further increases in LML to inform future TACC determinations.*

A4.5 Economic performance indicators

Economic data for the fishery are not collected routinely so assessments of economic performance rely on imperfect indicators such as changes in CPUE and quota trading amounts or prices.

The Committee notes that the only available direct information on the economic performance of the NSW Abalone Fishery relates to the 2011–12 fishing period. Price, productivity, and cost conditions have changed considerably since then so these data are likely to have materially diminished relevance as indicators of current performance. The Committee would like to see analogous surveys run more regularly (every 1–2 years) to capture structural economic dynamics of the fishery.

A model of data collection that the industry might wish to consider is that of the Commonwealth Northern Prawn Fishery (NPF). The industry association collects economic information from its members which is passed to a third body for analysis. The analysed results, and de-identified data, are then available to

[10] Based on information on the Southern Oceans Seafood webpage.

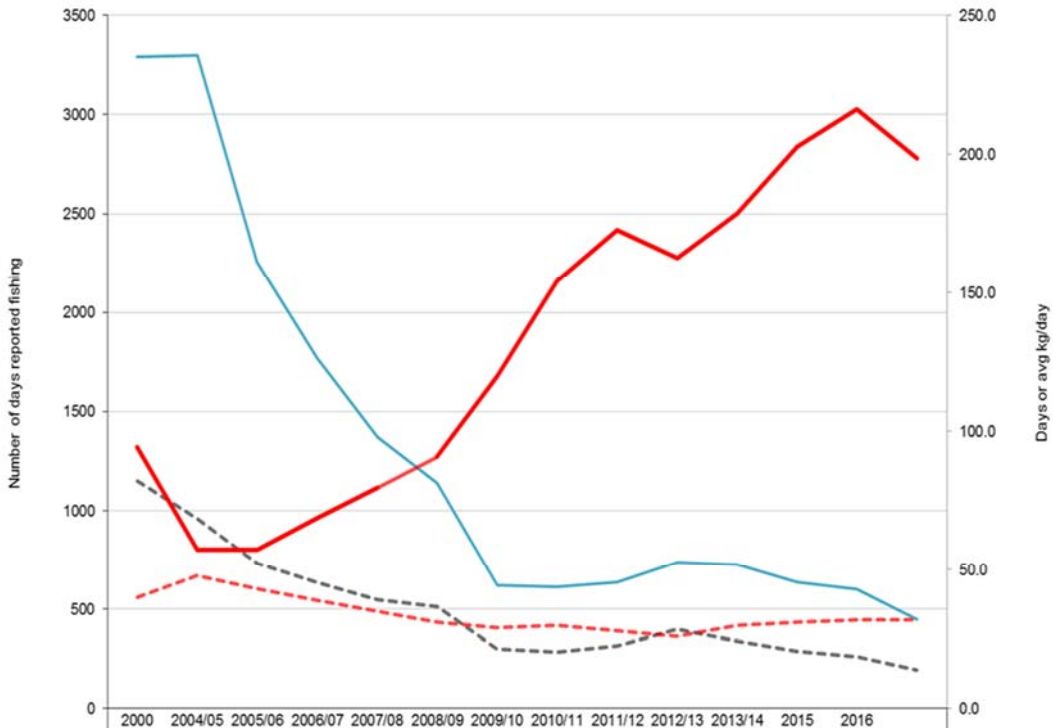
[11] Worthington, D. and Andrew, N. (1998). Small-scale variation in demography and its implications for an alternative size limit in the fishery for blacklip abalone (Haliotis rubra) in New South Wales, Australia, *Canadian Special Publication of Fisheries and Aquatic Sciences*341-348.

managers and industry to assess any implications for changes in economic performance of the fishery and provide timely input into the bio-economic modelling used to determine the next year's (effort) quota. Advantages of this model include that it is relatively low cost, backing from the industry association results in relatively high participation rates, and concerns about revealing individual commercial information to government agencies are removed by having industry contract an independent analyst, with appropriate confidentiality provisions.

Industry indicated at the public forum that they would be willing to undertake an economic survey of fishers to provide better input into the 2019 quota considerations. It would be beneficial if a regular survey could be undertaken to monitor economic performance of the industry and better assess the effects of potential changes in TACCs, given recent and proposed changes in the fishery.

*The Committee **recommends** that Industry and the Department regularly update economic data for the fishery.*

The higher catch rates of larger animals in recent years has resulted in relatively small changes in the total number of days fished to take the higher TACCs (Figure A4.8), with average days fished declining since 2014 despite an increase in TACC. This suggests that the cost per unit of catch generally would have declined over time, with an improvement in economic performance of the fishery, all else being equal. The decline in total and average days fished, however, might also reflect the reduced catch rate.



	2000	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2015	2016	
Total Number of days reported fishing	3290	3298	2257	1770	1373	1138	622	612	636	738	729	638	600	448
Average days fished per year	82.3	68.7	52.5	45.4	39.2	36.7	21.4	20.4	22.7	28.4	24.3	20.6	18.8	14.0
Average ratio catch per day	94.4	57.2	57.1	68.8	79.7	90.9	120.0	154.1	172.7	162.5	178.6	202.7	216.3	198.4
Total number of divers reported fishing	40	48	43	39	35	31	29	30	28	26	30	31	32	32

Total Number of days reported fishing — Average days fished per year — Average ratio catch per day — Total number of divers reported fishing

Figure A4.7. Days fished (total and average per diver) and catch rates since 2000. Note data gap between 2000 and 2004–05. Data to August 2017 only.

Share trading prices (based on Industry information) increased slightly between 2016 and 2017, suggesting continued optimism for the medium to longer term economic outlook for the fishery. Share prices in theory reflect longer term expectations of profitability of the fishery. The incidence of share trading in 2017 was lower than previous years (80 shares traded compared with 344 in 2016 and 254 in 2015). The limited share trading was reported to be linked to individuals increasing shareholding to enable them to become endorsed to actively participate in the fishery (i.e. hold more than 70 shares) rather an existing endorsed fishers expanding their share in the fishery.

Quota trading price information, a good indicator of short term economic performance, is unavailable for this fishery. Quota trading price information is supplied on a voluntary basis only and industry generally has not reported sufficient data on which to estimate trading prices reliably. Anecdotal information

provided by Industry, however, suggests that these transfer prices also have increased in 2017, despite other indicators of a short term decline in fishery performance. It would be helpful to the Committee if the Department required the collection of quota price data and undertook such calculations in the same manner that data on share trading prices are collected. Reporting by shareholders of all information on the price of share and quota transfers would provide invaluable information for assessing the economic status of the fishery and implementing management settings, including TACCs, which favoured optimum economic performance.

The Committee suggests that Industry make available information on the price of share and quota transfers in the abalone fishery and that the Department and Industry work together to develop more detailed information on the structure and operation of the quota market.

A4.6 Share and Quota markets

A key feature of fisheries operating with individual transferable quotas is the opportunity for fishers to adjust quota holdings to improve their individual economic performance. The potential for the economic performance in the fishery to improve is dependent on the ability for fishers to adjust their operations in response to changing stock, price, or cost conditions. This may be either long term adjustment through trade of shares in the fishery or shorter term adjustment through leasing quota on an annual basis.

The fishery has had a total of 3,454 shares since 2003–04, with the quota attached to each share determined by the TACC divided by the total share. The quota per share in 2017 was 37.64kg (Table A4.1).

Table A4.1. Quota per share and quota transfers 2003–04 to 2017 (to 31August)

Fishing period	TACC (t)	Quota (kg/share)	Total quota transferred (kg)	% TACC	Nº shareholders supplying quota
2003-04	281	76.90	34,937	12	25
2004-05	206	56.38	29,474	14	23
2005-06	130	35.58	23,428	18	21
2006-07	125	34.21	29,743	24	21
2007-08	110	31.85	24,590	22	20
2008-09	105	30.40	32,826	31	NA
2009-10	75	21.71	24,512	33	21
2010-11	94	27.21	29,911	32	22
2011-12	110	31.85	31,993	29	25
2012-13	120	34.74	36,703	31	21
2013-13*	125	36.19	17,472	28	21
2014	125	36.19	42,263	34	27
2015	130	37.64	37,413	29	21
2016	130	37.64	44,640	33	28
2017**	130	37.64	29,090	22	19

* 6 month fishing period. ** Incomplete fishing period to 31 August 2017.

There were 48 shareholders in 2017 (decreased from 51 in 2016), with shareholdings ranging between 10 and 150 shares. Thirty six of these shareholdings were eligible for an endorsement to fish in 2017 (up to August 31), which requires a holding of ≥ 70 shares. The remaining 15 shareholders were able to lease their quota to active fishers.

The Fisheries Management (Abalone Share Management Plan) Regulation 2000 stipulates that shares can be traded only in packages of 10. Restrictions also exist on quota trading, including that quota may be transferred only in lots of 100 kilograms (or as otherwise approved by the Director) and that a shareholder may not acquire by any quota transfer more than twice the amount of quota owned by the shareholder at the beginning of the fishing period. Previous Committees have expressed a concern that these restrictions may impede potential improvements in efficiency compared with what might arise if

transfers were less restricted. Share trading occurs despite these restrictions, although only around 2% of all shares were transferred in 2017, substantially fewer than the number transferred in earlier years (e.g. 21% in 2013–14).

Around one third of the total available quota has been transferred each year since 2008–09, with the number of shareholders actively involved in trading also being fairly constant. These short term and long term transfers suggest that the share and quota markets are fairly healthy despite the current share transfer restrictions[12] and are not likely to be impediments to economic performance in the fishery. The proportion of total available quota traded in 2017 (to 31 August) has been lower than in previous years, most likely reflecting changes in the economics of the fishery rather than the efficiency of the market.

The number of shareholders owning 70 or more shares generally has declined over time, with 36 in 2017 (Table A4.2). The number of non-fishing shareholders, with less than 70 shares, decreased from 15 in 2016 to 12 in 2017, suggesting that investors are engaging in the quota market as well as active fishers increasing their holdings. The 210 share cap could be considered unnecessarily restrictive as it is far smaller than would be necessary to prevent any near-monopoly situation. The Committee notes the Department's intention to amend the maximum shareholding to 40% of the total number of shares initially issued in the fishery, which should facilitate improved opportunity of rationalisation of the fishery.

Table A4.2. Distribution of shares among 48 shareholders in 2017 (to 31 August)

# Shares Held	10	20	30	50	70	80	84	90	100	120	150
# Shareholders	4	4	3	1	13	3	1	3	13	2	1

A4.7 Recreational and Aboriginal catch

Recreational and cultural catch of abalone generates non-market values to the groups that participate in these activities. Studies to estimate those values for abalone harvesting in NSW have not been done, so it is not possible to quantify associated economic values.

Recent advice suggests that abalone are not often targets of recreational fishing *per se* but are harvested by recreational divers whilst targeting rock lobster (West *et al.* 2015)[13]. Recreational take of abalone is restricted to 2 animals in possession per-person. Estimates of total recreational catch in 2013–14 were 18,423 individuals (West et al. 2015), equivalent to around 5.4 tonnes assuming an average of 300g per individual. This catch was taken across three regions – Hunter, Sydney, and mid-south coast, all north of Tuross Heads and hence in the "Northern" zone of the fishery. Commercial catch for 2016 in these areas was estimated to be 1.4 tonnes, substantially lower than the estimated recreational catch. The distribution of recreational fishing and the relatively low catch overall suggest that recreational fishing is unlikely to have material impact on the main areas of the commercial fishery. A better understanding of the economic value of recreational abalone fishing may help appropriate allocations to be made in those areas of higher recreational and low commercial harvest.

Aboriginal peoples' connection to the fisheries resource was formally recognised in fisheries legislation through the introduction of a new object to the Act, distinctly from recreational and commercial fishing. The current policy makes special provisions for Aboriginal people to take up to 10 abalone to provide for cultural needs where elders, the incapacitated, or other community members are unable to fish for themselves. Allowances also are made for cultural events in which greater numbers may be taken if an appropriate permit is obtained. There have been no attempts to equate an economic value to these cultural activities.

A4.8 Illegal and unreported removals

Previous reports by the Committee have discussed the loss of economic value from the fishery due to perceived high levels of illegal catch. Illegal take has been estimated previously to be as high as 40 per cent of legal take but the more recent compliance reports suggest that there was a downward trend in serious illegal abalone activity after about 2010 and illegal harvest in recent years has been estimated

[12] Newell *et al.* (2005), for example, concluded that the New Zealand quota market was operating efficiently with 5-10% of the total shares being transferred annually. Higher levels of quota leasing were observed, although this was largely from non-fishing quota owners to fishers.

Newell, R.G., Sanchirico, J.N. and Kerr, S. (2005). Fishing quota markets, *Journal of Environmental Economics and Management* 49, 437-462.

[13] West, L., Stark, K., Murphy, J., Lyle, J. and Ochwada-Doyle, F. (2015). Survey of Recreational Fishing in New South Wales and the ACT, 2013/14, *Fisheries Final Report Series*. NSW Trade & Investment, Sydney, pp 150.

to be 20-40t. Discussion of illegal take at the 2017 open forum suggested that there likely had been an increase in illegal activity in the last 1–2 years, such that the most recent illegal catches were likely to be nearer the upper end of that 20–40t range.

The black market demand for abalone in NSW remains potentially high but also appears to have tapered gradually from historical levels. A contributing mitigating factor affecting black market demand is the increase on the market of farmed abalone at a competitive price. The lower and more competitive prices of legally caught abalone and its availability on domestic markets also reduces the incentives for buyers to operate in the black market. Falling prices globally for abalone also reduce the incentive for illegal export operations. There appears some evidence that improved intelligence also is increasing the detection rate of illegal activity, perversely resulting in an apparent decrease in compliance rates (see Section A5.2.5). The compliance report also notes, however, that illicit buyers are becoming more attuned to fisheries compliance and new trafficking laws, which in turn is forcing the black market to be more secretive.

Compliance activities in 2016-17 have focused on buyers with some successful large prosecutions. The compliance report also notes successful cases of prosecution of aboriginal fishers taking and selling excessive catch illegally and claiming cultural rights to abalone.

A4.9 Community Contribution

The Community Contribution charge in the NSW Abalone Fishery was based on a decision by the NSW Government to return to society economic rent earned by abalone fishers. The Community Contribution for a fishing period is calculated annually and considers CPI, abalone beach price, and TACC. It is payable by each shareholder following each fishing period. The Community Contribution has been calculated at zero ($0) since 2005–06 following declines in TACCs and average estimated beach prices.

The aim of the community contribution is to return some of the resource rent generated through fishing back to the community. Resource rent represents the economic profits being generated in the fishery once all costs, including unpaid labour and a normal return to capital, have been taken into account. The results of the earlier economic survey suggest that economic rent was being generated in the NSW Abalone Fishery in 2011–12, although that calculation excluded the costs of fisheries management. True economic rent is likely to be lower than was estimated through that survey, though it is unclear whether the actual value in 2016 would be zero. Some of this rent also is not true 'resource rent' that is a result of the natural resource being used (i.e. the abalone stock). The other types of rent — entrepreneurial rent that is attributable to the skill of the fisher and quasi-rent that is surplus that can occur for external reasons such as exchange rate fluctuations — should not be removed from the fishery.

Estimating how much of each of the different types of rent is present and, therefore, how much should be extracted from the fishery each year for Community Contribution is a complex task and has not yet been undertaken, and would not be feasible without detailed economic information on the fishery.

A4.10 Economic targets and performance indicators for the fishery

The Committee notes that the economic indicators and triggers in the Fishery Management Strategy for abalone lack specificity and relevance and fail to stipulate clear management responses to trigger point violations. These indicators and triggers need to be revised as a matter of urgency to make them more relevant to measuring the economic status of the industry.

The Committee notes that such indicators should be refined and expanded as a formal harvest strategy is developed and in any revised management plan for the fishery. Economic performance indicators for the fishery should relate to long-term profitability.

*The Committee **recommends** that a more meaningful set of performance indicators and economic reference points be developed as part of the proposed harvest strategy for the Abalone fishery.*

A4.18 Conclusion

The long-term economic outlook for the NSW Abalone Fishery remains uncertain in the light of increasing aquaculture production and the effect of cultured product on global prices. NSW abalone product is competing with strong market-place competition from aquaculture product nationally and internationally.

The apparent decline in productivity, associated with a decline in stock biomass, likely will result in reduced short term profitability in the industry. This will be offset to some extent by recent price increases resulting from a reduction in Chinese aquaculture (and consequently higher Chinese and global prices).

This Chinese production reduction is likely to be temporary, so the prospect exists that recent price increases will diminish in the longer term. They provide, however, a short term opportunity for the industry to offset some of the potential revenue loss from a reduced quota whilst ever beach prices remain elevated.

Limited existing studies suggest consumers in the main export markets do not differentiate between aquaculture and wild product of the same size, though Industry comment at the most recent public forum indicated that this might be changing in some sectors of the Japanese market. Farmed product tends to be marketed at smaller sizes to avoid long grow-out periods and supply of larger individuals may be the best option for wild-harvest industries to differentiate their product from cheaper aquaculture product. There potentially are strong economic arguments, therefore, for increasing the LML for the NSW fishery.

Increasing the LML may also require a trade-off of reduced TACC, at least in the short term. The committee suggests that these trade-offs be assessed through quantitative modelling to inform future TACC setting. *The Committee also suggests that industry investigates preferences for abalone on overseas markets and size–price relationships for abalone to inform future harvesting strategies.*

Quota markets appear to be functioning well, and autonomous adjustment seems to be occurring in the fishery. Information on quota trading and leasing prices would provide useful data for assessing the short term economic performance of the fishery and help inform future TACC determinations.

The Committee also notes that economic information for the fishery is lacking and recommends that steps be taken to develop a more routine economic data collection process. Analyses of such data would inform the setting of TACCs and size limits for harvest, increase or optimise returns from the fishery, and inform the risk–catch–cost trade-offs for investing in research and monitoring for the fishery. Industry appear willing to participate in such a data collection.

The Committee notes that the economic indicators and triggers in the proposed Fishery Management Strategy for abalone are lacking in specificity and relevance. These indicators and triggers should be revised during development of a formal harvest strategy to make them more relevant to measuring the economic status of the industry.

APPENDIX 5. MANAGEMENT CONSIDERATIONS — DETAILS

A5.1. Data collection and stock assessment

A5.1.1 Recreational Fishing

Targeted surveys to estimate recreational abalone catch and effort would be required to provide robust estimates of total harvest, particularly if bag limits are increased (see below). Identifying an adequate sample size in small recreational dive fisheries is notoriously difficult and therefore expensive unless divers are identified through some type of registration such as a licence endorsement, as is the case in Tasmania. Experience in other jurisdictions would suggest that the costs of surveying divers would be prohibitive without some way of identifying an appropriate target sampling frame. Consideration therefore should be given to licensing recreational dive fishing to enable cost-effective surveys of recreational catch and effort, or some other method of identifying divers should be implemented, such as formal endorsements or statements of intent on the existing recreational licence application forms.

The Department advises that both the former Abalone Management Advisory Committee and the Advisory Council on Recreational Fishing previously have supported an increase in the recreational bag limit for abalone from two to five. The Department has advised that it intends to consider this increase in future reviews of recreational catch limits but such a review has not occurred yet. It is noted that the Department does not intend to review other restrictions on recreational effort and that the restrictions on fishing only on weekends and adjacent public holidays in the area from Port Stephens and Wreck Bay Beach, and spatial closures around heavily populated urban areas, won't be lifted.

The Committee considers that the proposed change in bag limit may result in a significant increase in recreational harvest and in particular could cause localised depletion in areas adjacent to large population centres. This proposed change highlights the need to improve the accuracy of estimates of the recreational harvest, to assess the stock taking into account estimates of all fishing mortality, and for a decision-making framework against which to assess the risks of increased recreational catches. It also raises the possibility that recreational catch could materially affect commercial catches in some Areas, particularly given the decline in stock status that now is becoming apparent. There currently is no resource sharing arrangement to manage such interactions.

The Committee considers that it would be prudent to delay any decision to increase the recreational bag limit until the current recreational harvest is known, regular monitoring of recreational catch is established, the extent of the recovery of the resource is better understood and given recent evidence of reduced stock status and productivity, and a management plan and harvest strategy for the fishery are in place to manage any increases in total catch and changes in relative share between the commercial and recreational sectors.

A5.1.2 Aboriginal Fishing

The current interim compliance policy for Aboriginal fishing allows an Aboriginal person to take up to 10 abalone to provide for cultural needs where elders, the incapacitated, or other community members are unable to fish for themselves. The arrangements apply by increasing an individual fisher's limit – it is not an accumulating limit related to the number of people for who the abalone are being provided.

Applications for Aboriginal cultural fishing permits can be made if Aboriginal people have a need to access the fisheries resource for larger cultural events. A written request to the Department outlining species and numbers proposed to be taken is required before aboriginal cultural fishing permits can be issued. Permits that have been issued over recent years are set out in Table 10 of the Department's Fisheries Management Report for the fishery, which is reproduced in Table A5.1.

Table A5.1. Aboriginal cultural event fishing permits that included abalone harvest issued since 2014–15 (frim 2017 Management Report to the TACC Committee).

	District	Target species	Maximum abalone	No. of persons attending
2014/15				
	Far South Coast	Abalone, lobster, mussel	150	>100
	Shoalhaven	Abalone, lobster	150	40
	Far South Coast	Abalone, lobster, mussel, oyster	1000	500+
2014/15				
	Far South Coast	Abalone, lobster, oyster	150	30 - 40
2015/16				
	Shoalhaven	Abalone, lobster, mussel, oyster	150	60
	Far South Coast	Abalone	200	500
	Shoalhaven	Abalone, lobster	300	300 – 400
2016/17				
	Batemans Bay	Abalone, lobster, finfish	550	100+

It should be noted that permits are issued for a basket of species, not just abalone, and so it is unlikely that the full number taken will be all abalone. Advice from the fishery compliance officers is that actual take is significantly less than the amounts formally permitted, suggesting that such catch is unlikely to have a detectable impact on the resource.

A5.1.3 Commercial Fishing

Formal catch and effort information is collected through regulated logbooks and managed in a Departmental database (the quota management system). The data logger program is implemented by the Abalone Council of NSW as a service provider to the Department. The Abalone Council of NSW (and specifically one of its Directors, Duncan Worthington) provide scientific services under contract to the Department, using the Department's catch and effort data and the logger data. Data loggers are not mandatory but are used by a majority of divers. It is the position of the Abalone Association of NSW as stated at the TACC meeting that loggers be made mandatory. The stock status sections of this report discuss in detail the commercial fishery data and their implications, and the shortcomings in the available data and analysis.

The Council's presentation to the Committee and subsequent provision of data on request again built on the feedback from previous years, with some useful simplifications in presentation but also some inconsistencies that undermine the Committee's confidence in the information presented and underscore the need to continually interrogate the analysis provided. It is still the case therefore that work is needed to identify the key indicators that should be used in decision-making, to standardise and document how the data will be treated, and decide what analyses would best inform the management of the fishery. This should be done through the development and implementation of a harvest strategy.

A5.2 Current management arrangements for the commercial fishery

A5.2.1 Quota management system, size limits and finer spatial scale management

The core management arrangements in the commercial abalone fishery are the system of individual transferable quotas and Minimum Legal Length (LML) regulations. The history of these management tools is outlined in previous reports. These measures are relatively blunt instruments for managing an abalone fishery in the absence of explicit spatial management arrangements. Species like abalone with relatively low movement among local populations often have different recruitment, growth, and productivity characteristics in different areas and also are vulnerable to 'hyper-stability' of catch rates where catch rates can continue to appear healthy or stable as successive local populations are targeted even though the stock overall is declining. The existing management tools need to be applied differentially, at a finer spatial scale, to be more effective and appropriate to the abalone fishery.

Spatial management

NSW has implemented some finer scale management of the commercial abalone fishery, to a small extent, with voluntary catch caps for Areas and two LMLs, 117mm for most of the fishery and 123mm from Wonboyn south. This spatially explicit management system is being developed and implemented informally, however, without penalty for non-compliance. The industry is to be commended for the progress that has been made in this environment but the system requires further work to improve its consistency, rigour, transparency and, ultimately, its effectiveness at regulating catch spatially. The last three years of fishing have demonstrated that voluntary caps have not been implemented to keep fishing levels at those recommended by the Committee for some Areas. The Committee therefore is not recommending Area caps in making the TACC determination this year, given evidence that effective mechanisms for implementing such recommendations do not exist. The revised TACC for the whole fishery is not based on Area-specific limits, though catch limits for the larger Spatial Management Units (SMUs) are recommended.

A5.2.2 Management plan and decision-making framework

The current management plan is obsolete. It does not reflect the status of the stock, changes in monitoring and assessment, or (informal) implementation of fine scale approaches and knowledge of the resource, and it contains inappropriate targets and indicators.

The fishery has no long-term objectives, meaningful indicators, or reference points, which materially impacts TACC decisions (e.g. what rate of rebuilding is desired, what trade-offs should be made between total yield, catch rates, or range of size classes available). Defined objectives for the fishery and, in particular, the operational objectives contained in a harvest strategy would guide these decisions and inform the balance of the various risks.

The lack of a meaningful harvest strategy and management plan leaves the fishery in a very uncertain management environment. There is no structure to maximise the benefit from the fishery in the medium to long term and no basis on which to make decisions about the appropriate level of investment in either the fishery's management or fishing businesses. Lack of guidance to the decisions that can be made mean that there is no explicit choice between growing the fishery to its potential or, alternatively, to stabilise it more conservatively at some lower stock levels. There was constructive discussion this year at the TACC public forum by members of the Abalone Association of NSW about the central importance of stock security and a preference for conservative decision-making and secure stock rebuilding. This discussion would be a positive starting point for developing a harvest strategy for the fishery and specifically for articulating the objectives for the fishery.

The Department's initial work to prepare a draft interim harvest strategy was seen as a significant step forward in meeting the deficiencies in the current management arrangements. That work has not progressed since 2015 but, ideally, the ongoing harvest strategy will sit within a revised management plan for the fishery, which the Committee continues to recommend as an urgent priority. The revised management plan should, among other things, formalise the co-management arrangements in place for the abalone fishery and establish appropriate governance mechanisms to ensure agreed regulatory mechanisms function as intended.

The Committee is firmly of the view that the development of a harvest strategy is a role of fisheries management. Science is fundamental to a good harvest strategy but it is not the only factor. Harvest strategy development should be led by fisheries managers skilled in bringing relevant stakeholders together and creating an objective-driven framework that provides structure for trade-offs and risk-weighted decisions, informed by appropriate research and monitoring.

A5.2.3 Co-management

The history of industry involvement in the management of the fishery has been documented in previous reports. The relationships between government and industry has at times been acrimonious. The industry appears to have been moving to a greater level of consensus as the stock has improved over the last decade and cautious TACC setting is appropriate but the advisory and co-management processes remain relatively unstructured. Standard governance arrangements such as the use of independent chairs, Departmental oversight of industry driven research, communication protocols, peer review processes, etc., have been identified in the past for consideration.

The Committee's observation is that the input of the Abalone Association of NSW into the management of the fishery in general, and TACC decision-making specifically, in the last two years has been very constructive with markedly improved relations with the Department. The Committee has confidence that it is being provided with balanced and strategic advice from the Association.

A5.2.4 Fees

The abalone fishery is subject to the Government's policy on cost recovery whereby shareholders must meet all identified management costs attributable to the commercial fishery, less any savings passed on to shareholders. Management charges are payable by each shareholder in proportion to shareholdings. The management charge is reviewed and re-determined annually. The management charge for 2017–18 remained at $64.21 per share, the same as the previous year.

The Department outlined the following in relation to how the charge was calculated:

The management charge is based on:

- Salary costs for staff directly providing administration services to the commercial fishery as well as those conducting the policy development and research (external service) needed for effective management of the Fishery.
- Operating costs associated with the above fishery management services along with compliance operations.
- Contribution towards corporate overheads (estimated as 48% of base salary costs).

less

- An "efficiency" discount of 30% on the corporate overheads contribution.
- An "efficiency" discount of 20% on total salary costs.
- A proportional recreational discount of for the indirect benefit to recreational fishers.
- A discount of 6.65% to offset the increase in shareholder costs due to the cancellation of shares in marine park buyouts.

Abalone shareholders may be required to make an annual Community Contribution for the right of access to the fisheries resource, similarly to other share management fisheries, but the community contribution for the abalone fishery has been set at $0 since 2005–06.

The Committee has noted before that the decision to drastically reduce funding for research and monitoring in 2008 had over-whelming support from shareholders but also notes that that decision has left the fishery in a difficult position with respect to management decision making. The consequences of the reduction and the flow-on effects to the task of setting a TACC have been discussed extensively in previous reports and we note again here that absence of robust assessments will continue to constrain TACC setting whilst ever this low investment persists.

An immediate priority for the fishery is the development of a harvest strategy, led by an experienced person with fisheries management expertise. Insufficient resources are allocated to fisheries management currently (less than 0.5FTE) as part of the cost recovery process to lead such development. It is in the industry's and the fishery's interests that this work is resourced – whether that be through licence fees or some other mechanism.

A5.2.5 Compliance

Reporting on compliance and infringement detection rates is notoriously difficult as improvements in the targeting of compliance effort can lead to more offences being detected, which then can appear as higher levels of non-compliance when reported statistically. Use of an intelligence-led approach should lead to a higher rate of detections and therefore seemingly lower rates of compliance, at least initially. It is difficult to draw conclusions from crude 'compliance rate' information, therefore, without supporting qualitative explanations or separation of metrics about intelligence-driven targeted enforcement from more routine 'on patrol' compliance data.

The licensed commercial compliance rate of 57% in 2017 (Table A5.2) has stabilised (last year 52%) but is consistent with an overall downward trend in compliance rate over the last ten years from a high of around 90% in the period 2005–08.

Table A5.2. Compliance rates by sector.

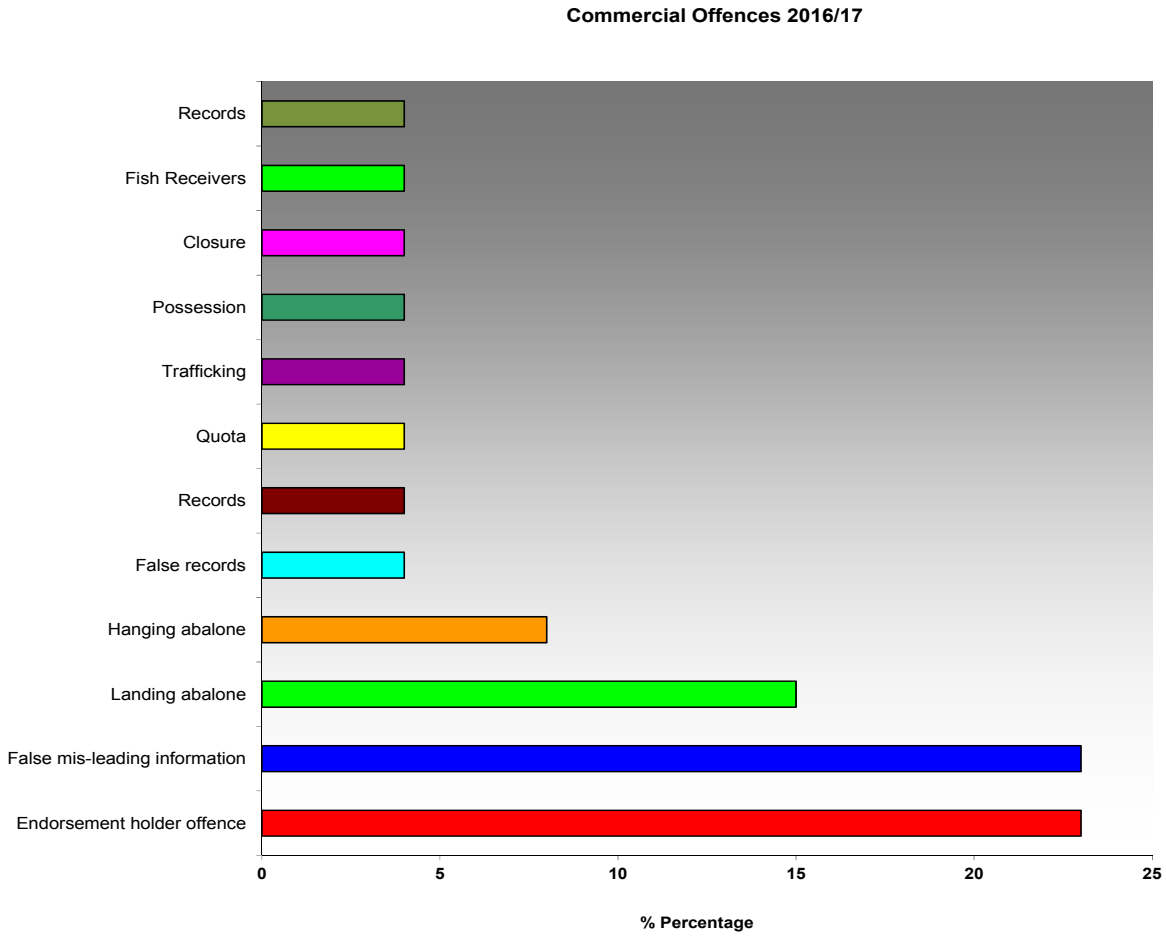
	Compliance Rate				
Compliance activity type	**2012–13**	**2013–14**	**2014–15**	**2015–16**	**2016–17**
Unlicensed and recreational	56%	69%	73%	63%	73%
Licensed commercial	71%	51%	64%	52%	57%

Table A5.3. The amount of compliance effort put into the abalone fishery in recent years.

	Compliance Effort (hours)					
Compliance activity type	**2011–12**	**2012–13**	**2013–14**	**2014–15**	**2015–16**	**2016–17**
Unlicensed and recreational	4670	4790	3189	2390	2090	2358
Licensed commercial	1478	1654	452 (37 QA inspections)	402 (33 QA inspections)	461 (27 QA inspections)	569 (18 QA inspections)

Figure A5.1 has been reproduced from the Department's Compliance Report – Abalone September 2017. It displays the frequency and the type of offences that have been detected in the commercial abalone fishery during the 2016–17 period. The commercial offences reported in the 2016–17 period were dominated by 'Endorsement holder offences' (23%), 'False and misleading information' (23%), and 'Landing abalone' (15%) offences, and predominantly were in the southern part of the fishery. These offences represent a shift to more serious offences from the previous year which was dominated by infringement notices in relation to administration of the quota system and catch returns.

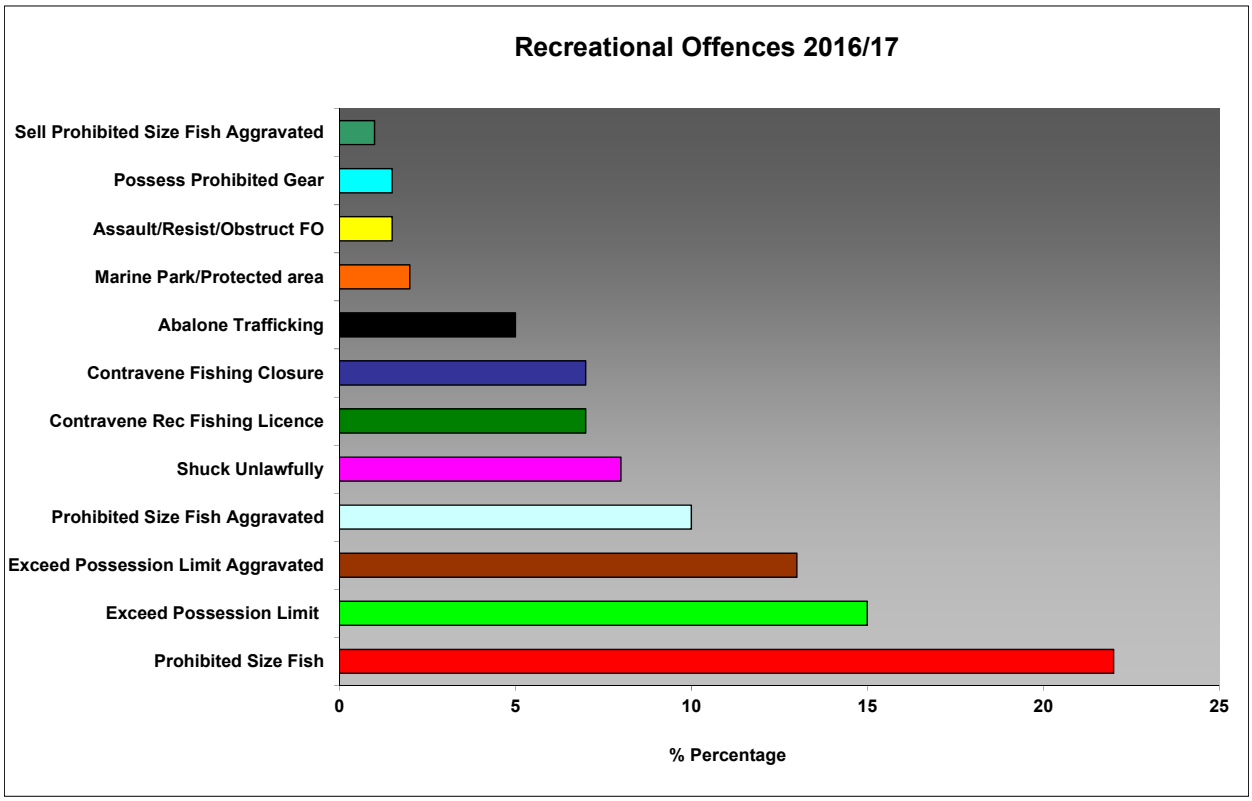
Figure A5.1. Frequency of offences of different types detected in the commercial abalone fishery for 2016–17.



The 'unlicensed and recreational' compliance rate includes offending by fishers undertaking genuinely recreational fishing, either with or without a licence, as well as intentional illegal fishing of a commercial nature but that is unlicensed. The compliance rate (73%) has increased compared to the previous year and is back at the upper end of the range seen over the last ten years of 75%–56%. Nevertheless, the most common offences in the unlicensed sector were serious offences, reflecting some major post-harvest operations in Sydney focussing on illegally-taken abalone at the point of sale.

Figure A5.2 has been reproduced from the Department's Compliance Report – Abalone September 2017 and displays the frequency and the type of offences that have been detected in the recreational and unlicensed abalone fishery during the 2016–17 period. The top three recreational offences recorded in the 2016–17 period were 'Possess prohibited size fish' (22%), 'Exceed possession limit' (15%) and 'Exceed possession limit in circumstances of aggravation' (13%).

Figure A5.2. Frequency of offences of different types detected in the unlicensed and recreational abalone fishery for 2016–17.



A5.4 Total Allowable Commercial Catch (TACC) for 2018

The Committee last year retained the TACC at 130 tonnes, the level first set in 2015 with explicit explanation of the importance of a spatial management regime to be implemented to avoid serial depletion of the stocks. The Committee noted that "*… if [neither] the requisite 'northern zone quota' nor the 'cap and close' arrangements are in place for 2015, the impact of the 130t TACC on the fishery could be to further slow the rate of recovery for the fishery and in particular in some Areas. Future TACC determinations will take this into account.*" The continued absence of any formal spatial management arrangements means the Committee is bound to take an appropriately precautionary and conservative approach to setting future TACCs.

More worryingly, signs have emerged in recent years that the performance of the fishery may be being impacted by reduced recruitment, sustained catch pressure on some areas, and lower recent productivity. The precautionary strategy of the Committee in this context has shifted from one of maintaining the TACC to now reducing the TACC in the interests of protecting the abalone stock from further decline.