SMALL BIVALVE SURVEY, ASSESSMENT AND STOCK STATUS UPDATE: 2016

Ostrea angasi - Georges Bay

Venerupis largillierti - Northern Zone, Georges Bay

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Executive Summary

Flat Oyster STOCK STATUS	SUSTAINABLE
Biomass in the Flat Oyster fishery is estimated from diver quadrat counts which are extrapolated across the area of the oyster beds to provide an estimate of overall biomass. Total biomass was estimated in 2016 as 391.3 tonnes, which is above reference points of historical lows. This means the fishery is not overfished. The allocated total allowable commercial catch was 10% of the stock which is a level that implies low risk of overfishing. The combination of biomass that is not overfished and fishing mortality that has low risk of overfishing results in a classification for this stock of sustainable.	
STOCK	Georges Bay
INDICATORS	Randomised quadrat based biomass estimates, catch.

Venus Clam STOCK STATUS	ENVIRONMENTALLY LIMITED
Biomass in the Venus Clam fishery is estimated from quadrat counts that are extrapolated across a defined region where fishing occurs. This means that the biomass estimate is for the total biomass within the active fishery area, not the total biomass of Georges Bay. No estimate of biomass was made in 2016 because fishers had observed sharp declines in stock. A large reduction in CPUE in 2015 and 2016 along with the associated catch being significantly lower than the available TACC suggest that biomass in this fishery has been depleted to the point that recruitment could become affected. Since 2013 catches have been < 8% of the estimated fishable biomass and fishing mortality is likely less than indicated by this percentage because Venus Clams also occur outside the defined beds that are fished and used for the biomass estimate. Previous assessment on length frequency distribution in 2014 indicated that a settlement pulse had occurred but this has failed to translate to significant recruitment to the fishery. On the basis of the low rate of fishing mortality, the reduction in biomass is most likely attributable to environmental causes. For fishing year September 2015 – August 2016 the two Georges Bay Northern Zone licensees took a voluntary reduction in TACC to 3 t (< 1% of estimated biomass of 2014). This voluntary reduction in TACC has been extended by the licensees for fishing year September 2016 – August 2017 and implies that fishing mortality is negligible and may allow recovery in this fishery. On the basis of the low rate of fishing mortality, and the pattern of length frequency data, the decline in stock is attributed to environmental causes.	
STOCK	Georges Bay Northern Zone
INDICATORS	Randomised quadrat based biomass estimates, catch, CPUE trends.

The four commercial small bivalve fisheries in Georges Bay and Ansons Bay are surveyed every two to three years for the purposes of estimating total biomass and assessing fishery status in order to assist with the allocation of quota for the forthcoming fishing year. In 2016, a stock assessment with total allowable commercial catch recommendations (TACC) was conducted for the Flat Oyster *Ostrea angasi* fishery in Georges Bay. A limited pilot survey was also conducted for the Georges Bay Northern Zone Venus Clam *Venerupis largillierti* fishery in response to a voluntary TACC limit being agreed prior to the assessment period.

The *O. angasi* survey recorded an increased estimated area of fishable reef than previously used for assessments and a best estimate of total biomass of 391.3 tonnes (± s.e. 362.6 – 420.0). Best estimates of total abundances from survey data across the fishing area suggested that there was a 90% chance the total abundance exceeded 5.3 million oysters. The current harvest fraction for *O. angasi* is set at 10% of the estimated total biomass. TACC recommendations are provided in the form of probability tables calculated from estimated total biomass and converted to counts per dozen at the 50th, 20th and 10th quantile of the estimated total biomass mean. The TACC allocations presented in the probability table provide a choice in certainty that the estimation of total biomass is greater than the probability value. The low proportion of annual catch to TACC recorded in the *O. angasi* fishery since 2008 would suggest that the current level of fishing pressure is unlikely to cause the stock to become recruitment overfished. In accordance with national stock status definitions, this fishery is assessed as sustainable. Recommendations to changes in the harvest strategy for this species are given in light of the DPIPWE shellfish rules document review for 2017. These recommendations follow Commonwealth Harvest Strategy guidelines for the inclusion of limit reference points with harvest strategies.

The *V. largillierti* area survey for 2016 recorded an estimated fishery area of 99,713 m^2, which represented a slight enlargement to the estimated area in 2014 but lower than previous survey records in 2003, 2009. There were also substantial changes in the location of the *V. largillierti* beds in 2016 compared to previous years. No formal biomass survey was conducted in 2016 due to the voluntary reduction in TACC to 3 t agreed by licensees for fishing years ending August 2016 and August 2017. The large reduction in catch and geometric mean catch per unit effort (CPUE) data from fishing years ending 2013 to 2016 are interpreted as a decline in biomass which may have been caused by change in environmental conditions affecting recruitment. With total catches for 2013-2014 at <8 % of the estimated fishable biomass fishing mortality is unlikely to be responsible for biomass decline. Cohorts of undersize clams identified in 2014 would have been expected to reach the LML in 2015 - 2016 but have not been sufficient to rebuild stock. Based on national stock status definitions this species is assessed as environmentally limited. The current low TACC and subsequent minimal level of fishing pressure may be expected to allow the stock to recover provided suitable environmental conditions exist. A small pilot survey in one of the fishing beds indicated evidence of pre-recruits and marketable size animals which may provide a basis for the recovery of the fishery in the future. Recommendations to changes in the harvest strategy for this species are given in light of the DPIPWE shellfish rules document review for 2017. These recommendations follow Commonwealth Harvest Strategy guidelines for the inclusion of limit reference points, which will assist in reducing the risk of recruitment overfishing in the future.

Contents

Ostrea angasi

Background

In Georges Bay, north-east Tasmania, a commercial dive fishery has operated for the native flat oyster (*Ostrea angasi*) since approximately 1985. The fishery operates on mixed species shellfish beds with the area harvested varying between years (Figure 1). Until 2007 the fishery was managed principally through the allocation of half yearly or yearly permits. From the start of fishing year 2007 a formal TACC structure was introduced with two associated commercial licences. TACC allocation is based on fishery dependent surveys of estimated total biomass conducted every two or three years with the TACC set as equal to 10% of the estimated total biomass. Legal minimum length of *O. angasi* has been set at 70 mm shell length on the basis of market demand. In recent years' market demand for *O. angasi* has been weak, and consequently harvest levels are typically less than the available TACC. Total catch and catch per unit effort data are available for this fishery from 2007 onwards, with the fishing year running from 1st September to 31st August.

Figure 1. Example of mixed species shellfish bed in Georges Bay, St Helens.

Objectives

This is the third report on the status of the *O. angasi* fishery since the introduction of TACC in 2007. Its objectives are; 1. Provide an estimate of the total biomass of *O. angasi* in Georges Bay. 2. Use this information to provide a probability table of TACC allocations for 2016-2017 fishing year. 3. Assess previous years CPUE and catch trends with reference to the allotted TACC.

Methods

The survey design for 2016 is consistent with methods used in other small bivalve fisheries in Australia (Dent et al. 2014), but varies from the previous assessments of 2010 and 2013 (Tarbath 2010, Tarbath and Gardner 2013) in that the total area of the fishery surveyed and used to estimate biomass only includes areas considered to be active fishing grounds by the licenced fishers. Prior to the survey each licenced fisher was provided with a high resolution image of Georges Bay with previously surveyed oyster beds clearly marked (appendix 1). Each fisher was asked to submit an annotated version of the image with any additions or subtractions to the fishing grounds and this information was digitized (manifold.net) with the resultant GPS file used to guide the survey area design. Drop lines were deployed from the survey vessel prior to survey at the boundaries of the oyster beds identified by fishers. A total of 87 quadrats (50 cm x 50 cm) were sampled by commercial diver within the bounds of the beds by systematic sampling across the long axis of the bed. Due to the current within the bay exact positioning of the quadrats was not always achievable, however each quadrat position was marked by GPS and used to guide subsequent quadrat position. From each quadrat all *O. angasi* present were harvested, returned to the vessel and measured across the longest axis (± 1mm) using electronic measuring boards, before being returned to the fishing grounds.

Survey area was calculated as the maximal polygon area of the fishing beds surveyed including all quadrat locations and boundaries positions (drop line locations) using manifold GIS software (manifold.net). Weight estimates for each oyster were calculated from length-weight relationships previously established for this species in Georges Bay (Figure 2).

$w = 0.0002*l^{2.8924}$

where *w* is the estimated total weight of *O. angasi*, and *l* is the shell length at longest axis.

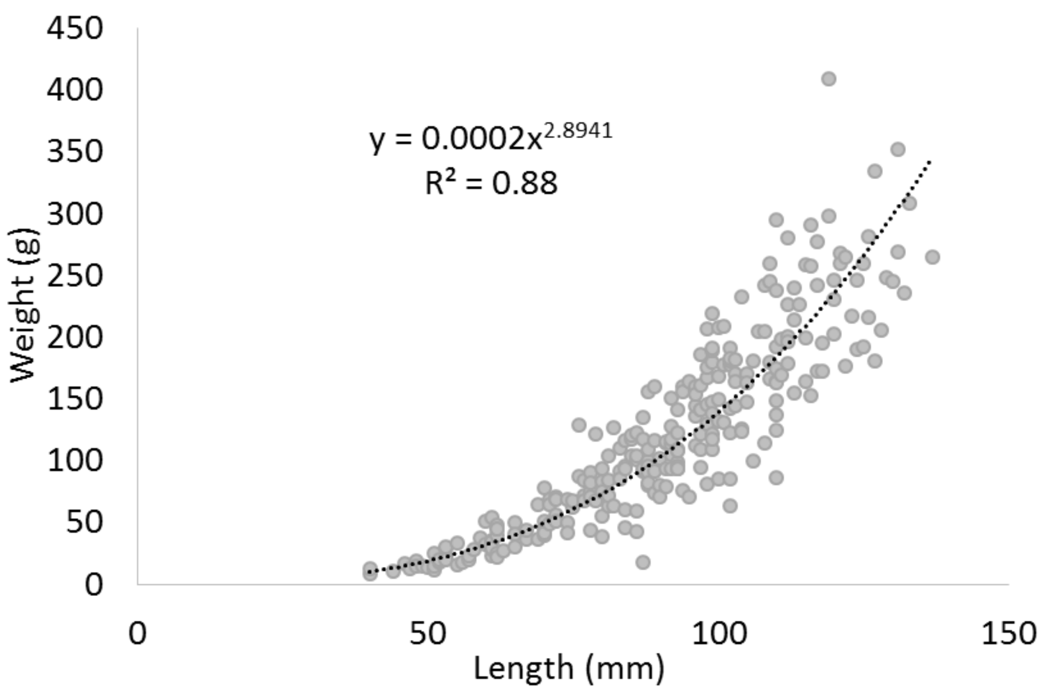

Figure 2. Length-weight relationship of O. angasi from Georges Bay (data from TAFI 2008, Tarbath 2010).

Estimation of total abundance of *O. angasi* across the survey area were calculated as the mean density per m^2 multiplied by the survey area. A non-parametric bootstrap method (100,000 iterations with repeats) was employed to extract the 50th, 20th and 10th quantiles of the bootstrapped mean with standard errors. Estimates of total survey area abundance are reported together with the estimated abundance as dozens (total abundance/12).

Estimation of total biomass of *O. angasi* across the survey area was calculated as the mean biomass per m^2 multiplied by the survey area. The same non-parametric bootstrap method (100,000 iterations with repeats) as for total abundance estimation was employed to extract the 50th, 20th and 10th quantiles of the bootstrapped mean with standard errors. Estimates of total survey area biomass are reported together with confidence levels and standard errors. TACC recommendations at each confidence level are provided as 10% of the estimated total biomass in tonnes and as counts of dozens to provide a risk assessment framework for determining the TACC. Conversion of TACC in tonnes to counts in dozens was calculated as the biomass in kilograms divided by the mean weight of harvestable sized oysters. Mean weight of harvestable sized oysters (>70 mm) was calculated from the estimated weights of all legal size oysters from the previous surveys (TAFI 2008, Tarbath 2010, Tarbath and Gardner 2013) and from the 2016 survey.

CPUE and catch data were extracted from the Department of Primary Industries, Parks, Water and Environment (DPIPWE) database to include all data from 01/09/2007 to 23/05/2016. CPUE data is presented as the fishing year (1st Sept – 31st August) geometric mean (dozensHr^{-1}) with catch recorded in dozens. Years refers to the end of each fishing year e.g. 01/09/07 to 31/08/08 is year 2008.

Results

A total of 1591 *O. angasi* were collected from the 87 quadrats across the surveyed area with a mean shell length of 76.3 mm (± s.d = 18.1) and an estimated mean weight of 65.1 g (± s.d.= 47.8 g) (Figure 3). Of all animals sampled 59.2% were greater than the LML which represents 82.0% of the estimated total weight sampled. Estimated mean weight of harvestable animals from surveys between 2008 and 2016 (*n* = 7296) was 125.7g (± s.e. = 0.9) therefore a dozen is estimated to weigh 1.51 Kg. The density of *O. angasi* per quadrat in 2016 ranged from 0 to 72 with a mean of 18.3 (± s.d. = 16.7). The mean biomass per metre square of *O. angasi was* estimated at 4.74 Kg (± s.d. = 0.81). Spatial representation of density (per quadrat) and weight (m^2) showed a degree of spatial clustering within the surveyed beds (Figure 4).

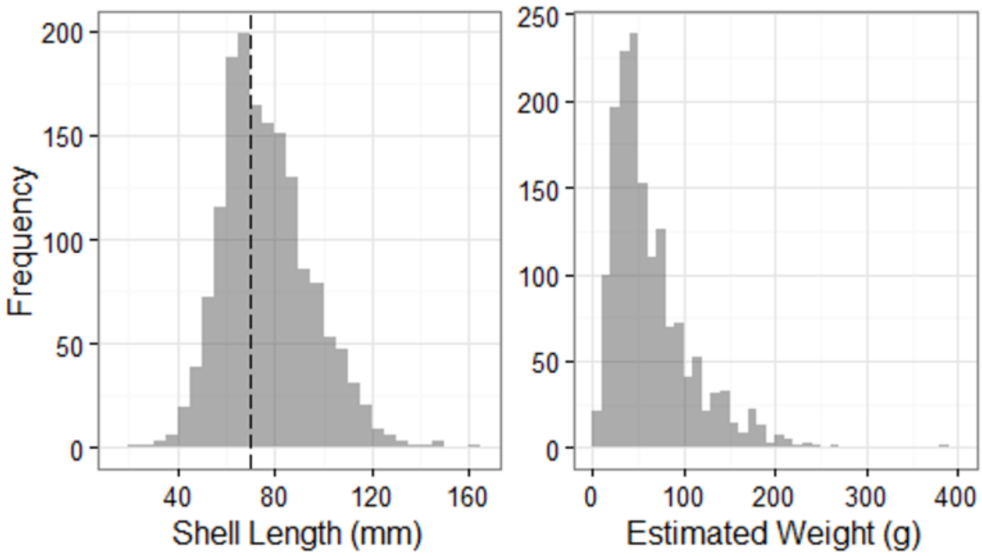

Figure 3. Frequency histograms of shell length and estimated weight of O. angasi from Georges Bay 2016. Dashed vertical line represents the legal minimum length (70 mm).

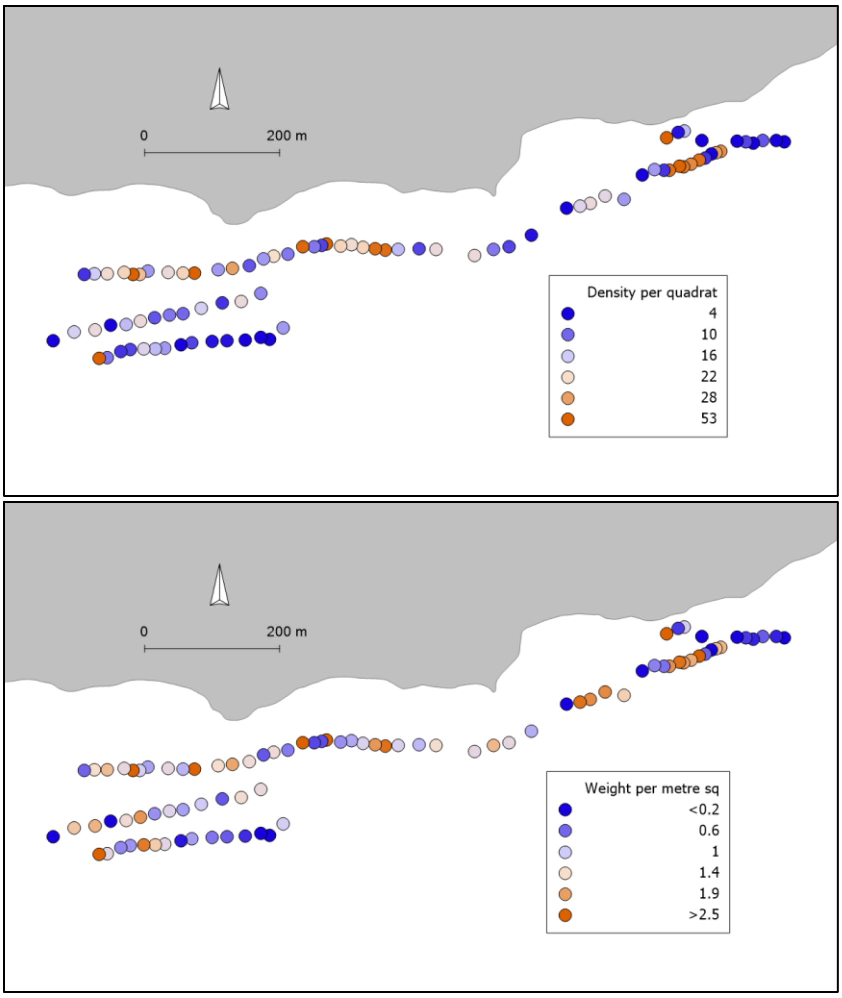

Figure 4. Distribution map of densities per quadrat (top) and total weight (Kg m^2) (bottom) for O. angasi in Georges Bay from 2016 survey.

The estimated total area of *O. angasi* fishable reef in 2016 was 82,540 m^2 with large changes to the previous locations estimated for *O. angasi* in 2003 (Figure 5). Estimated total biomass (50th quantile of the mean) for the fishable reef area was 391.3 tonnes (± s.e. = 28.7 tonnes) (Table 1). TACC estimations for each probability estimate for total biomass and counts in dozens are given in Table 1. Probability estimates of density ranged from 73.0 m^2 (50th quantile) to 63.9 m^2 (10th quantile), with the estimated total abundances across the fishing area surveyed ranging from 6.0 million (50th quantile) to 5.3 million (10th quantile) (Table 2).

Figure 5. Map of Georges Bay O. angasi beds from 2003 and 2016. Total O. angasi area for 2016 is estimated at 82,540 m^2 as calculated by the maximal dimensions of the quadrat samples and boundary marks. The 2003 O. angasi beds were surveyed by DPIPWE and reproduced by Tarbath and Gardner (2013) from GPS marks.

Table 1. Biomass estimates and TACC recommendations as biomass and number of dozens. Probability estimates are calculated from bootstrapped (100,000 iterations) of O. angasi from the 2016 fishery survey with 50th, 20th and 10th quantile of the bootstrapped mean biomass with standard errors in parenthesis. TACC estimates are provided in tonnes as 10% of total biomass estimates and counts in dozens based on a mean weight of harvestable sized oysters per dozen of 1.51 Kg.

Probability estimate	Biomass (Kg m^2)	Total Biomass (tonnes)	Biomass TACC (tonnes)	TACC estimate in dozens
50th Quantile	4.7	391.3	39.1	25,906
	(3.4 – 5.1)	(362.6 – 420.0)	(36.2- 42.0)	(24,017 – 27,800)
20th Quantile	4.5	367.4	36.7	24,328
	(4.1 – 4.8)	(338.7 – 396.1)	(33.8 – 39.6)	(22,437 – 26,220)
10th Quantile	4.3	355.0	35.5	23,528
	(4.0 – 4.6)	(326.3 – 383.7)	(32.7 – 38.4)	(21,636 – 25,420)

Table 2. Density estimates calculated from bootstrapped (100,000 iterations) of O. angasi densities from the 2016 fishery survey in Georges Bay. 50th, 20th and 10th quantile of the bootstrapped mean density with standard errors in parenthesis.

Probability estimate	Density (m^2)	Total abundance estimate (millions)	Total number of dozens estimated for survey area
50th Quantile	73.0	6.0	501,885
	(65.9 - 80.1)	(5.4 – 6.6)	(453,048 - 550,722)
20th Quantile	67.1	5.5	461,405
	(60.0 - 74.2)	(5.0 – 6.1)	(412,568 - 510,242)
10th Quantile	63.9	5.3	439,267
	(56.7 – 71.0)	(4.7 – 5.9)	(390,115 – 488,420)

Total catch of *O. angasi* in 2015 was the lowest since the introduction of TACC's in September 2007 and was associated with a reduced CPUE (Figure 6). Mean catch, since introduction of the TACC in 2007, is 1535 dozen (± s.d. = 996). The maximum annual catch was 3240 dozen in 2008 which equates to 7.8% of the allocated TACC in that year which is also the maximum percentage of TACC caught in any year (Table 3).

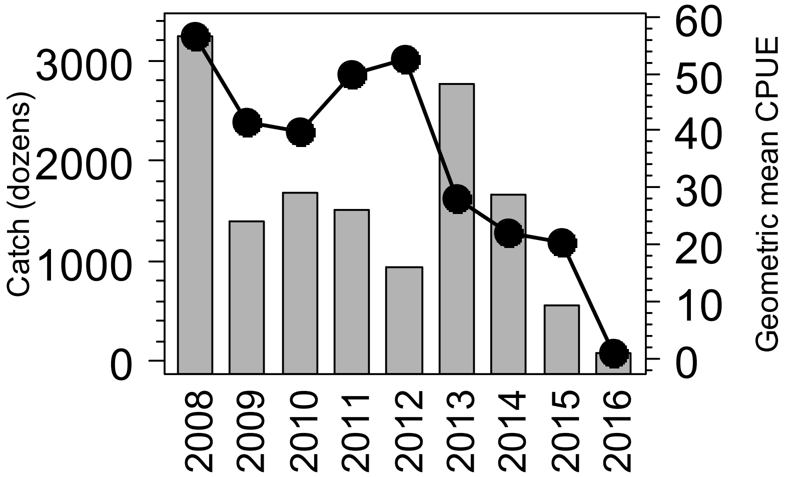

Figure 6. Catch (dozens) and geometric mean catch per unit effort (CPUE) (DozensHr^{-1}) for O. angasi in Georges Bay from fish year ending 2008 to fish year end 2015. Fishing year runs from 01 September to 31st August.

Table 3. Catch (dozens), TACC (dozens) and percentage of TACC caught for O. angasi in Georges Bay St Helens since 2008.

Year	Catch	TACC	% TACC
2008	3240	41369	7.83
2009	1395	41369	3.37
2010	1677	39025	4.30
2011	1507	39025	3.86
2012	940	39025	2.41
2013	2770	39796	6.96
2014	1656	39796	4.16
2015	550	39796	1.38
2016	80	39796	0.20

*Table 4. Estimates of area, biomass and TACC from fishery assessments of O. angasi in Georges Bay. St Helens since 2007. * 50th quantile of bootstrapped mean.*

	2008	2010	2013	2016
Est. area of fishery (m^2)	55,036	69,895	52,104	82,540
Est. mean biomass (Kg/m^2)	12.2	8.2	11.1	4.7*
Est. total biomass (t)	670.6	569.5	618.4	391.5*
Est. total number in fishery (millions)	5.0	4.7	4.8	6.0*
TACC (dozens)	41,369	39,025	39,796	See table 1

Discussion

The 2016 survey area, based on licensee recommendations, recognised a single large bed of *O. angasi* within Georges Bay which was actively fished. Previous surveys have included part of the area identified in 2016 as small individual beds but the presence of *O. angasi* from samples across this entire area suggests this may have been previously underrepresented. The smaller *O. angasi* beds identified in earlier surveys to the east and north of the bay are now either no longer fished due to very low production or no longer exist, these were not assessed in 2016 and do not form part of the estimated total biomass available, although they may hold biomass which contributes to the reproductive capacity of the bay. The 2013 *O. angasi* survey (Tarbath and Gardner 2013) indicated a similar spatial trend away from the former fishing beds to the north and east of the bay with preference to the area identified in this work. The authors also note the likelihood of the oyster bed sampled in 2016 (Figure 5 this report and figure 3 in Tarbath and Gardner 2013) as being one continuous area which would have been underrepresented in that report. As a result the active fishing area reported in this work is larger (82,540 m^2) than that in previous reports (Table 4) which all rely on an initial survey data from 2003. The current work varies from previous survey estimation of area for *O. angasi* in Georges Bay by using the only the area occupied by the current survey as the estimated total area of the fishery. Previous surveys, dependent on the 2003 survey to estimate area, may have underestimated total area or overestimated the abundance/biomass of the 2003 beds as not all of the beds were sampled as part of each survey. The current method provides a level of precision with regard to the abundance and biomass of *O. angasi* for the area sampled without making assumptions on the biomass available more widely within the bay. Calculation of TACC based on the estimated total biomass of *O. angasi* across the entire bay area assumes that the TACC will be taken across the entire area, not just the active fishing grounds. By basing abundance and total biomass calculations only to the extent of the active fishing areas, the total biomass and abundance estimations are likely to underestimate the overall total of *O. angasi* present within the Georges Bay catchment and as such provide a level conservatism within the TACC allocation. This method of biomass estimation is considered a robust technique for providing information for TACC estimations in shellfish fisheries as it targets only productive fishing grounds and made no assumptions with regard to non-sampled areas (Dent et al. 2014).

The TACC is the primary tool used to ensure biological sustainability within the *O. angasi* fishery and is determined as 10% of the total biomass estimate. The TACC is set typically set for a period of two to three quota years. This document provides a probability estimate of total estimated biomass and TACC and subsequent TACC in dozens for assessment by management. The estimated biomass is presented at three levels of confidence based on the mean biomass per m^2 from the survey and total fished area examined in the survey. Each estimate provides a biomass with standard errors together with the level of confidence that the true biomass within the fishery is greater than the estimated biomass. The resultant TACC is derived from the estimated biomass in dozens for each confidence level and allows management to determine the level of risk that is associated with each TACC allocation. The 20^{th} quantile TACC allocation approximates the TACC calculated in previous surveys principally as a result of the increased area identified in this study (Table 4) compared to earlier reports. When considering this information for determining the management arrangement for the fishery, consideration needs to be made of the risk of population depletion. Reducing the exposure to risk by adopting the 10^{th} quantile TACC (the most conservative) would not appear to significantly impact the fishery at present, given the historic levels of catch to TACC allocation in this fishery. The likelihood of catch reaching the prescribed TACC would appear to be low as market demand appears low for this product, however demand may chance in the future as pressures on other sources of oysters change e.g. the arrival of Pacific Oyster Mortality Syndrome in Tasmania 2016.

Recommendations

Increased precision in the estimation of the area occupied by the fishery may be achieved by the compulsory use of GPS and depth/time loggers (spatial data), providing reducing uncertainty in the estimate of biomass. The coupling of CPUE and catch data to GPS records by fishing event also provides the opportunity to explore spatiotemporal patterns in harvest. Use of the loggers is currently voluntary for the commercial harvest of *O. angasi* but has proven useful in assisting management decisions in Australian abalone fisheries where it has become mandatory in some states (Mundy 2011).

Reporting of catch in this fishery is recorded in dozens within the DPIPWE database system. Estimation of total biomass is calculated by weight with conversion to TACC (dozens) requiring the conversion using an average harvestable weight estimate which may under or overestimate TACC depending on the size frequency of the catch. The majority of Tasmanian fisheries establish TACC and catch in kilograms, it is suggested that this fishery adopts a TACC setting by weight in the 2017 policy document and an agreement is reached on the conversion of all previous TACC's to date into this format.

Calculation of TACC within the current fishery policy is set as 10% of the estimated biomass which allows for no set TACC minimum or no upper TACC limit. This has the potential to result in overfishing of the stock and subsequent losses to the fishery should the demand for the product increase. Harvest strategies (HS) with limit reference points are being implemented across Australian fisheries (Smith et al., 2007) and provide guidelines for the application to fisheries current managed without lower or upper limits to TACC. These guidelines initially developed for finfish species and are viewed as acceptable starting points for the development of HS for many data poor species. There are obvious significant differences between the life histories, fishing practices and environmental settings of finfish and estuarine bivalves (e.g. spawning mechanisms, spatial dynamics, stock-recruitment and habitat sensitivities) but the HS can be structured to incorporate the framework of the Commonwealth HS and use empirical evidence (previous catch levels and TACC) from the fishery so as to provide a baseline HS which is useful now and whose values can be modified in future assessments.

The following terms are typically employed in a HS:

B_{MSY} - Biomass at maximum sustainable yield: average biomass corresponding to maximum sustainable yield.

> B_{MSY} can be defined as the maximum average annual catch that can be removed from a stock over an indefinite period under prevailing environmental conditions. The Commonwealth HS guidelines suggest that the proxy for B_{MSY} in the absence of more specific information be 40% of the unfished biomass (B_0). Within the *O. angasi* fishery B_0 is unknown however a proxy for B_0 would be the maximum estimated biomass recorded in the fishery since its inception. This value is 670.6 T recorded in 2008 and as such could be used as the proxy for B_0. This gives a B_{MSY} = 268.2 t.

B_{MEY} - Biomass at maximum economic yield: average biomass corresponding to maximum economic yield.

> B_{MEY} is considered the point at which sustainable catch or effort level across the whole fishery maximises profits. When a B_{MEY} is unknown as it is in the *O. angasi* fishery, a proxy of $B_{MEY} = 1.2*B_{MSY}$ may be appropriate. While this may over or underestimate the true value, if the unit cost of catch is dependent on the size of the stock, and practical discount rates apply, B_{MEY} will always be larger than B_{MSY} and in the *O. angasi* fishery is estimated at 321.8 t. Biomass increases above B_{MEY} do not result in further increases in TACC, instead remaining at the TACC level reach at B_{MEY}.

B_{LIM} - Biomass limit reference point: the point beyond which the risk to the stock is regarded as unacceptably high.

> The biomass limit reference point B_{LIM} is a key component in the HS. It defines the point at which a stock will be defined as “overfished”, and the point in the HS below which there will be no further targeted fishery on that species, and a stock rebuilding strategy has to be set in place. In general, B_{LIM} should correspond to a level of stock depletion, at which the risk to the stock is unacceptably high, for example the point at which recruitment overfishing is thought to occur. The Commonwealth guidelines suggest in the absence of more specific knowledge that B_{LIM} be set at 20% of the unfished B_0. Based on this the TACC, for *O. angasi* would be zero when the estimated biomass or B_{LIM} = 134.1 t.

The B_0 proxy of maximum recorded biomass may underestimate or overestimate the true B_0 resulting in similar uncertainty in the reference points. The underlying recruitment dynamics which drive production in this fishery are likely affected by environmental conditions but the exact relationship between biomass and recruitment in this fishery has not been explored. In the absence of a stock recruitment model, length frequency data collated from the biannual surveys should give some guidance on the acceptability of this value. Recruitment overfishing of mature biomass may result in decline of pre-recruits to the fishery and detection of this through the length frequency data may be used for revising B_{LIM}. Further, it is suggested that the B_0 value of 670.6 t should prompt further discussion between DPIPWE and licensees with regard to the economic viability of the fishery at such as level of biomass and whether biomass should be maintained at a higher level.

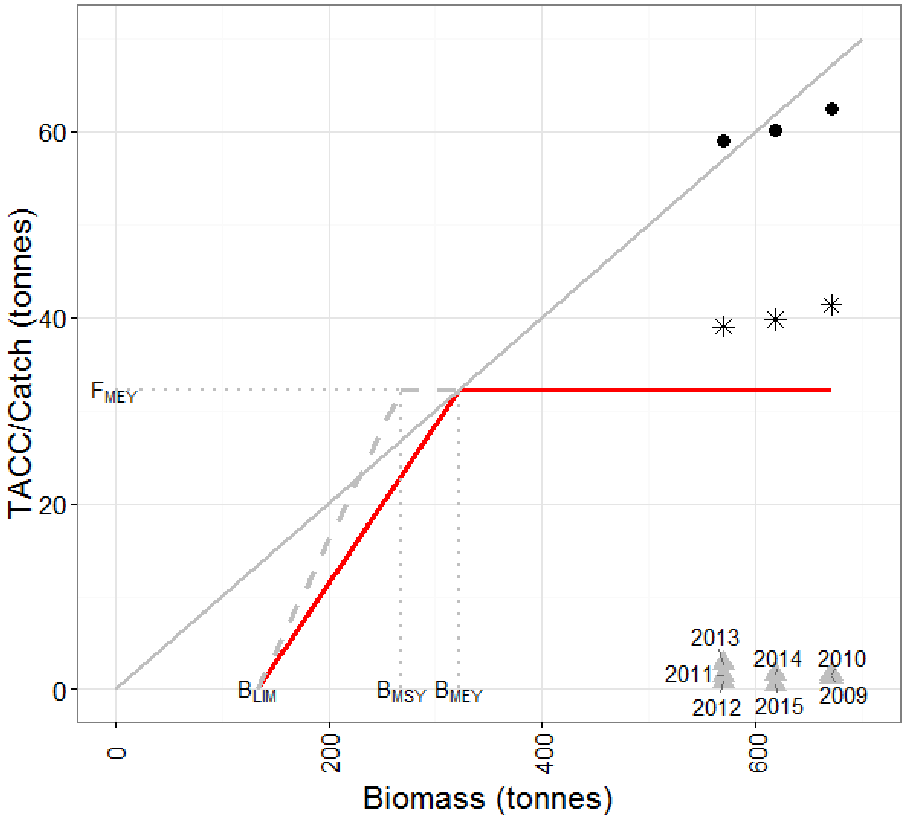

*Figure 7. Proposed harvest strategy (HS) (red line) with harvest control rules for the Georges Bay O. angasi fishery. The solid grey line represents the current TACC setting process = estimated total biomass*0.1. The TACC's applied for fishery years 2008-2015 are represented as tonnes (black circles) and as thousands of dozens (black stars). Grey triangles indicate annual catch and associated fishing year ending 2008-2015. The proposed HS is based on the commonwealth harvest strategy, with control rules B_{MSY} (B_0*0.4), B_{MEY} (B_{MSY}*1.2) and B_{LIM} (B_0*0.2) where B_0 = maximum estimated biomass = 670.6 t. B_{LIM} represents the minimum TACC > zero, B_{MSY} = 268.2 t, B_{MEY} = 321.9 t. F_{MEY} is the TACC limit which is derived from B_{MEY}*0.1 = 32.1 t. The solid red line is the proposed HS, dashed grey line is a HS based on B_{MSY}. Note: The catch data is derived from annual catch data held by DPIPWE.*

Venerupis largillierti Northern Zone

Background

In Georges Bay, north-east Tasmania, a commercial dive fishery has operated for the Venus Clam (*Venerupis largillierti*) since approximately 1985. *V. largillierti* is endemic to New Zealand but its range extended to Tasmania by 1963 possibly earlier. It remains indistinguishable from New Zealand populations, on the basis of allozyme analysis (Macguire and Ward 2005). *V. largillierti* grows to a length of 70 mm and is found in the intertidal zone and subtidally in both muddy and sandy substrates in shallow estuarine waters (Gabriel and Macpherson 1962) on parts of Tasmania's east and south-east coasts (Grove 2011). Experimental estimation of growth rates indicate growth increments at 1.3 $mm.month^{-1}$ at 27 mm and 0.5 $mm.month^{-1}$ at 43.5 mm (Kent et al., 2005 Maguire and Paturusi 2005). Sexual maturity is estimated to occur below 27 mm (Maguire and Paturusi 2005). Georges Bay is the only commercial fishery for this species in Tasmania, where the species forms beds on both intertidal sandbars and in subtidal deeper channels subjected to tidal flow. The Georges Bay *V. largillierti* fishery is subdivided into two zones (Northern and Southern) with two licences in the Northern Zone and one in the Southern Zone (DPIPWE 2007).

The Northern Zone fishery operates on mixed species shellfish beds in the bay with the area harvested varying between years. Until 2007 the fishery was managed principally through the allocation of half yearly or yearly permits. From 2007 a formal TACC structure was introduced with two associated commercial licences (DPIPWE 2007). TACC allocation is based on fishery dependent surveys of estimated available biomass conducted every two or three years with the TACC set as equal to 10% of the estimated biomass. Legal minimum length of *V. largillierti* is set at 40 mm shell length on the basis of market demand (DPIPWE 2007). Total catch and catch per unit effort data are available for this fishery from 1st September 2007 onwards, with the fishing year operating from 1st September to 31st August.

For the 2015-2016 fishing year the two licensees agreed a voluntary reduction in TACC to 3 t a consequence of low availability of stocks. Prior to the 2016 survey period this TACC allocation was voluntarily extended into 2016-2017 at the same TACC of 3 t. As a consequence, the formal biomass survey for the allocation of TACC for 2016-2017 was not requested by DPIPWE.

Objectives

Without need for biomass estimation for the setting of TACC the objective of this report was to: 1. Evaluate the CPUE and catch records within the fishery. 2. Provide a limited pilot sample of quadrats from the fishery to identify if there is any evidence of recruitment. 3. Develop a new formal harvest strategy with limit reference points for consideration in the review of the shell fish policy due to be undertaken by DPIPWE in 2017.

Methods

CPUE and catch data were extracted from the Department of Primary Industries, Parks, Water and Environment (DPIPWE) FILMS database to include all data from 01/09/07 to 23/05/16. Each fishing year is denoted by the end year e.g. 01/09/2007 to 31/08/2008 is fishing year 2008. CPUE data is presented as the yearly geometric mean with catch recorded in tonnes. Biomass estimates from the fishery were taken from previous reports on this fishery (Haddon 2003, TAFI 2009, Tarbath 2012, Tarbath and Gardner 2014).

The survey of fishing area for 2016 was conducted from one of the licensee's vessels with guidance from the licensee. Mapping of the active fishing beds took the form of GPS marks taken at the perimeter of the beds with the resultant waypoints digitized (manifold.net) and bounded to provide an estimate of area in m^2. A limited pilot survey of three quadrats (50 cm x 50 cm) were sampled by commercial diver and IMAS researcher in the western most bed identified in the survey in order to observe fishing technique, species habitat and collect samples (Figure 8). All *V. largillierti* within the quadrats were harvested, returned to the vessel and measured across the longest axis (± 1 mm) using electronic measuring boards, before being returned to the fishing grounds.

Figure 8. Sampling of V. largillierti bed in Georges Bay Northern Zone with quadrat and sample bag.

Results

Annual catch approached TACC each year from 2008 to 2012 and increased from 24 t in 2009 to 28.4 t in 2010 where it remained relatively stable until 2013 (Figure 9, Table 5). In 2013 the TACC was raised to 53.7 t (Tarbath and Gardner 2012) with 78.8% (42.2 t) of the TACC caught at a CPUE of 76.4 $KgHr^{-1}$ (Figure 9, Table 5). In 2014, the TACC remained at 53.7 t with 74.3% (39.9 t) caught at a CPUE of 64.0 $KgHr^{-1}$ (Figure 9, Table 5). The biomass survey conducted in 2014 estimated that biomass had decreased to 463 t or 86.2% of the 2012 survey level (Tarbath and Gardner 2014). The 2012 and 2014 biomass survey estimates represent the highest recorded in the fishery, mean estimate since 2003 = 412.9 t (± s.d. = 110.5). Based on recommendations in Tarbath and Gardner (2014) the TACC was reduced in 2015 to 46.3 t of which 52.5% (24.3 t) was caught at a CPUE of 27.0 $KgHr^{-1}$ (Figure 9, Table 5). For 2016 the two licensees agreed a voluntary reduction in TACC to 3 t from the allocated 46.3 t (6.5%) TACC available due to the reduction in harvestable stocks. Geometric mean CPUE for 2016 from 1st September 2015 to 23rd May 2016 is 8.6 $KgHr^{-1}$ (Figure 9, Table 5).

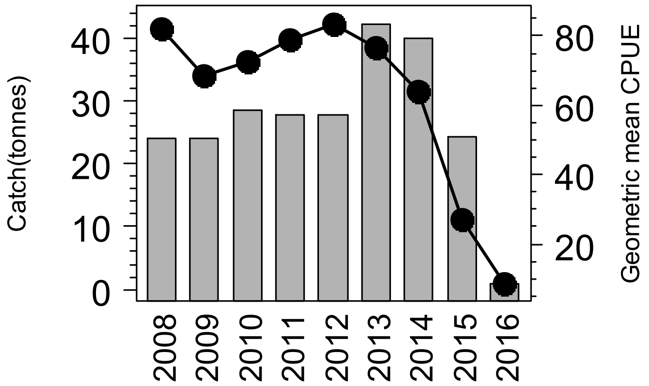

Figure 9. Catch (tonnes) and Geometric mean catch per unit effort (CPUE) ($KgHr^{-1}$) for V. largillierti in Georges Bay Northern Zone from fish year 2008 to fish year 2016. Fishing year runs from 01 September to 31st August, fish year 2016 comprises of partial year data complete to 23/05/2016.

Table 5. Total catch and percentage of total allowable commercial catch (TACC) in parenthesis, TACC, estimated fishery area, estimated total biomass (m^2) and estimated mean biomass (Kg) per m^2 for V. largillierti in Georges Bay Northern Zone. For each Fish Year catch represents the total caught to the end of August of that year. TACC, Area, estimated total biomass and biomass per m^2 are the values presented from the latest survey preceding that Fish Year. Catch prior to 2008 is derived from permit reports held by DPIPWE or DPIPWE (2007), catch 2008 onwards taken from DPIPWE database catch records. There was no formal TACC set prior to 2008. Biomass and area estimates from 2003 to 2009 are taken from the lower estimate of shellfish area described in Haddon (2003). TACC, Area, estimated total biomass and biomass Kg per m^2 estimates from 2010 to 2012 sourced from TAFI (2009). TACC, Area, estimated total biomass and biomass per m^2 estimates from 2013 to 2014 sourced from Tarbath (2012). Area, estimated total biomass and biomass per m^2 estimates from 2015 to 2016 sourced from Tarbath and Gardner (2014). TACC for 2016 is set at the voluntary reduced level accepted by licensees.

Fish Year	Catch (t)	TACC (t)	Area (m^2)	Est. Total Biomass (t)	Biomass Kg per m^2
2003	43.2		176,258	366.5	2.1
2004	26.4		176,258	366.5	2.1
2005	26.4		176,258	366.5	2.1
2006	26.4		176,258	366.5	2.1
2007	26.4		176,258	366.5	2.1
2008	24.0 (100)	24	176,258	366.5	2.1
2009	23.9 (99.6)	24	176,258	366.5	2.1
2010	28.4 (99.6)	28.5	121,111	284.7	2.4
2011	27.8 (97.5)	28.5	121,111	284.7	2.4
2012	27.8 (97.5)	28.5	121,111	284.7	2.4
2013	42.2 (78.6)	53.7	121,111	537.4	4.4
2014	39.9 (74.3)	53.7	121,111	537.4	4.4
2015	24.3 (52.5)	46.3	96,393	463	4.8
2016	-	3.0	96,393	463	-

The total fishery area identified in 2016 comprised of four beds with an estimated fishery area of 99,713.4 m^2 (Figure 10, Table 5). This represents a small increase in area estimated in 2014 (Tarbath and Gardner 2014) and a significantly smaller estimate that in earlier surveys (Table 5).

Of the limited survey data collected in 2016 (three quadrats 0.25 m x 0.25 m) 111 individuals were recovered with a mean shell length of 26.7 mm (± s.d. = 11.2) and modal group at 16-24 mm, 18.9% of individuals were equal to or greater than the LML (Figure 11). This differs from previous survey length frequency distributions (Figure 12) but is from a smaller pilot sample.

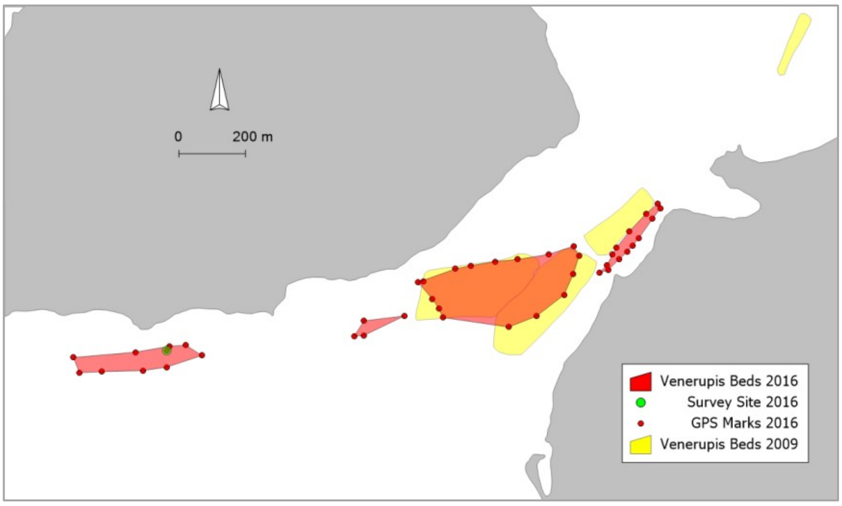

Figure 10. Map of Georges Bay V. largillierti beds from 2009 and 2016. 2009 beds were reported by TAFI (2009) and formed basis of area estimates in 2014 (Tarbath and Gardner 2014). Total V. largillierti area for 2016 is estimated at 99,713 m^2. Green point shows location of the pilot survey of three quadrats (0.5 m x 0.5m) taken in 2016. Red points indicate GPS marks from the vessel survey which define the boundaries of the estimated bed area for 2016.

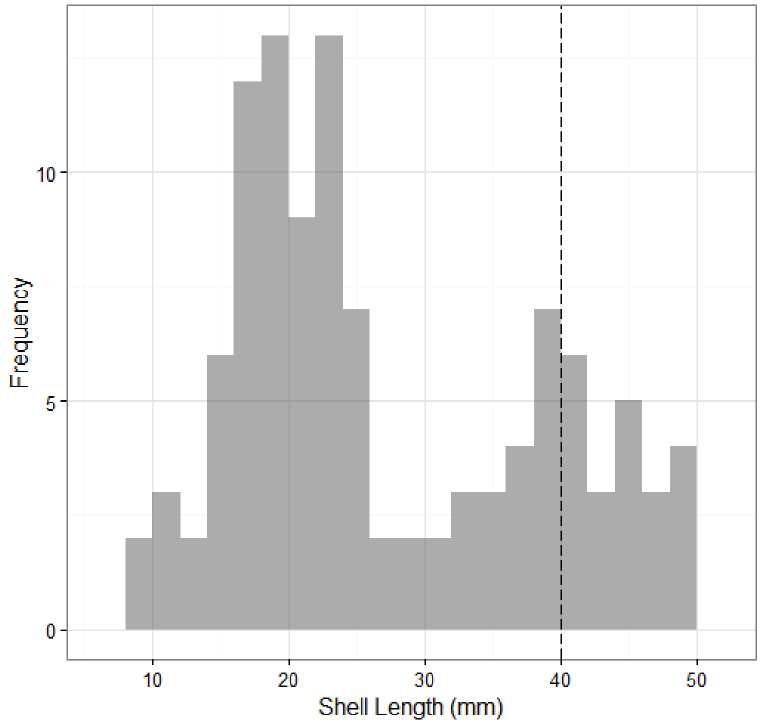

Figure 11. Frequency histograms of shell length of V. largillierti from Georges Bay Northern Zone 2016. Dashed vertical line represents the legal minimum length (40 mm).

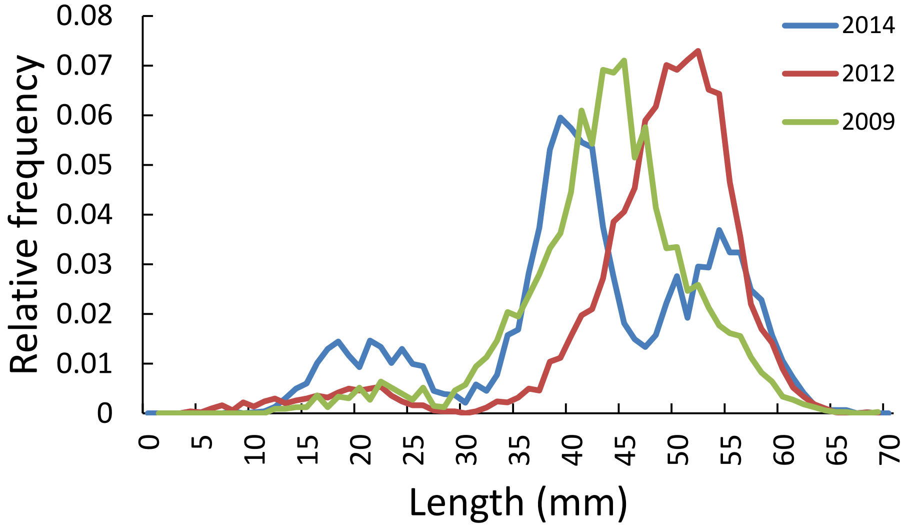

Figure 12. Length frequency distribution of V. largillierti from Georges Bay Northern Zone from previous surveys (reproduced from Tarbath and Gardner 2014).

Discussion

A large reduction in CPUE in 2015 and 2016 along with the associated catch being significantly lower than the available TACC suggest that biomass in this fishery has been depleted to the point that recruitment could become affected. With total catches for 2013-2014 at <8 % of the estimated fishable biomass fishing mortality is unlikely to be solely responsible for biomass decline. The 2014 survey showed the percentage of biomass greater than the LML as being > 60% with two modal groups at or above the LML (Figure 12). The larger cohort size class >55 mm identified in 2014 would be expected to be nearing maximum size by 2016 (plus 24 months) and therefore may have been reduced in abundance by natural mortality as well as fishing mortality. Growth data for *V. largillierti* in Georges Bay is limited to animals of 43.5 mm with estimated growth rates of 0.5 $mm.month^{-1}$ (Maguire and Paturusi 2005). The larger *V. largillierti* are likely to have slightly reduced growth rates compared to this but even if growth was reduced this cohort would be nearing maximum size (70 mm) within the 2016 fishing year. Without formal information on size at maturity, maximum size and growth data across the size spectrum in Georges Bay assumptions on growth are limited. The modal group identified at 38 mm-45 mm in 2014 are unlikely to have reached maximum size by 2016 and therefore may be assumed to have either been reduced in abundance by fishing or as a result of environmental change. A smaller modal cohort at 15-25 mm was also identified in 2014 which should have been expected to be reaching LML in 2015 and 2016 however the low CPUE and catch data from 2015 and 2016 and the acceptance of a low TACC from licensees in 2016-17 would suggest that this cohort has not been sufficient to rebuild stock. The voluntary reduction in TACC taken by the licensees for 2016 and 2017 may allow the stock to recover from the current stock state; however measurable increases in biomass to determine this can only be detected with a biomass survey, now scheduled for 2017. The limited survey that took place in 2016 did show some evidence of recruitment at the location sampled, however no assumptions with regard to recruitment across the remainder of the fishery area can be made from this limited dataset.

The total fishable area estimated in 2016 is similar to that in 2014, with the distinct addition of the bed to the west of previous fishing grounds, removal of the small north eastern bed and slight adjustments in the estimated areas of the beds in the middle of the fishery. The estimates from surveys 2014 (derived from 2009 data) and 2016 are lower than those estimated in 2003 (Haddon 2003) and may be the result of changing estuarine dynamics or area estimation. Estimation of fishing grounds from a single day's survey (in spite of detailed fisher knowledge) is likely to be accompanied by some measurement error, resulting in over or under estimation of total area. This can have significant knock on effects on biomass and TACC estimates. Establishment of the fishing grounds is essential to biomass estimates and recommendations for the mandatory use of spatial loggers is recommended in future to provide an annual total of fished area from which to derive the total fishable area.

Recommendations

Increased precision in the estimation of the area occupied by the fishery may be achieved by the compulsory use of GPS and depth/time loggers (spatial data). This will provide reduced uncertainty in the estimate of biomass and subsequent calculation of TACC. The coupling of CPUE and catch data to GPS records by fishing event, through docket records also provides the opportunity to explore spatiotemporal patterns in harvest and population dynamics. Use of the loggers is currently voluntary for the commercial harvest of *V. largillierti* but has proven useful in assisting management decisions in Australian abalone fisheries where it has become mandatory in some states (Mundy 2011). It is viewed within other dive fisheries, as an important tool to better understanding fishery mobility and resource use (Fernandez-Boan et al., 2013).

Development of an optimized sample method for the estimation of biomass in this fishery is key to reducing the uncertainty in biomass estimation and TACC allocation. Coupled with a harvest strategy that meets the standards within other fisheries this should help to reduce the risk of recruitment overfishing and provide a sustainable harvest more closely aligned to maximum sustainable yield (B_{MSY}) over multiple years, providing benefit to licensees in the form of stabilized stocks levels and for the state government in terms of having a defendable sustainable assessment process.

For future biomass estimate surveys the use of spatial data within the fishery would provide an accurate picture of the total fishable area, which could replace in part, the use of fishery images used prior to surveys to establish the boundaries of the beds (see *O. angasi* method above and appendix 1). Should there be a need to add additional areas to the geospatial data this can simply be achieved using a suitable GIS program and consultation with licensees. Using the GPS records as a measure of effort and fishery area as scale, the intensity of samples taken in each bed could be determined giving spatial resolution to the fishery. It is also recommended that a retrospective analysis of the previous survey data (2009, 2012, 2014) in this fishery is conducted to estimate the most efficient sample number to be taken from this fishery. A monte carlo simulation with constraints on strata (fishing beds) would be a valid approach. Future biomass survey design should be consistent with methods used in other small bivalve fisheries in Australia (Dent et al. 2014), and that used in this document for *O. angasi.* Estimation of total biomass of *V. largillierti* across the survey area would be calculated as the mean biomass per m^2 multiplied by the survey area with a non-parametric bootstrap method (100,000 iterations with repeats) employed to extract the 50^{th}, 20^{th} and 10^{th} quantiles of the bootstrapped mean with standard errors.

Calculation of TACC within the current fishery policy is set at estimated biomass*0.1 which allows for no set TACC minimum and no upper TACC limit. Harvest strategies (HS) with limit reference points are being implemented across Australian fisheries (Smith et al., 2007) and provide guidelines for the application to fisheries current managed without lower or upper limits to TACC. These guidelines, initially developed for finfish species, are viewed as acceptable starting points for the development of HS for many data poor species. There are obvious significant differences between the life histories, fishing practices and environmental settings of finfish and estuarine bivalves (e.g. spawning mechanisms, spatial dynamics, stock-recruitment and habitat sensitivities) but the HS can be structured to incorporate the framework of the Commonwealth

HS and use empirical evidence (previous catch levels and TACC) from the fishery so as to provide a baseline HS which is useful now and whose values can be modified in future assessments.

The following terms are typically employed in a HS:

B_{MSY} - Biomass at maximum sustainable yield: average biomass corresponding to maximum sustainable yield.

> B_{MSY} can be defined as the maximum average annual catch that can be removed from a stock over an indefinite period under prevailing environmental conditions. The Commonwealth HS guidelines suggest that the proxy for B_{MSY} in the absence of more specific information be 40% of the unfished biomass (B_0). Biomass increases above B_{MSY} do not result in further increases in TACC, instead remaining at the TACC level reach at B_{MSY}. Within the *V. largillierti* northern zone fishery B_0 is unknown. A proxy for B_0 would be the maximum estimated biomass recorded in the fishery since its inception. In the *V. largillierti* northern zone fishery this value is 537.4t recorded in 2012 and as such is used as the proxy for B_0. This gives a B_{MSY} = 215t.

(B_{MEY}) - Biomass at maximum economic yield: average biomass corresponding to maximum economic yield.

> B_{MEY} is considered the point at which sustainable catch or effort level across the whole fishery maximises profits. When a B_{MEY} is unknown as it is in the *V. largillierti* northern zone fishery, a proxy of $B_{MEY} = 1.2*B_{MSY}$ may be appropriate. While this may over or underestimate the true value, if the unit cost of catch is dependent on the size of the stock, and practical discount rates apply, B_{MEY} will always be larger than B_{MSY} and in the *V. largillierti* northern zone fishery is estimated at 258t.

(B_{LIM}) - Biomass limit reference point: the point beyond which the risk to the stock is regarded as unacceptably high.

> The biomass limit reference point B_{LIM} is a key component in the HS. It defines the point at which a stock will be defined as "overfished", and the point in the HS below which there will be no further targeted fishery on that species, and a stock rebuilding strategy has to be set in place. In general, B_{LIM} should correspond to a biomass level, or level of stock depletion, at which the risk to the stock is unacceptably high, for example the point at which recruitment overfishing is thought to occur. The Commonwealth guidelines suggest in the absence of more specific knowledge that B_{LIM} be set at 20% of the unfished biomass B_0 (or proxy B_0). Based on this the TACC, for Georges Bay Northern Zone *V. largillierti,* would be zero when the estimated biomass or B_{LIM} = 107.5t. The B_0 proxy of maximum recorded biomass may underestimate or overestimate the true B_0 resulting in similar uncertainty in the B_{MSY}. The underlying recruitment dynamics which drive production in this fishery are likely affected by environmental conditions but the exact relationship between biomass and recruitment in this fishery has not been explored. In the absence of a stock recruitment model, length frequency data collated from the biannual surveys should give some guidance on the acceptability of this value. Recruitment overfishing of mature biomass may result in decline of pre-recruits to the fishery and detection of this through the length frequency data may be used for revising B_{LIM} in the future. Further, it is suggested that the B_{LIM} value of 107.5t should prompt further discussion between DPIPWE and licensees with regard to the economic viability of the fishery at such as level of biomass and whether biomass should be maintained at a higher level.

Table 6. Calculation of fishery harvest strategy control rules for the Georges Bay Northern Zone V. largillierti fishery. B_0 is the unfished biomass or in the case of the V. largillierti fishery the maximum surveyed biomass is used as its proxy. B_{LIM} is the limit biomass reference point. B_{MSY} is the biomass which provides the maximum sustainable yield. B_{MEY} is the biomass that provides the maximum economic yield.

Term	calculation	Biomass in t
B_0	maximum surveyed biomass	537.4
B_{LIM}	B_0*0.2	107.5
B_{MSY}	B_0*0.4	215.0
B_{MEY}	1.2*B_{MSY}	258.0

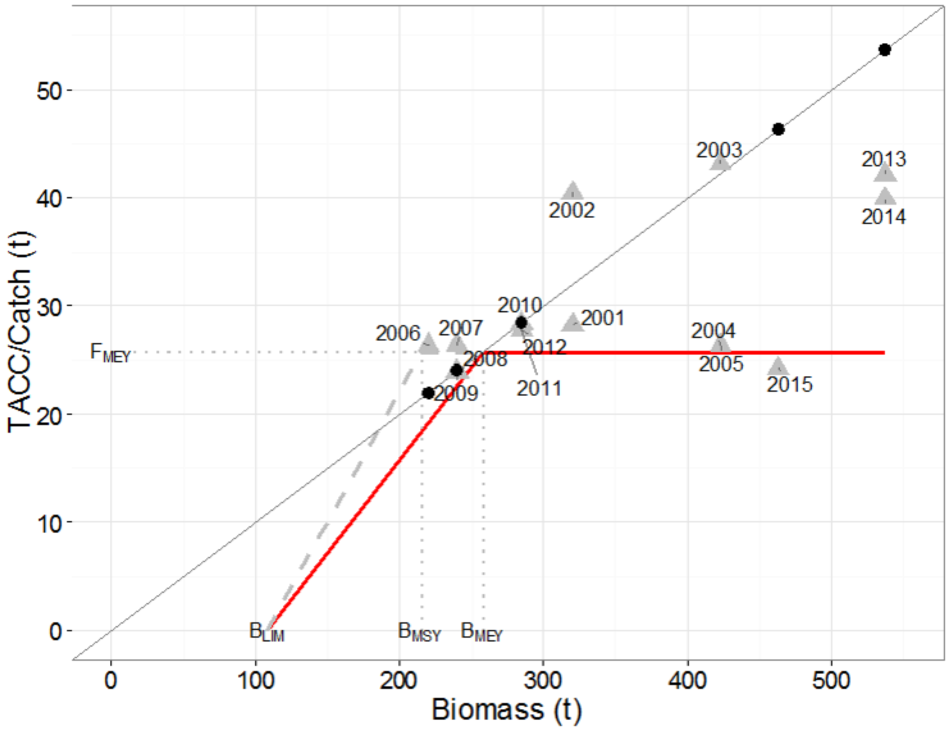

*Figure 13. Proposed harvest strategy (HS) (red line) with harvest control rules for the Georges Bay V. largillierti fishery. The solid grey line represents the current TACC setting process = Biomass*0.1. Black circles indicate the TACC's applied for fishery years 2008-2015. Grey triangles indicate annual catch and associated year for years. Proposed HS is based on the commonwealth harvest strategy, with control rules B_{MSY} (B_0*0.4), B_{MEY} (B_{MSY}*1.2) and B_{LIM} (B_0*0.2) where B_0 = maximum estimated biomass = 670.6 t. B_{LIM} represents the minimum TACC > zero, B_{MSY} = 268.2 t, B_{MEY} = 321.9 t. F_{MEY} is the TACC limit which is derived from B_{MEY}*0.1 = 32.1 t. The solid red line is the proposed HS, dashed grey line is a HS based on B_{MSY}. Note: The catch data is derived from annual catch data held by DPIPWE.*

Stock status – small bivalves

The stock status of the small bivalve's fisheries in Tasmania have been assessed using national stock status categories and now applied for Tasmanian fisheries. These categories define the assessed state of stocks in terms of recruitment overfishing. Recruitment overfishing occurs when the mature adult (spawning biomass) is depleted to a level where it no longer has the reproductive capacity to replenish itself. Recruitment overfished stocks have not necessarily collapsed but do have reduced recruitment capacity.

The findings of current surveys, in particular density and size composition information (indicators of adult abundance and recruitment success), and consideration of former surveys along with catch and CPUE data represent the key inputs into the determination of stock status.

Species	Status	Comments
Georges Bay – Native Flat Oyster *Ostrea angasi*	SUSTAINABLE	Species has a history of being fished at a level lower than the TACC. There is strong evidence of significant biomass within the active fishing area and large proportion of animals below the LML.
Northern Zone Georges Bay - Venus Clam *Venerupis largillierti*	ENVIRONMENTALLY LIMITED	Biomass in the Venus Clam fishery is estimated from quadrat counts that are extrapolated across a defined region where fishing occurs. This means that the biomass estimate is for the total biomass within the active fishery area, not the total biomass of Georges Bay. No estimate of biomass was made in 2016 because fishers had observed sharp declines in stock. A large reduction in CPUE in 2015 and 2016 along with the associated catch being significantly lower than the available TACC suggest that biomass in this fishery has been depleted to the point that recruitment could become affected. Catches for the two previous years were only <8% of the estimated fishable biomass. Fishing mortality is less than indicated by this percentage because venus clams also occur outside the defined beds that are fished and used for the biomass estimate. One plausible cause for the decline may be environmental processes linked to reduced recruitment. Previous information on length frequency distribution indicated that a settlement pulse had occurred but this has failed to translate to significant recruitment to the fishery. On the basis of the low rate of fishing mortality, and the pattern of length frequency data, the decline in stock is attributed to environmental causes. The voluntary reduction in TACC taken by the licensees for 2016 and 2017 implies that fishing mortality is negligible and may allow recovery in this fishery.

Southern Zone Georges Bay - Venus Clam *Venerupis largillierti* **(NOT ASSESSED IN THIS DOCUMENT)**	**ENVIRONMENTALLY LIMITED**	Surveyed in 2013 (Tarbath and Gardner 2013), no clam stocks at harvestable size were identified. Anecdotal evidence suggests flood events may have contributed to population decline. No TACC for 2016. Survey due in 2017.
Ansons Bay - Vongol *Katelysia scalarina* **(NOT ASSESSED IN THIS DOCUMENT)**	**ENVIRONMENTALLY LIMITED**	Surveyed in 2015 (Tarbath and Gardner 2015). Anecdotal evidence of flood event and almost complete loss of this species from the fishery area suggests that this species is classified as environmentally limited. Populations outside of the fishery area within Ansons Bay may drive recruitment back into the fishery although there is no knowledge of the extent of these populations or of those in adjacent bays. This fishery is currently closed to commercial catch.

Appendices

Establishing the boundaries of the Commercial Angasi Beds in Georges Bay prior to fishery survey 2016.

This document is designed to give licensees of the Angasi fishery of Georges Bay the opportunity to inform IMAS of any changes that have taken place in the position and extent of the Angasi beds since the last fishery surveys in 2010 and 2013 (figure 2). It is the intention of IMAS that any additions and substitutions to the beds will be lodged prior to the 2016 survey and provide a baseline for directing the survey locations and ultimately the establishment of total fishable reef area for allocating TACC. Each fisher is asked to mark onto figure 1 any amendments to the Angasi beds which they feel is relevant and return the document via email or mail to:

Hugh Jones

Private Bag 49

IMAS Taroona

University of Tasmania

7001

Hjones1@utas.edu.au

Kind Regards

Hugh Jones and Caleb Gardner

Figure 1. Map of Commercial Angasi beds based on previous survey work. Please mark on to this figure any variations to the beds that you feel are relevant to the survey that will take place in 2016.

Figure 2: Angasi oyster surveys in Georges Bay, showing GPS tracks from the 2010 (yellow marker) and 2013 (green marker) surveys, with respect to the position of mapped oyster beds and the undefined bed between beds 4, 5 and

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