2021 SMALL BIVALVE FISHERY ASSESSMENT
Ostrea angasi - Georges Bay

John Keane

August 2021

Institute for Marine and Antarctic Studies, University of Tasmania, Private Bag 49,

Hobart TAS 7001

Enquires should be directed to:
Dr John Keane
Institute for Marine and Antarctic Studies
University of Tasmania
Private Bag 49, Hobart, Tasmania 7001, Australia
John.Keane@utas.edu.au
Ph. (03) 6226 8265

Citation: Keane, J.P. (2021), 2021 Small Bivalve Fishery Assessment, *Ostrea angasi* - Georges Bay. Institute for Marine and Antarctic Studies Report. University of Tasmania, Hobart. 17 p.

Executive Summary

In 2021, stock assessment with total allowable commercial catch recommendations (TACC) was conducted for the Georges Bay flat oyster, *Ostrea angasi*, fishery. The current harvest fraction for *O. angasi* is set at 10% of the estimated total biomass, with a harvest strategy recommendation of a TACC limit set at 32.2 t based on the biomass at maximum economic yield. The 2021 survey recorded an estimate of total biomass (50th quantile of the mean) of 824.5 (± s.e. 757.4 - 891.7) tonnes, a 226% increase on the 2018 survey. Best estimates of total abundances from survey data across the fishing area suggested that there was a 90% chance the total abundance exceeded 10.5 million oysters. 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. Given no data on the size structure of the harvest, TACC estimates in dozens are provided based on mean weight per legal dozen as well as the upper 80th percentile of the legal-size structure. All estimates of biomass in this survey are above the biomass at maximum economic yield recommended by IMAS (Jones and Gardner, 2016), and thus it is recommended here that the 2021 TACC limit be set at 32.2 t. In 2021, the 80% percentile (upper) of the legal-size structure was 95 mm, equating to an estimated weight of a dozen harvested animals to be 1.27 Kg and 32.2 t being 25,331 dozen. Samples taken in beds outside the current designated fished area showed decreases in densities of up to 87%, indicating that the significant increase in biomass observed within the fished area is not consistent throughout the estuary. 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.

Stock status – small bivalves

The 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 years.

The status of Tasmania's small bivalve's fisheries have been assessed in terms of the lower acceptable limit of the stock, which is the point where recruitment overfishing occurs. Recruitment overfishing implies that the mature adult (spawning biomass) is depleted to a level where the future productivity of the stock is diminished. Recruitment overfished stocks have not necessarily collapsed, but do have fewer recruits than a healthy stock.

It's important to note that fishery management generally includes both limit reference points that define the lower acceptable point for the stock plus target reference points, which are the ideal level for the stock. In this report we assess bivalve fisheries against only the limit reference point, which is also the process used nationally for stock status reporting.

Stock status of these bivalve fisheries was based on density and size composition data from the most recent surveys, plus consideration of trends in catch and CPUE data.

Species	Status	Comments
Georges Bay – **Native Flat Oyster** ***Ostrea angasi***	**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 2021 as 824.5 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.

Native Flat Oyster, Ostrea angasi - Georges Bay

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 (DPIPWE, 2007). TACC allocation is based on fishery surveys of estimated total biomass conducted every two to three years with the TACC set as equal to 10% of the estimated total biomass. A harvest strategy was developed in 2016 (see below) with limit reference points (DPIPWE, 2017) and a 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. Data from previous surveys can be found in TAFI (2008), IMAS (2010), Tarbath and Gardner (2013), Jones and Gardner (2016) and Keane and Gardner (2018).

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

Harvest strategy

A harvest strategy (HS) with limit reference points for *O. angasii* was developed in 2016 to prevent overfishing of the stock should the demand for the product increase (Jones and Gardner 2016; DPIPWE, 2017). The HS, based on the Commonwealth fisheries harvest strategy (Smith et al., 2007), are employed (Fig. 2):

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

> B_{MSY} is 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.

F_{MEY} - Fishing mortality resulting in MEY.

> F_{MEY} is defined as Fishing mortality, i.e. the proportion of fish caught and removed by fishing, resulting in MEY. The current harvest fraction is set at 10% of the estimated biomass, thus FMEY = *0.1*BMEY, or 32.2 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}.

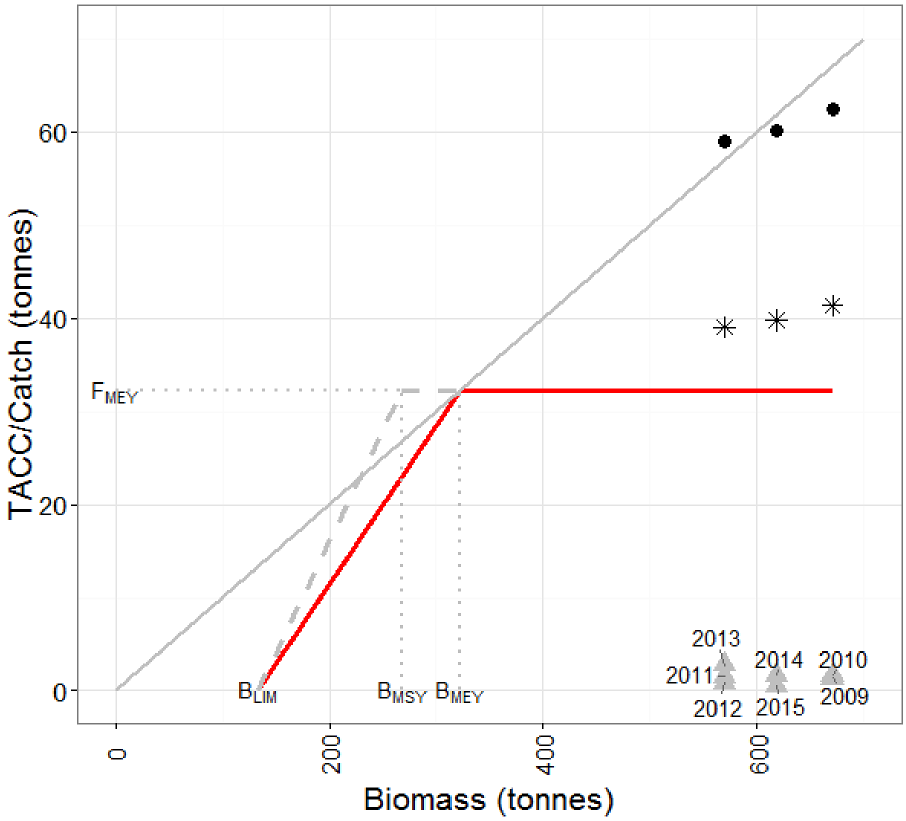

Figure 2. Harvest strategy (HS) (red line) with harvest control rules for the Georges Bay O. angasi fishery. The solid grey line represents the current TACC setting process = estimated total biomass*0.1. The TACC's applied for fishery years 2008-2015 are represented as tonnes (black circles) and as thousands of dozens (black stars). Grey triangles indicate annual catch and associated fishing year ending 2008-2015. The 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} = 321.8 t. F_{MEY} is the TACC limit which is derived from B_{MEY}*0.1 = 32.2 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. (Source: Jones and Gardner, 2016)

Objectives

This is the 6th 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 2021-2022 fishing year. 3. Assess previous years CPUE and catch trends with reference to the allotted TACC.

Methods

The survey design for 2021 is consistent with methods used in other small bivalve fisheries in Australia (Dent et al. 2014), and is replicate of the 2016 and 2018 Angasi surveys where the total area used to estimate biomass only includes areas considered to be active fishing grounds (82,540 m^2; Fig. 3; Jones and Gardner, 2016). Within the identified oyster beds, transects of 100 m in length were laid randomly from the vessel. Samples (0.25 m^2 quadrats) were collected by IMAS researchers at 0 m and every 20 m along the transect (i.e. 6 samples per 100 m transect). A total of 12 transects and 72 quadrats were sampled within the active fishing grounds. From each quadrat all *O. angasi* present were harvested, returned to the vessel and measured across the longest axis (± 1mm) using electronic measuring boards. Weight estimates for each oyster were calculated from length-weight relationships previously established for this species in Georges Bay (Fig. 3).

$w = 0.0002 * l^{2.8924}$

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

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. A non-parametric bootstrap method (100,000 iterations with repeats) as for total abundance estimation was employed to extract the 50^{th}, 20^{th} and 10^{th} 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 estimated weight of harvestable sized oysters. In the absence of information on the size structure of the catch, the estimated weight of harvestable sized oysters is calculated both in terms of mean weight of legal-sized animals as well as from the 80% percentile (upper) of the legal-size structure at the time of the survey.

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. The same non-parametric bootstrap method (100,000 iterations with repeats) was employed to extract the 50^{th}, 20^{th} and 10^{th} 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).

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 31/08/2017. CPUE data is presented as the fishing year (1^{st} Sept – 31^{st} August) mean (dozens/hr) 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.

This survey also recorded mean density in four historically fished *O. angasi* beds; Bed 1, Bed 2 Bed 3 and Bed 4 (Fig. 3) to determine the extent of resources outside the currently fished area. Densities were determined by six quadrats sampled along a single transect laid along the centreline of each bed.

Figure 3. Map of Georges Bay *O. angasi* beds surveyed between 2008 to 2021. Total *O. angasi* area for 2016 - 2021 biomass surveys (green polygon) is estimated at 82,540 m^2 (Jones and Gardner 2016).

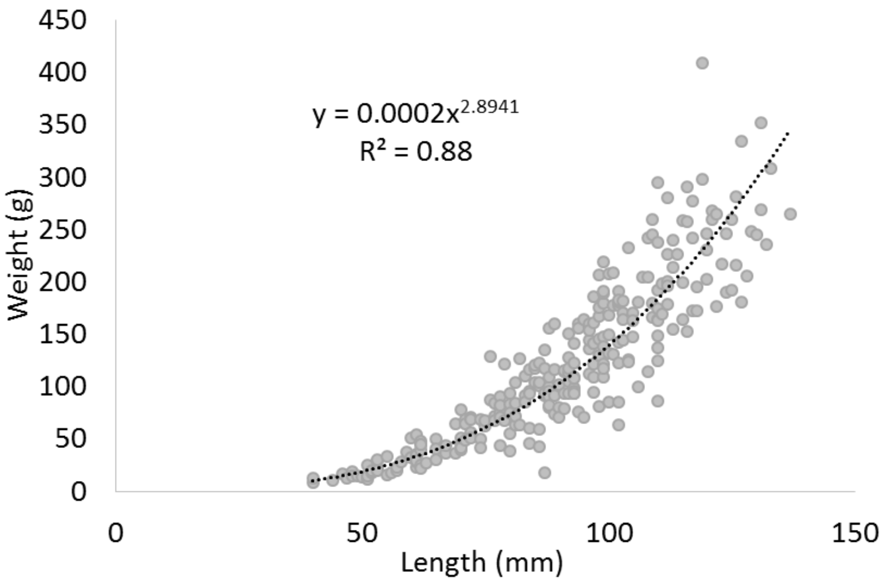

Figure 4. Length-weight relationship of O. angasi from Georges Bay (data from TAFI 2008, Tarbath 2010).

Results

A total of 2545 *O. angasi* were collected from the 72 quadrats across the fished area with a mean shell length of 80.1 mm (s.d = 15.2) and an estimated mean weight of 70.8 g (s.d.= 35.7 g) (Fig. 5). Of all animals sampled 76.4% were greater than the LML which represents 90.7% of the estimated total weight sampled. Estimated mean weight of legal sized animals from the 2021 survey was 83.8 g (s.d. = 30.2) therefore a dozen is estimated to weigh 1.01 Kg. The 80% percentile (upper) of the legal size structure was 95 mm, equating to an estimated weight of a dozen harvested animals to be 1.27 Kg. The density of *O. angasi* per quadrat in 2021 ranged from 0 to 85 with a mean of 35.3 (s.d. = 23.5). The mean biomass per metre square of *O. angasi was* estimated at 10.0 Kg (s.d. = 6.9).

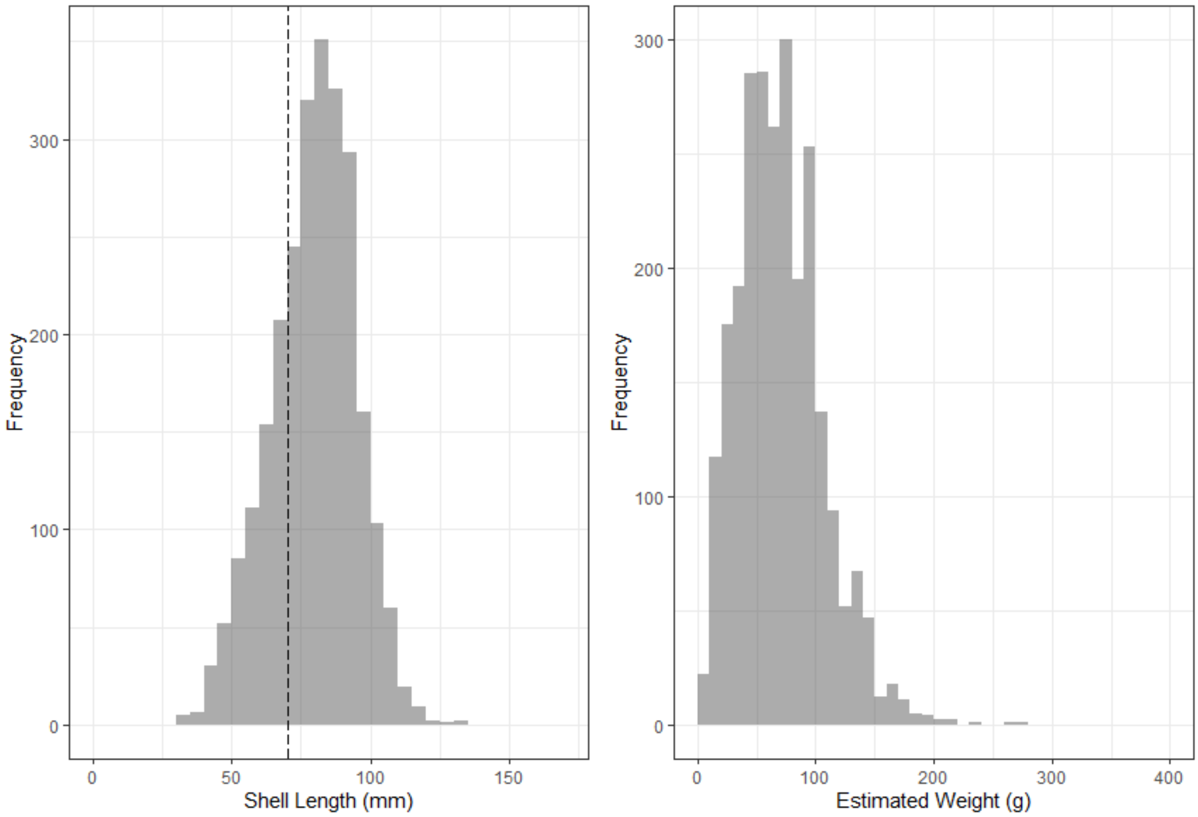

Figure 5. Frequency histograms of shell length and estimated weight of O. angasi from Georges Bay 2021. Dashed vertical line represents the legal minimum length (70 mm).

Total biomass estimates for the fishable reef area ranged from 824.5 t (50th quantile of the mean) to 739.0 t (10th quantile) (Tab. 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 141.2/m^2 (50th quantile) to 127.2/m^2 (10th quantile), with the estimated total abundances across the fishing area surveyed ranging from 11.7 million (50th quantile) to 10.5 million (10th quantile) (Tab. 2). Maximum biomass under the harvest strategy (B_{MEY} = 321.9 t; F_{MEY} = 32.2t), calculated from the 80% percentile (upper) of the legal-size structure , equates to a TACC of 25,331 dozen.

Mean catch per annum, since introduction of the TACC in 2007, is 1832 dozen (± s.d. = 1712) (Tab. 3). Total catch of *O. angasi* averaged 1,896 dozen over 2007 - 2014 period before declining to as low as 180 dozen in the 2015/2016 season (Fig. 6). The maximum annual catch of 6230 dozen was recorded in 2018/19, which equates to 29.1% of the allocated TACC in that year. It is also the maximum percentage of TACC caught in any year (Tab. 3). Catch fell to 830 dozen in the 2019/20 season. There has been no catch reported in the first 11 months (to 31st July 2021) of the 2020/21 fishing season.

Mean densities of *O. angasi* in beds outside the fished area ranged from 2.0 to 6.9 kg/m^2, respectively (Tab. 5). Beds 1 and 2, closer to the estuary mouth, had a 75% - 87% decrease in density between 2018 and 2021, equating to a 63-83% decrease in biomass. The density in Bed 4 remained unchanged, however biomass doubled given a substantial increase in mean size.

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 2021 fishery survey with 50th, 20th and 10th quantile of the bootstrapped mean biomass with standard errors in parenthesis. TACC (10% biomass) 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 (1.01 Kg) and upper 80% percentile (1.27 kg) of the legal size structure. Biomass at maximun economic yeild (MEY; Jones and Gardner, 2016) and associate TACC estimates are also provided.

Estimate	**Biomass (Kg m²)**	**Total Biomass (tonnes)**	**Biomass TACC (tonnes)**	**TACC Estimates 10% biomass (dozens)** ***Based on mean legal weight***	**TACC Estimates 10% biomass (dozens)** ***Based on 80% percentile***
50th Quantile	10.0	824.5	82.4	81,949	64,903
	(9.2 - 10.8)	(757.4 - 891.7)	(75.7 - 89.2)	(75,254 – 88,44)	(59,601 – 70,205)
20th Quantile	9.3	768.2	76.8	76339	60,460
	(8.5 - 10.1)	(701.1 - 835.4)	(70.1 - 83.5)	(69,645 - 83034)	55,158 – 65,762
10th Quantile	9.0	739.0	73.9	73,410	58,140
	(8.1 - 9.8)	(671.9 - 806.2)	(67.2 - 80.6)	(66,715 – 80,105)	52,838 – 63,442
MEY		**321.8**	**32.2**	**31,983**	**25,331**

Table 2. Density estimates calculated from bootstrapped (100,000 iterations) of *O. angasi* densities from the 2021 fishery survey in Georges Bay. 50th, 20th and 10th quantile of the bootstrapped mean density with standard errors in parenthesis.

Probability estimate	Density (m²)	Total abundance estimate (millions)	Total number of dozens estimated for survey area
50th Quantile	141.2	11.6	971,381
	(130.2 - 152.3)	(10.7 - 12.6)	(895,498 – 1,047,263)
20th Quantile	131.9	10.9	907,565
	(120.9 - 143)	(10 - 11.8)	(831,682 – 983,447)
10th Quantile	127.2	10.5	874,701
	(116.1 - 138.2)	(9.6 - 11.4)	(798,819 – 950,584)

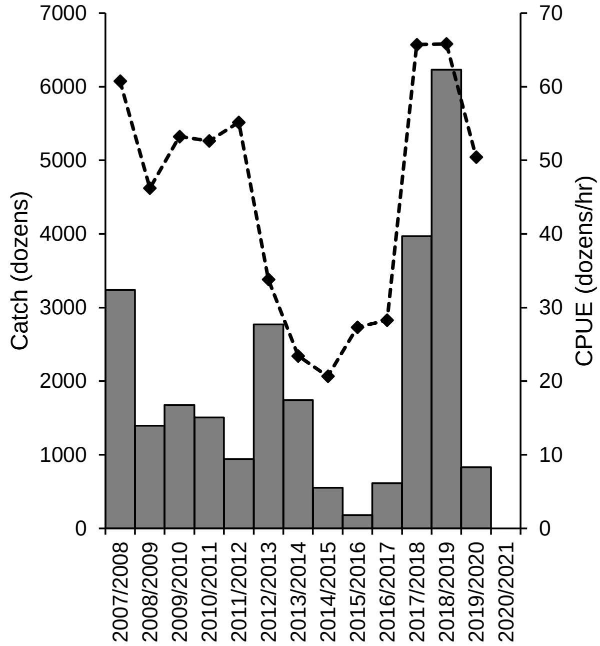

Figure 6. Catch (dozens) and mean catch per unit effort (CPUE: dozens/hr) for *O. angasi* in Georges Bay from fishing seasons between 2007 to 2021. Fishing year runs from 01 September to 31st August; 2021 data as at 31 July 2021.

Table 3. Catch (dozens), TACC (dozens) and percentage of TACC caught for O. angasi in Georges Bay St Helens since 2008. *2021 data to 31st July 2021

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	180	39796	0.45
2017	615	21400	2.87
2018	3968	21400	18.54
2019	6230	21400	29.11
2020	830	21400	3.88
2021*	0	21400	0

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

	2008	2010	2013	2016	2018	2021
Est. area of fishery (m^2)	55,036	69,895	52,104	82,540	82,540	82,540
Est. mean biomass (Kg/m^2)	12.2	8.2	11.1	4.7*	4.4*	10.0*
Est. total biomass (t)	670.6	569.5	618.4	391.5*	364.8*	824.5*
Est. total number in fishery	5.0	4.7	4.8	6.0*	4.0*	11.6*

Table 5. Mean length, density and biomass (with 95% confidence intervals) of *O. angasi* in Georges Bay outside the current fished area in previously defined beds, Bed 1, Bed 2 and Bed 4 (see Fig. 3).

	length (mm)				Density No. / m2				Biomass kg / m2			
	Bed 1	Bed 2	Bed 3	Bed 4	Bed 1	Bed 2	Bed 3	Bed 4	Bed 1	Bed 2	Bed 3	Bed 4
2021 Mean	90.6	102.8	88.6	89.2	36.0	50.0	22.7	59.3	3.8	6.9	2.0	5.6
CI	(84.6 - 96.6)	(100.2 - 105.4)	(84.9 - 92.4)	(86.0 - 92.3)	(11.0 – 61.0)	(23.9 - 76.1)	(4.1 - 41.2)	(3 - 115.7)	(1.6 - 6.1)	(2.9 - 10.8)	(0.4 - 3.7)	(0.1 - 11.1)
2018 Mean	84.5	91.2		71.1	283.2	197.3		59.2	22.7	18.9		2.8
CI	(77.5 - 91.5)	(81.8 - 100.5)		(50.2 - 91.9)	(196.8 - 369.6)	(138.2 - 256.5)		(15.4 - 103)	(18 - 27.4)	(15.6 - 22.1)		(1 - 4.5)

Discussion and Recommendations

The 2021 survey area replicated that of the 2016 and 2018 surveys which recognised a single large bed of *O. angasi* within Georges Bay. Surveys prior to 2016 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 suggested this may have been previously underrepresented (Jones and Gardner 2016). Four of the five smaller *O. angasi* beds to the east and north (identified as fished area prior to 2016) were also surveyed here but do not form part of the estimated total biomass, with results indicating they hold biomass which is likely to contribute to the reproductive capacity of the bay. The 2013 *O. angasi* survey (Tarbath and Gardner 2013) indicated a spatial trend away from these former fishing beds with preference to the area identified in 2016. The 2021 survey showed a decline in abundance in these north-eastern beds since 2018 (Keane and Gardner, 2018).

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 estimates of total biomass and abundance are less than 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 excludes animals in 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 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. In 2021, all three levels of biomass estimates are above the biological limit reference point (B_{LIM}) of 134.1 t defined in the 2017 update of policy document for the Tasmanian minor shellfish fishery (Jones and Gardner, 2016; DPIPWE, 2017). Furthermore, all biomass estimates are above the B_{MEY} of 328.1 t inferring that the TACC should be capped at F_{MEY}, i.e. 32.2 t, or 25,331 dozen.

The use of the 80% percentile (upper) of the legal size structure as the estimated weight of harvested oysters for the conversion of biomass to dozens for the TACC setting is recommended in the absence of data surrounding the size structure of the catch. This robust and conservative measure reduces potential catch bias to the larger size classes theoretically allowing the TACC, in terms of biomass, to be exceeded. Increasing precision in this estimate could be achieved by assessing by the size structure of the catch compared to the population. Alternatively, adapting the harvest strategy to an abundance based measure would eliminate biomass to dozens conversion uncertainty.

Increased precision in the estimation of the area occupied by both the resource and the fishery is seen as the best way to reducing uncertainty in the estimate of biomass. Resource boundaries are currently defined by fishers approximating bed boundaries, however could be spatially mapped by towed video and diver swims with increased accuracy. The use of GPS and depth/time loggers (spatial data) has proven useful in assisting management decisions in Australian abalone fisheries where it has become mandatory in some states (Mundy 2011), and could be applied to the *O. angasi* fishery.

The 226% increase in biomass of *O. angasi* from 364.8 t (4.0 million individuals) to 824.5 t (11.6 million) can be attributed to the survival and growth of large numbers of small juvenile *O. angasi* < 25 mm observed throughout the fished area in 2018 (Fig. 6; Keane and Gardner, 2018). In 2018, small juveniles were observed to have settled on dead shell throughout the fished area, but not in the high-density areas of Beds 1 and 2. Subsequently, Beds 1 and 2 had 63 and 83% decline in biomass, respectively, between 2018 and 2021. Substantially lower numbers of juveniles were observed over the fished area during the 2021 survey compared to the 2018 survey, and suggest that the record biomasses reported here may not persist into the future.

Figure 6. Juvenile *O. angasi* < 25 mm settled on oyster shell observed during 2018 surveys (Keane and Gardner, 2018)

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