Interim report - Macquarie Harbour Maugean skate population status and monitoring

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Executive summary

The Maugean skate (*Zearaja maugeana*) is an endangered species, now restricted to Macquarie Harbour on the west coast of Tasmania, Australia. The environmental conditions in the harbour, particularly dissolved oxygen levels, have been impacted by anthropogenic inputs. Recent research has detected a potential decline in the skate population, raising concerns for the conservation status of the species. In response, this project developed a gillnet survey monitoring program to provide information on the status of the last known population of the species. Results presented here cover the first year of sampling (2021) in a three-year (2021-2023) monitoring program.

Size composition data collected between 2012 and 2021 indicated that the median size of females had significantly increased, and the proportion of juveniles captured had significantly decreased, consistent with recruitment failure. Using catch per unit effort (CPUE) as a measure of relative abundance, we demonstrated a substantial decline in CPUE between 2014 and 2021 of 47%.

The scale of the overall decline and the scarcity of new recruits creates significant concern for the conservation of the species and implies the need for immediate action. Furthermore, our results highlight the vulnerability of the species to degraded environmental conditions and the need for further monitoring of the population.

Introduction

The endangered micro-endemic Maugean skate (*Zearaja maugeana*) is only known from two isolated estuarine systems located on the west coast of Tasmania, Australia, Bathurst and Macquarie Harbours, representing one of most restricted distributions of any elasmobranch (Last and Gledhill, 2007). However, a recent environmental DNA study (Moreno et al., 2022) demonstrated that the vast majority, if not all, of the remaining Maugean skate live only in Macquarie Harbour. These findings highlight the vulnerability of the species and the need for urgent conservation action to ensure the persistence of this unique species.

The physicochemical conditions in Macquarie Harbour have changed markedly since European settlement, influenced by anthropogenic activities in and around the estuary (e.g., mining, forestry, hydro-electricity generation, and marine farming operations), as well as the more general effects of climate change. Of recent concern, has been a significant decline in deep water (>10 m) dissolved oxygen (DO) conditions in the Harbour (Ross et al., 2020).

There is mounting evidence that these low DO conditions are impacting the Maugean skate population, including inducing mortality events (Moreno et al., 2020). Furthermore, analysis of research gillnet data collected between 2012 and 2018 strongly suggests that this changed environment has reduced the relative abundance of juvenile and sub-adult individuals, likely due to lower egg hatching success and/or juvenile survival (Moreno et al., 2020)

Given the results of Moreno et al. (2020) suggest that the extinction risk for Maugean skate has increased since netting surveys first commenced in 2012, additional surveys were funded by the Tasmanian sustainable marine research collaboration agreement (SMRCA) for a further three years from February 2021 to December 2023. However, the risk to the species makes it prudent to provide an interim report of results prior to the project's completion, such that an updated assessment of Maugean skate population changes in Macquarie Harbour can be outlined and fed into current/planned federal (Environment Protection and Biodiversity Conservation Act 1999) and state (Threatened Species Protection Act 1995) conservation actions. Here we report on data from the 2021 net surveys and a reanalysis of the entire data set from 2012 to 2021.

Objectives

The primary aims of this interim netting survey assessment are to:

1. Use the size composition of Maugean skate catches as an indicator of population change, in particular recruitment variability.
2. Compare catch per unit effort (CPUE) changes across the netting surveys to describe any declines in relative abundance.
3. Assess the implications of declining environmental conditions in Macquarie Harbour on the future viability of the Maugean skate population.

Methods

1. Sampling methodology and historical data

Gillnet surveys were conducted at roughly three-month intervals between February and December 2021 to coincide with the austral seasons. Each survey sampled three primary areas based on previous knowledge of the movement and distribution of the skate around Macquarie Harbour (a) the Table Head / Liberty Point area, b) the World Heritage Area, and c) the Swan Basin / Pine cove area (Figure 1). Maugean skate were captured using standard monofilament graball nets (50 m long by 33 mesh drop; 114 mm stretched mesh). Nets were set during daytime and soak times were restricted to under 2 hrs. All Maugean skate captured were measured (total length (TL)) and sexed before being released.

Preceding this study, there had been a near continuous sampling effort that commenced in 2012 and was carried out through three Fisheries Research and Development Corporation (FRDC) studies (Bell et al., 2016, Lyle et al., 2014; Moreno et al., 2020).

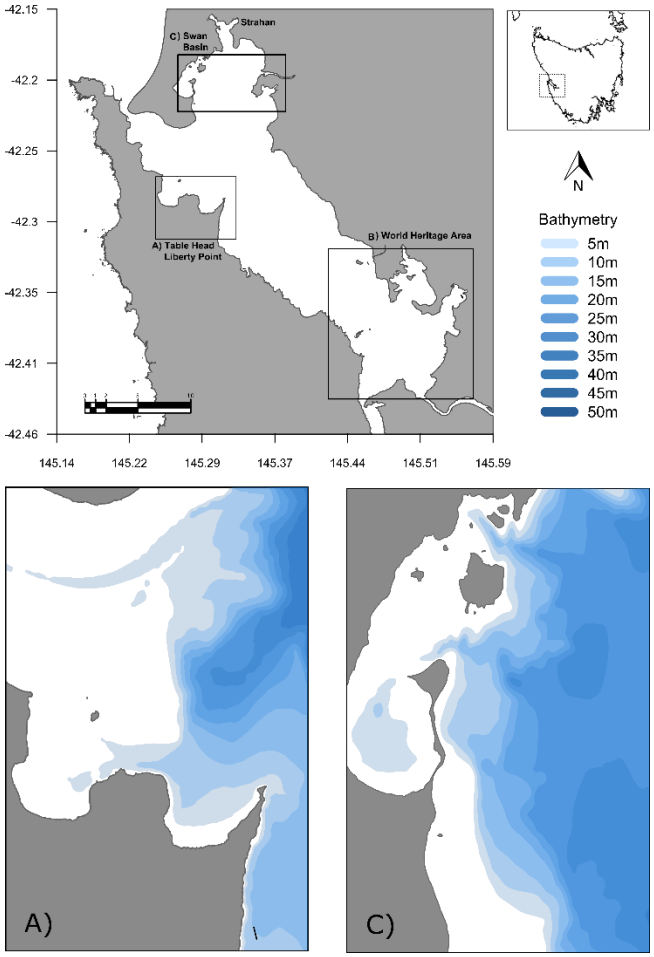

Figure 1. Map showing the primary sampling areas for Maugean skate population monitoring with inserts showing the complex bathymetry of Table Head (a) and Swan Basin (c).

2. Size composition

The sampling gear (gillnets) and broad methodology used throughout the current and previous studies has not changed, allowing for direct comparison of catch size structure across sites and through time. However, the distribution of fishing effort in the previous studies varied based on the individual research objectives, with the Table Head / Liberty point area being the only site that was consistently sampled throughout.

There is strong evidence that Maugean skate in Macquarie Harbour constitute a single population (Weltz et al., 2018), and that there are no site-specific differences in sex or size distribution (Bell et al., 2016). In contrast, there are clear differences in site specific abundance patterns, with the Table Head / Liberty point area containing a significantly higher proportion of skate than any other site in Macquarie Harbour (Bell et al., 2016). Therefore, to account for potential site-specific biases introduced by changes in the fishing effort across the different studies, analysis of size frequency data was conducted for both total catch across all sites (2014 and 2021 data only), and the Table Head/ Liberty Point area only (all years).

Size frequency data for each study, FRDC 2010-016 (April to November 2012), FRDC 2013-008 (October 2013 to November 2014), FRDC 2016-068 (October 2017 to November 2018) and the SMRCA 2021 data set (February to December 2021), was separated by sex and plotted alongside each other to explore possible changes in the size distribution (based on TL) of the population through time. Changes in size distributions were tested using bootstrapped Kolmogorov-Smirnov tests with a Bonferroni adjusted alpha value to account for multiple comparisons. Likewise, sex-specific median total lengths were compared using a Wilcoxon rank test.

3. Relative abundance

In the SMRCA and FRDC 2016-068 (Moreno et al., 2020) studies, a maximum set duration of two hours was applied, with fishing limited to daytime sets only. By contrast, longer daytime set durations, along with overnight sets, were applied in the earlier studies (Bell et al., 2016, Lyle et al., 2014). Several skate mortalities were linked to these longer set durations, necessitating a more conservative approach to gear usage to reduce the likelihood of negative impacts on the skate (and other bycatch).

While necessary to ensure animal welfare, these changes in methodology could affect catchability and gear efficacy, potentially introducing methodological biases that would affect CPUE calculations. Accordingly, in order to explore changes in relative abundance through time, only data from 2014 and 2021 were used. Sampling in both years was restricted to daytime only and had a similar spatial and temporal design (4 seasonal surveys targeting the same sites). There was a small number of longer duration deployments in 2014, with ten outlier deployments where soak times were greater than 5 hrs. These ten deployments were excluded from CPUE calculations to account for potential effects of increases in catch from extended soak times. Mean soak time for the analysed deployments was 2.6 and 1.9 hrs respectively for 2014 and 2021.

CPUE was estimated as the number of Maugean skate caught per net metre per hour (N/m/hr). As with the size frequency data, CPUE metrics were calculated for the entire Harbour and the Table Head / Liberty point area separately.

Results

1. Size composition

There was a total of 260 individual gillnet deployments in Macquarie Harbour, with 112 in the Table Head / Liberty Point area between February and December 2021. A total of 45 individual skate were captured (female=20, male=25), of those, 33 were captured in the Table Head / Liberty point area (females=13, males=20). The smallest individual captured was 568 (male) mm TL and the largest was 840 (female) mm TL (Fig. 2). Data were also available for 84 individuals sampled in 2012 (FRDC 2010-016), 131 individuals sampled in 2013 and 2014 (FRDC 2013-008) and 54 individuals sampled in 2017 and 2018 (FRDC 2016-068) (Fig. 2.)

As outlined in Moreno et al. (2020), median size and size distributions at the Table Head / Liberty Point area did not differ between the 2012 and 2014 sampling periods for either sex (Wilcoxon rank sum test [Males, W=1230, p=0.29; Females, W=1180.5, p=0.98], Kolmogorov-Smirnov test [Males, D=0.21, p=0.12; Females, D=0.14 , p=0.63]), but there was a significant difference between 2014 and 2017-18 for both median size and size distributions (Wilcoxon rank sum test [Males, W=1387, p=0.02; Females, W=957.5, p=0.01], Kolmogorov-Smirnov test [Males, D=0.29, p<0.01; Females, D=0.25, p=0.05]). 2021 median size and size distributions of females at the Table Head / Liberty Point area were significantly different from those for the 2014 baseline period (W=447.5, p>0.005; D=0.34, p=0.034), but non-significant for males (W=998, p=0.39; D=0.22, p=0.20). Furthermore, there was a significant difference in the proportion of juvenile and sub-adult size classes (≤ 600 mm; Bell et al., 2016) between sampling periods at the Table Head / Liberty Point area ($\chi 2$=7.03, p=0.03), with the lowest proportion (3%) for the 2021 data set, compared with ~17-21% in the 2012 and 2013-2014 studies and 9.3 % in the 2017-2018 study (Fig. 2).

In the Harbor wide data (all sites), median size and size distributions of females were significantly different between 2014 and 2021 (W=447.5, p<0.005; D=0.34, p=0.02). Conversely, median size and size distributions of males were not significantly different between 2014 and 2021 (W=998, p=0.39; D=0.22, p=0.2) (Fig. 3). Furthermore, there was a significant difference in the proportion of juvenile and sub-adult size classes (≤ 600 mm; Bell et al., 2016) between sampling periods at the Table Head / Liberty Point area ($\chi 2$=7.03, p=0.03), with the lowest proportion (3%) for the 2021 data set, compared with ~17-21% in the 2012 and 2013-2014 studies and 9.3 % in the 2017-2018 study (Fig. 2).

2. CPUE comparison

In 2014, CPUE was 0.17 and 0.25 N/m/hr for all sites and the Table Head / Liberty Point area, respectively. In 2021, CPUE was 0.09 and 0.14 N/m/hr for all sites and the Table Head / Liberty Point area, respectively. These numbers represent a 47 % decline in relative abundance across the harbour and a 44% decline in the Table Head / Liberty point region.

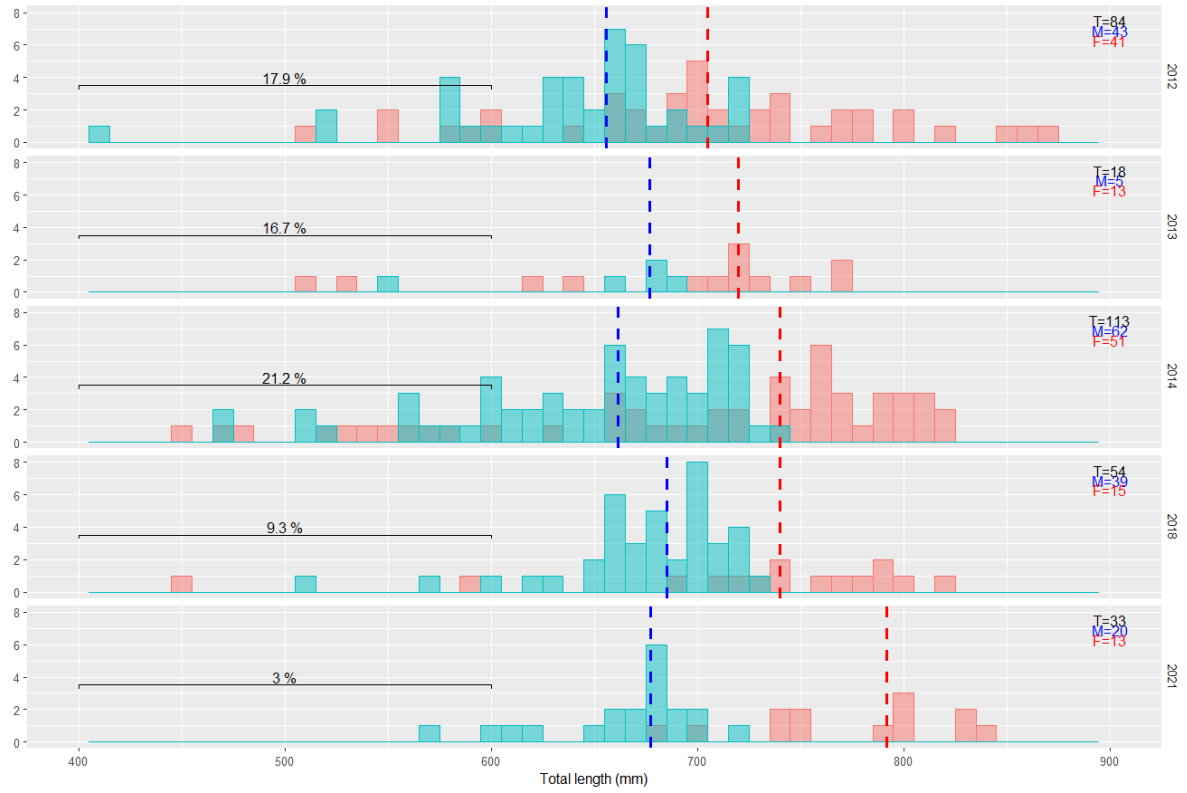

Figure 2. Size distribution of male (blue) and female (red) Maugean skate sampled from Table Head/Liberty Point during 2012 (top panel; FRDC 2010-016), 2013-14 (second panel; FRDC 2013-008), 2017-18 (third panel; FRDC 2016-068) and 2021 (bottom panel; current SMRCA study). Vertical dashed lines indicate median lengths of males (blue) and females (red). Sample sizes are indicated (T= sexes combined, M = males, F = females), value above the horizontal bracket indicates the proportion of individuals < 600 mm present in each sample.

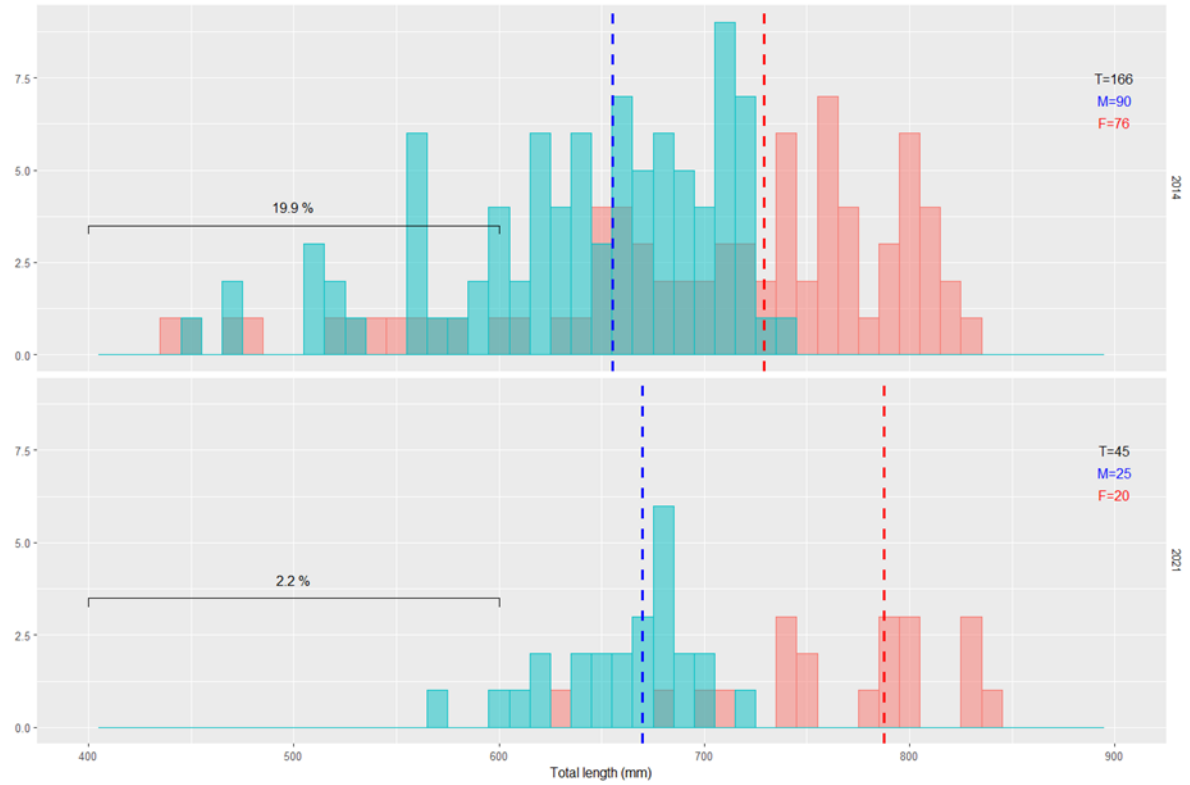

Figure 3. Size distribution of male (blue) and female (red) Maugean skate sampled from all sites during 2014 (top panel; FRDC 2013-008) and 2021 (bottom panel; current SMRCA study). Vertical dashed lines indicate median lengths of males (blue) and females (red). Sample sizes are indicated (T= sexes combined, M = males, F = females), value above the horizontal bracket indicates the proportion of individuals < 600 mm present in each sample.

Discussion

1. Size composition

Catch data from the present study, Lyle et al. (2014), Bell et al. (2016) and Moreno et al. (2020) represent a near continuous sampling record of the species in the Table Head / Liberty Point area since 2012. Size composition data indicated that the median size of females has increased since 2012. Likewise, the overall length frequency distribution of both sexes has shifted to the right, reflecting a reduction in the relative abundance of juvenile and sub-adult individuals (≤ 600 mm), along with an increase in the size of the larger females (adults) in the catches. The gillnets used in these surveys are size selective and most Maugean skate tend to be lightly entangled in the meshes by the rostrum (and rostral spines), such that some individuals have been observed to drop out of the meshes while the net is under tension during hauling. Small individuals (< 500 mm TL) with a less pronounced snout (and very small rostral spines) are thus less likely to be caught or retained in the meshes and thus expected to be underrepresented in the gillnet samples even when present. However, given that the same nets have been used in all four studies, any size selectivity bias is expected to have been constant through time, justifying an examination of temporal trends in size composition for inferences about changing population status.

Interestingly, unlike females, male median size has not significantly increased over time. This is likely due to the fact that even in early surveys, male median size was already close to the maximum known size for males. There is clear evidence for sexual dimorphism in the species, with males being considerably smaller than females despite reaching sexual maturity at similar sizes (Bell et al., 2016). Therefore, the size frequency distribution of adult males is more compact and skewed towards the upper end when compared with females, making it impossible for median sizes to increase much more.

Despite uncertainty as to the significance for the population, a recent decline in recruitment, possibly due to lower hatching success or juvenile survival, coupled with the growth of existing adults (i.e., an ageing population) would result in changes in catch size structure like those observed here. Unvalidated estimates of age and growth for the Maugean skate (Bell et al., 2016) are not inconsistent with the observed data in that if a period of reduced recruitment is assumed, then the continued growth of juveniles and adults over a three-to-four-year period (e.g., between 2013-14 and 2017-18) would give rise to a comparable change in size structure.

While the analysis presented herein is not definitive, the high likelihood that changes in population structure have occurred in the Maugean skate population within the past 10 years should be considered very seriously, particularly within the context of the other findings in FRDC 2016-068, namely; (i) the vulnerability of developing embryos to the environmental conditions experienced during the protracted incubation period, (ii) the vulnerability of early life stages to environmental stressors, and (iii) the evidence of adult mortalities linked with environmental factors (Moreno 2020).

2. CPUE comparison

Effort data from the first year of sampling in this current study show that a significant decline of up to 47% in the relative abundance of Maugean skate has occurred since 2014. While not directly comparable due to methodological inconsistencies, catch rates from 2017 and 2018 were relatively consistent with 2014 values (Moreno et al., 2020). However, Moreno et al. (2020) reported two environmental events in 2019 that resulted in high mortality (~44%) of individuals being electronically tracked. Therefore, the observed declines in relative abundance presented herein, are likely the result of high impact environmental events, and longer-term demographic effects resulting from changes in the size structure of the population and apparent decline in recruitment.

The unique hydrology of Macquarie Harbour results in a naturally challenging habitat. While anthropogenic activities since European colonisation have long impacted the harbour, in the past 15 years altered river flows (growing reliance on hydroelectric generation and production demand) and large-scale development of salmonid aquaculture have resulted in considerable changes to the environment. The Maugean skate has been shown to have behavioural and physiological mechanisms that allow it to survive in the challenging conditions of Macquarie Harbour. However, recent changes to the environment (particularly DO levels and mixing dynamics) mean that high impact environmental events have increased in duration, magnitude, and frequency (e.g., duration and severity of low DO periods). Likewise, there is an increased potential for overlap of multiple stressors that may have compounding effects (DO, salinity, temperature). Based on animal-borne environmental sensors and high-resolution environmental monitoring data of the system, Moreno et al. (2020) observed that Maugean skate mortalities were linked to two environmental events. The first occurred during summer (Jan-Feb 2019) when bottom water (<15 m) DO levels were extremely low (<25%), coinciding with high freshwater volumes that deepened the halocline and very high surface water temperatures (up to 22 °C). The second event occurred in April 2019 when a large westerly system forced a large volume of marine water into the system, causing a rapid displacement of the low DO water mass at the bottom of the harbour into shallow depths. Accordingly, it is apparent that the species is already being pushed beyond their adaptive threshold. This highlights one of the unique challenges of managing micro-endemic, hyper-specialised species, which is that the viability of the species is intrinsically linked to the health of their restricted habitat. Therefore, in the case of the Maugean skate, the ongoing impacts to DO levels and mixing dynamics are of extreme concern for the persistence of the species.

Previous investigations into the distribution, movement, and habitat use of the Maugean skate show that Table Head and Liberty Point constitute a critical habitat for the species within the harbour. This observation is in line with the differences in CPUE seen between the Table Head / Liberty Point area data and the harbour wide data in this study. Furthermore, despite the general decline in relative abundance seen between 2014 and 2021, the CPUE ratio between Table Head and the rest of the system remained consistent. This provides further supporting evidence to the conclusions in Moreno et al. (2020), who reported that movement and habitat use patterns in adults have remained consistent through time regardless of changes in environmental conditions or in the structure of the population. Therefore, the abundance and size structure patterns seen in the Table Head / Liberty Point area appear to be indicative of broader, population wide patterns.

As mentioned above, there is a size selectivity bias associated with the fishing gear used across all Maugean skate studies included here (see section 1 of discussion). The reported change in size structure (fewer juveniles and generally larger individuals) means that the current structure of the population has a higher proportion of individuals in the size ranges selected by the gear. Therefore, it is possible that the observed declines in relative abundance may underestimate the reduction in size of the overall population.

Implications

Results presented here cover only the first year (2021) and a small facet of a multi-year (2021-2023) assessment of the population. Further work is needed to understand long term trends in absolute population size, as well as the demographic consequences of the observed changes in size composition. However, we have opted to present this interim report because the magnitude of the observed decline in relative abundance is likely to have significant implications for the status of the population and therefore its conservation and management needs. Our results highlight not only a significant population decline having already occurred (based on changes in relative abundance), but also the ongoing risk of further large-scale declines as a result of sudden, high-impact environmental events.

Maugean skate are known to have an already restricted genetic diversity (Weltz et al., 2018), so any subsequent declines in the population are likely to have a considerable impact on the viability of the species, increasing their risk of extinction. Therefore, there is an urgent need to consider this new information in any future management action, particularly those actions that can help directly address habitat degradation in the harbour. It is also recommended that the current federal listing status (endangered) and both state and federal conservation advice for the species be re-assessed to incorporate these findings. Likewise, development of ex-situ conservation plans should be considered to ensure the persistence of the species and support on-site conservation management action.

We are fortunate that information has been collected on Maugean skate in Macquarie Harbour since 2012, as the decline in relative abundance could easily have gone undetected. This project emphasises the need for ongoing monitoring beyond 2023, as this will be critical for detecting any further declines or the impact of any mitigation strategies.

References

Bell, J.D., Lyle, J., Semmens, J., Awruch, C., Moreno, D., Currie, S., Morash, A.J., Ross, J. & Barrett, N. (2016). Movement, habitat utilisation and population status of the endangered Maugean skate and implications for fishing and aquaculture operations in Macquarie Harbour. Final Report, Fisheries Research and Development Corporation Project No. 2013-008, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart.

Last, P.R. & Gledhill, D.C. (2007). The Maugean skate, *Zearaja maugeana* sp. nov. (Rajiformes: Rajidae) — a micro-endemic, Gondwanan relict from Tasmanian estuaries, Zootaxa, vol. 1494, pp. 45–65.

Lyle, J. M., Bell, J. D., Chuwen, B. M., Barrett, N., Tracey, S. R., & Buxton, C. D. (2014). Assessing the impacts of gillnetting in Tasmania: implications for by-catch and biodiversity. Final Report, Fisheries Research and Development Corporation Project No. 2010-016, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart.

Moreno, D., Lyle, J., Semmens, J., Morash, A., Stehfest, K., McAllister, J., Bowen, B. & Barrett, N. (2020). Vulnerability of the endangered Maugean skate population to degraded environmental conditions in Macquarie Harbour. Final Report, Fisheries Research and Development Corporation Project No. 2016-068, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart.

Moreno, D., Patil, J., Deagle, B. & Semmens, J.M. (2022). Application of environmental DNA to survey Bathurst Harbour (Tasmania) for the endangered Maugean skate (*Zearaja maugeana*). Report to the National Environmental Science Program. Institute for Marine and Antarctic Studies, University of Tasmania, Hobart.

Ross J., Wild-Allen K., Andrewartha J., Beard J. & Moreno D. (2020). Environmental research in Macquarie Harbour. Understanding oxygen dynamics and the importance for benthic recovery in Macquarie Harbour. Final Report, Fisheries Research and Development Corporation Project No. 2016-067, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart.

Weltz, K., Lyle, J.M., Semmens, J.M. & Ovenden, J. (2018). Population genetics of the endangered Maugean skate (*Zearaja maugeana*) in Macquarie Harbour, Tasmania, Conservation Genetics, vol. 19, pp. 1505–1512.