Interim Report Number 2 - Macquarie Harbour Maugean skate population status and monitoring

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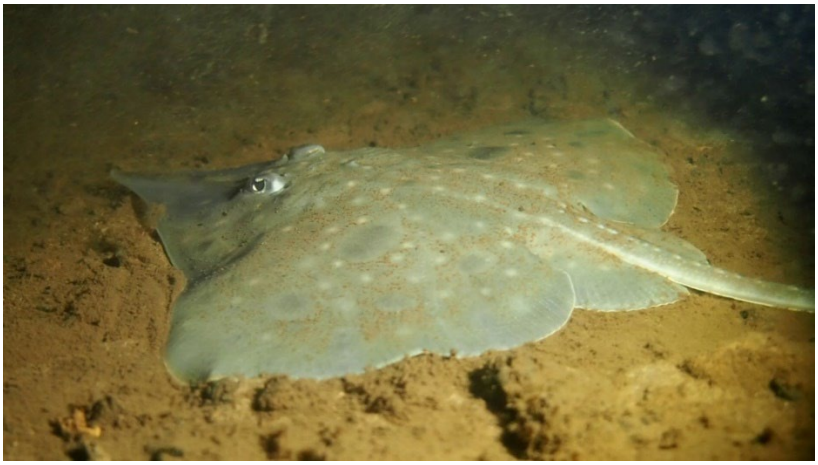
Executive summary

The Maugean skate (*Zearaja maugeana*) is an endangered species, now restricted to Macquarie Harbour on the west coast of Tasmania, Australia. Recent research has detected a potential decline in the skate population, raising concerns for the conservation status of the species. In response, a gillnet survey program to monitor the population status of the species was developed. The first interim report from this program was released in May 2023 and reported data up until the end of 2021. Results presented here cover all sampling events conducted to date, including the first full three-years (2021-2023) of the dedicated monitoring program, along with initial results from the program in 2024. A reanalysis of research gillnet data collected between 2012 and 2019 is also presented.

Size composition data collected across a range of projects on Maugean skate between 2012 and 2021 indicated that the median size of females had significantly increased, and the proportion of juveniles and sub-adults captured had significantly decreased with an absence of recruitment detected for a period of approximately eight years through the 2010s and into 2020. Using catch per unit effort (CPUE) as a measure of relative abundance, a significant decline of 47% in CPUE was identified between 2014 and 2021.

The updated relative abundance data reported here shows the population does not appear to have declined further and there are positive signs of at least one year-class of recruits coming into the population since 2021, although it is too early to determine what this leveling of the population trend and recruitment event mean for the future population trajectory. It is important to note that the Maugean skate population in Macquarie Harbour has not significantly increased since 2021. However, significant recovery of the adult biomass is not expected in the time frame of the most recent monitoring, as it takes six years for hatchlings to become mature adults.

This interim report highlights the crucial importance of further monitoring to understand population trends. Considering new data, it is also critical to update population models that are being considered regarding conservation action plans for the species.



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). A recent environmental DNA study (Moreno et al., 2022) has demonstrated that the vast majority, if not all, of the remaining Maugean skate live only in Macquarie Harbour. Monitoring the population of Maugean Skate in Macquarie Harbour is critical to ensure the most contemporary information is available to determine population viability and apply appropriate conservation action as required.

Netting surveys in Macquarie Harbour to accommodate a range of project objectives first commenced in 2012, additional surveys were funded by the Sustainable Marine Research Collaboration Agreement (SMRCA) from 2021 to 2023 and the Department of Natural Resources and Environment Tasmania from 2024 to September 2025. The first interim report in this series reported on data from the 2021 survey and a reanalysis of the survey data set from 2012 to 2019 (Moreno and Semmens, 2023). Findings identified that the median size of females had significantly increased between 2014 and 2021, while there was no significant change in the median size of males. The proportion of juvenile and sub-adults relative to adults caught declined significantly from ~17-21% in the 2012 and 2013-2014 surveys to the lowest proportions recorded in 2021 at 2.2%.

In 2014, catch per unit of effort (CPUE) was 0.17 skate caught per metre of net per hour (N/m/hr) for all sites combined. In 2021, CPUE was 0.09 N/m/hr. This represented a 47% decline in estimated relative abundance across the harbour.

Here we report an update on the current data set, including the reanalysis of the data set from 2012 to 2019, the 2021-2023 net surveys, and the data collected to date from the 2024 surveys (Aug and Sept 2024).

Objectives

The objectives addressed in this report are:

Assess the size composition of Maugean skate catches as an indicator of population change, in particular recruitment variability.

Compare catch per unit effort (CPUE) changes through time to describe changes in relative abundance.

Methods

Sampling methodology and historical data

Gillnet surveys were conducted at roughly three-month intervals between February 2021 and December 2023 to coincide with the austral seasons, noting that previous analysis demonstrated that CPUE was not related to season (Bell et al., 2016). In 2024, sampling was conducted in August (five days) and September (four days). Sampling was not conducted earlier in 2024 due to a prioritisation for the research team to secure an ex-situ population of Maugean Skate at the IMAS Taroona facility in the first half of the year, and then adverse weather through winter was unsuitable for sampling. We have included 2024 data collected so far as a point comparison, but it is subject to change as two further trips are still planed. Therefore 2024 data should be seed as preliminary and we urge caution when interpreting trends.

Since 2021, surveys have been conducted in three areas within the Harbour based on previous knowledge of skate movement and distribution as determined by acoustic telemetry, and areas of higher skate abundance identified through earlier systematic random sampling across the Harbour (Bell & Lyle, 2016; Bell et al., 2016; Moreno et al., 2020, Treloar et al., 2016). Importantly, these three areas were comparable with the survey design in 2014 in terms of geographic location and fishing intensity, allowing 2014 to be considered a baseline for the post-2020 dedicated population monitoring program. These sites were (A) the Table Head / Liberty Point area, (B) the World Heritage Area, and (C) the Swan Basin area, which includes Pine Cove and Long Bay and Swan Basin (Figure 1).

Maugean skate were captured using standard monofilament graball nets (50 m long by 33 mesh drops with a 114 mm stretched mesh size). From 2021 nets were set during daytime and soak times were restricted to under 2 hrs. All Maugean skate captured from 2021 onwards were measured (total length (TL)), sexed, tagged, tissue samples collected, sexual maturity determined for females using ultrasonography, body condition assessed using a biometric impedance analysis (BIA) unit, 0.5 -1.0 ml of blood extracted via a caudal venipuncture, and a photograph taken before being released. Skate were submerged in a recirculating processing tub throughout the procedure (except for length measurement), with the dissolved oxygen levels kept at 100% through supplementary oxygen. The processing of each individual was completed in less than 10 minutes.

All animal handling and processing procedures were conducted under University of Tasmania Animal Ethics approvals (A23857 & A30685). The research was conducted under NRET Permits to Take Threatened Fauna for Scientific Purposes: TFA20167; TFA22271; TFA23014; TFA24130 and TFA23035 and NRET Living Marine Resources Management Act Scientific Research Permits: 20075; 21080; 22018; 22091; 24056 and 23087.

The sampling gear (gillnets) and broad methodology used throughout the current and previous studies has not changed. The Table Head / Liberty point area is the only site that has been consistently sampled throughout. However, the distribution, intensity and timing of sampling varied due to different project objectives (i.e., replicating netting behaviour of recreational gillnetting, acoustic tagging and collection of animals for experimental physiology), with these projects occurring in 2011, 2013, 2015, 2016, 2017 and 2019. Catches from these years are shown in Table 1, but are excluded from subsequent analyses due to potential sampling bias.

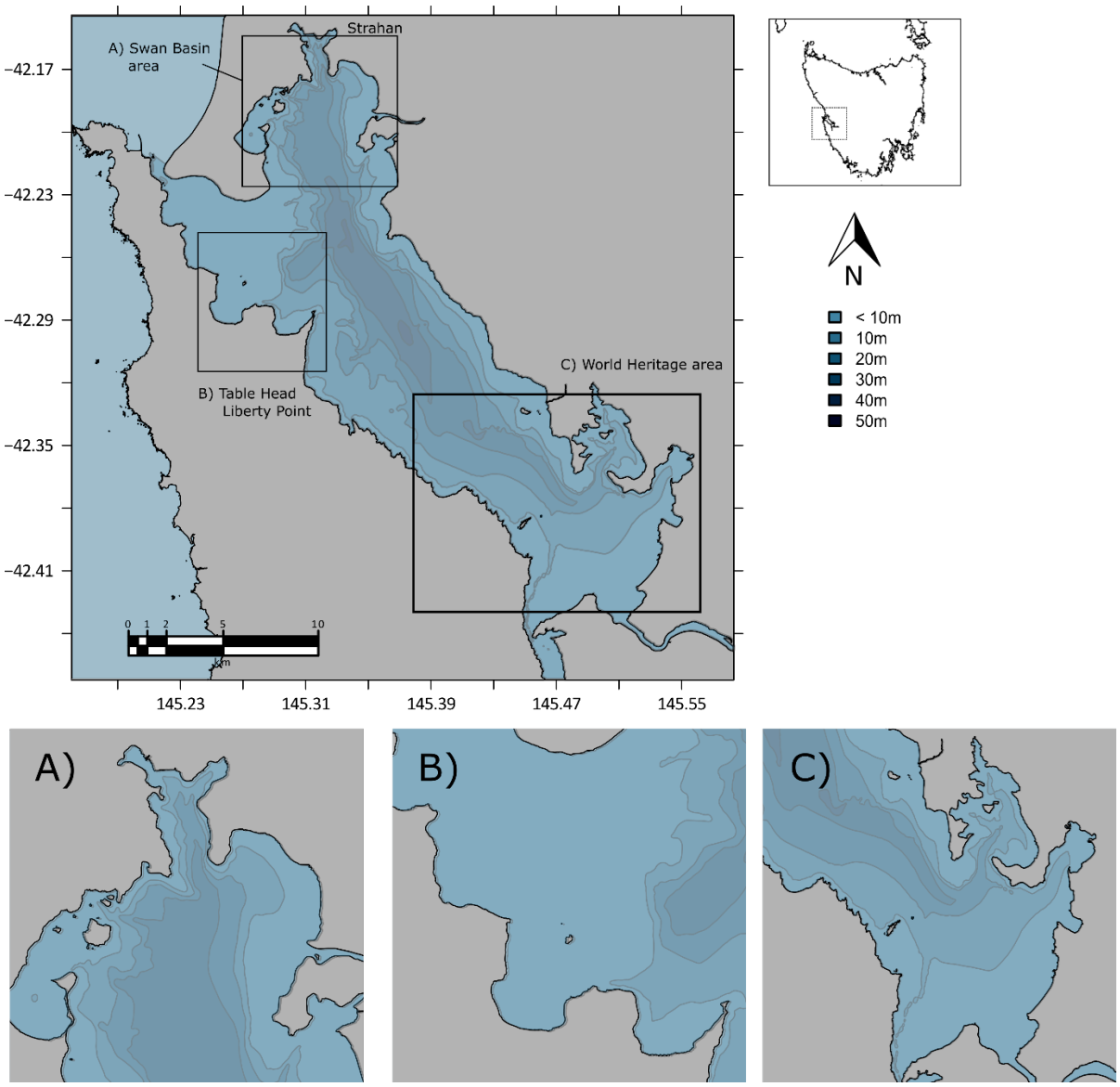


Figure 1. The primary sampling areas for Maugean skate population monitoring with inserts showing the complex bathymetry of (A) Swan Basin, (B) Table Head, and (C) and the World heritage Area.

Data analysis

Maugean skate in Macquarie Harbour constitute a single population (Weltz et al., 2018; Moreno et al., *In review*). There are no site-specific differences in sex or size frequency 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 the three reference sites (2014, 2021-2024 data only), and the Table Head/ Liberty Point area only (all years, noting exceptions outlined in previous section). Sex specific size dimorphism is a feature of Maugean Skate (Bell et al., 2016), as such, size frequency composition (total length; TL) was reported by sex.

A Kruskal Wallace (KW) test was used to test for Rank (~median) differences in size by year. A post hoc planned comparison of rank differences (~median) using a Dunn test with a Bonferroni correction was used to test for significant differences for each sampling year from 2021 against the baseline year

(2014). A post hoc planned comparison of mean size differences using a Wilcox test with a Bonferroni correction was used to test for significant differences for each sampling year from 2021 against the baseline year (2014). Significant differences in size frequency distribution for each sampling year from 2021 against the baseline year (2014) were tested using a bootstrapped Kolmogorov-Smirnov test with a Bonferroni correction.

Relative abundance

For the surveys conducted from 2017 onwards a maximum set duration of two hours was applied, with fishing limited to daytime sets only. By contrast, some longer daytime set durations, along with overnight sets were conducted 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).

To explore changes in relative abundance through time, only data from 2014 and 2021-2024 were analysed. Sampling in these years was restricted to daytime only and had a similar spatial and temporal design (4 seasonal surveys targeting the same sites). An exception was 2024, where seasonal sampling did not occur, due to reasons outlined previously. It is important to note that sampling in 2024 is incomplete and results from this year may be subject to change, therefore, 2024 values are presented as a point estimate and should be considered preliminary. There were 10 longer duration deployments in 2014, where soak times were greater than 5 hrs. These deployments were excluded from CPUE calculations to account for potential effects of increases in catch from extended soak times.

CPUE was estimated as the number of Maugean skate caught per net metre per hour (N/m/hr). Yearly CPUE metrics were calculated for the entire Harbour and each of the three reference areas separately. Juvenile /sub-adult and adult specific CPUEs are also presented.

Results and Discussion

Catch, effort and size composition

There was a total of 1,851 individual gillnet deployments in Macquarie Harbour from 2012 to September 2024 (Table 1), with 886 in the Table Head / Liberty Point (THLP) area. A total of 489 individual skate were captured (female = 224, male = 250, not recorded=15), of those, 333 were captured in the THLP area (females = 148, males = 176, not recorded = 9). The smallest individual captured was 150 mm TL and the largest was 870 mm TL (Figure 2).

A total of 140 skate have been tagged with dart tags since 2021 and this is now and ongoing feature of the monitoring program. A total of two tagged skate have been recaptured over this period. Three recaptures of two animals occurred soon after release on the latest trip (September 2024) at the THLP site (at liberty <1 day).

Table 1. The amount of net sampling effort and catch of Maugean skate from 2011 to 2024. There was no sampling in 2020 due to the COVID-19 pandemic. The data from 2011, 2013, 2015, 2016, 2017 and 2019 were excluded from subsequent analysis due to the potential for the introduction of sampling bias as described in main body of text.

Year	Days fished	Net deployments	Mean soak time (hours)	Total number caught	Total caught >600mm	Total caught <600mm
2012	10	201	2.6	113	80	28
2013	7	116	2.7	46	38	8
2014	23	354	2.7	169	133	33
2015	2	71	2.5	9	6	3
2017	1	18	1.8	9	7	2
2018	5	102	2.2	46	42	3
2019	9	95	1.3	16	16	0
2021	17	263	1.9	46	44	1
2022	18	455	1.6	25	18	6
2023	14	302	1.8	58	40	10
2024	9[1]	195[1]	1.5	38	31	6

[1]Additional trips planned for 2024.

Harbour wide size composition

In the Harbour wide data (all reference sites; Figure 2), the size of females differed significantly by year ($\chi^2 = 9.26$, $p = 0.054$). Compared to the 2014 baseline, median female size was significantly different in 2021 (D = 32.8, $p = 0.012$) but not in subsequent years. Mean female size was significantly different to the baseline in 2021 ($p < 0.01$) and 2022 ($p = 0.03$) but not subsequent years. Size frequency distribution of females differed significantly from the baseline in 2021 (D = 3.4, $p < 0.01$), 2022 (D = 0.33, $p = 0.037$), but not in 2023 ($p = 0.066$) or the portion of data so far collected in 2024 ($p = 0.16$). The size of males differed significantly by year ($\chi^2 = 9.16$, $p = 0.056$). Compared to the 2014 baseline, median male size was significantly different in 2022 (D = -33.3, $p = 0.04$) but not in other years. Mean male size was significantly different to the baseline in 2022 ($p < 0.01$) but not in other years. Size frequency distribution of males differed significantly from the baseline in 2021 (D = 22, $p = 0.058$), 2022 (D = 0.26, $p = 0.02$) and 2023 (D = 0.26, $p = 0.045$), but not so for the portion of data collected to date in 2024 ($p = 0.2$).

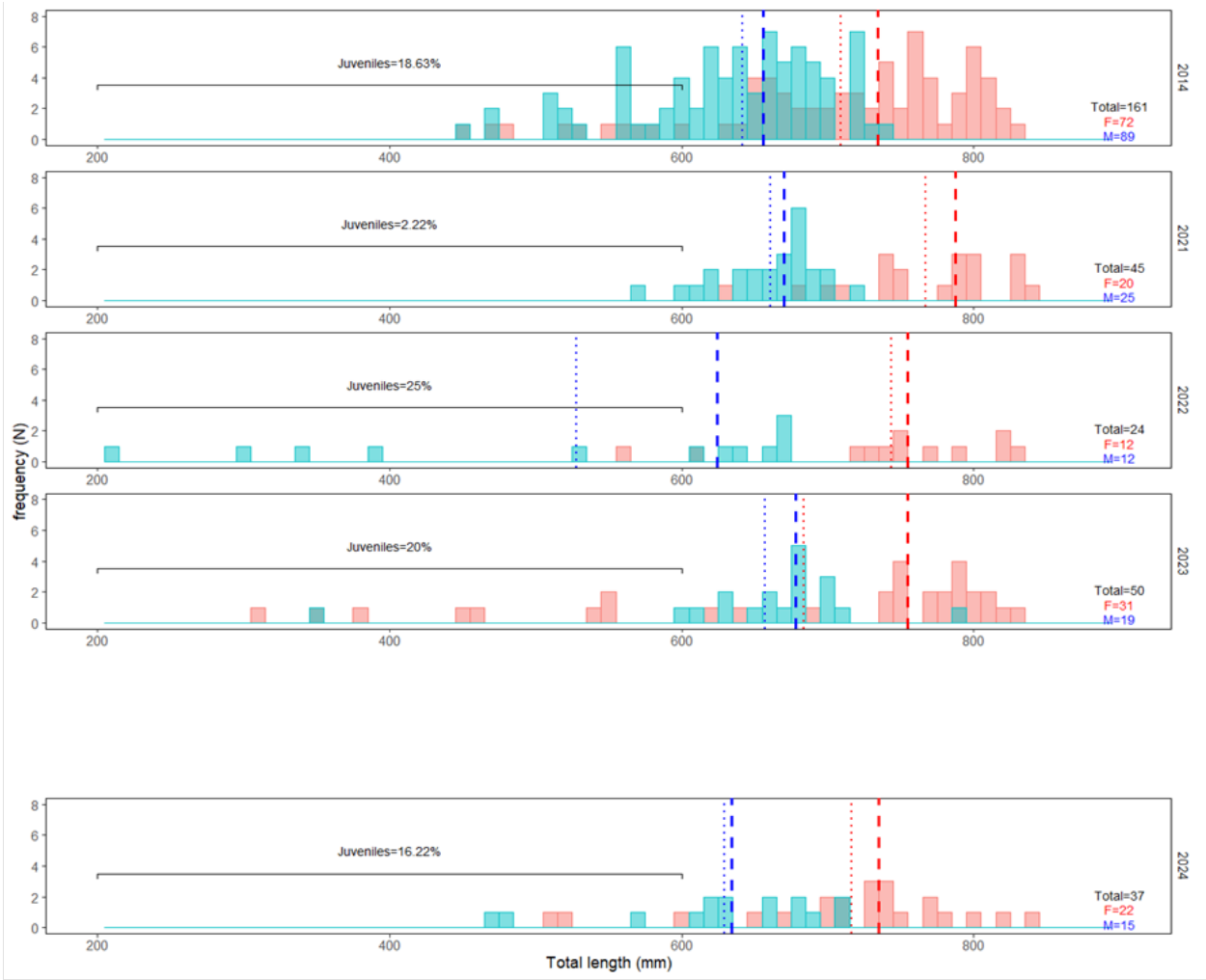


Figure 2. Size distribution of male (blue) and female (red) Maugean skate sampled from all sites during 2014 (top panel; FRDC 2013-008), 2021-2023 (second to fourth panels; SMRCA study), and 2024 (bottom panel; current NRE study). Note that this panel is separated from the other panels to highlight that 2024 sampling is currently incomplete. Vertical dashed and dotted lines indicate median and mean lengths of males (blue) and females (red), respectively. Sample sizes are indicated (Total = sexes combined, M = males, F = females). Values above the horizontal bracket indicates the proportion of individuals < 600 mm (juveniles and sub-adults) present in each sample. Note some individuals were released without length measurements.

The gillnets that have been used across all surveys are subject to a selectivity bias whereby smaller animals tend to be under-represented in the sample. 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 less likely to be caught or retained in the meshes. However, the same nets have been consistently used for all sampling, therefore, any size selectivity bias is expected to have been constant through time, justifying an examination of temporal trends in size composition.

The decline in recruitment, possibly due to lower hatching success or juvenile survival, coupled with the growth of existing adults (i.e., an ageing population) reported between 2014 and 2021 raised significant concern for the species due to the changes in population structure. The data indicated that there was an absence of successful recruitment for a period of approximately eight years up until 2021 based on back calculation of unvalidated size at age data founded on growth curves developed for the species (Bell et al., 2016). In 2021, the percentage of juveniles/sub-adults reported across the harbour was the lowest of all sampling years accounting for 2.2% of the total skate caught.

Sampling in 2022 identified the first evidence of juveniles since sampling in 2014. Although the total number of skate caught in this year was low, the percentage of recruits relative to adults sampled was 25%, equivalent to the percentage reported in 2012. Juvenile and sub-adults continued to appear in sampling in 2023 and 2024 at 20% and 16.2% respectively, the sample size in these years was comparable to those in 2018 and 2021, noting that there is an intention to conduct two additional sampling events in 2024.

Table Head / Liberty Point size composition

At THLP (Figure 3), the size of females did not show an overall difference by year ($\chi^2 = 6.2$, $p = 0.181$). However, compared to the 2014 baseline median female size was significantly different in 2021 (D = 21.04, $p = 0.035$) but not in subsequent years. Mean female size was significantly different to the baseline in 2021 ($p < 0.01$) but not in subsequent years. Size frequency distribution of females differed significantly from the baseline in 2021 (D = 3.5, $p = 0.026$), and 2024 (D = 0.37, $p = 0.024$), but not so for 2022 ($p = 0.238$) or 2023 ($p = 0.072$). The size of males did not show an overall difference by year ($\chi^2 = 0.743$, $p = 0.86$). Compared to the 2014 baseline median male size was not significantly different in 2021, 2023 or 2024. No males were captured at THLP in 2022. Mean male size was not significantly different to the baseline in any of the years with captures. Size frequency distribution of males did not differ significantly from the baseline in 2021 (D = 0.23, $p = 0.1$), 2023 (D = 0.29, $p = 0.1$), or for the portion of 2024 sampled to date (D = 0.3, $p = 0.12$).

Size composition data indicated that the median size of females caught at this site increased from 2012 to 2021. Since 2021 the median size has decreased to approximately the same as estimated in 2018. This shift is related to the detection of juveniles and sub-adults (≤ 600 mm), with the former absent and the latter in low numbers in the 2018 and 2021 sampling events. The median size of males at the THLP site has remained relatively stable since 2012, shifting to a lower size in 2022 and 2024 due to the relative number of juvenile and sub-adult skate sampled in these years.

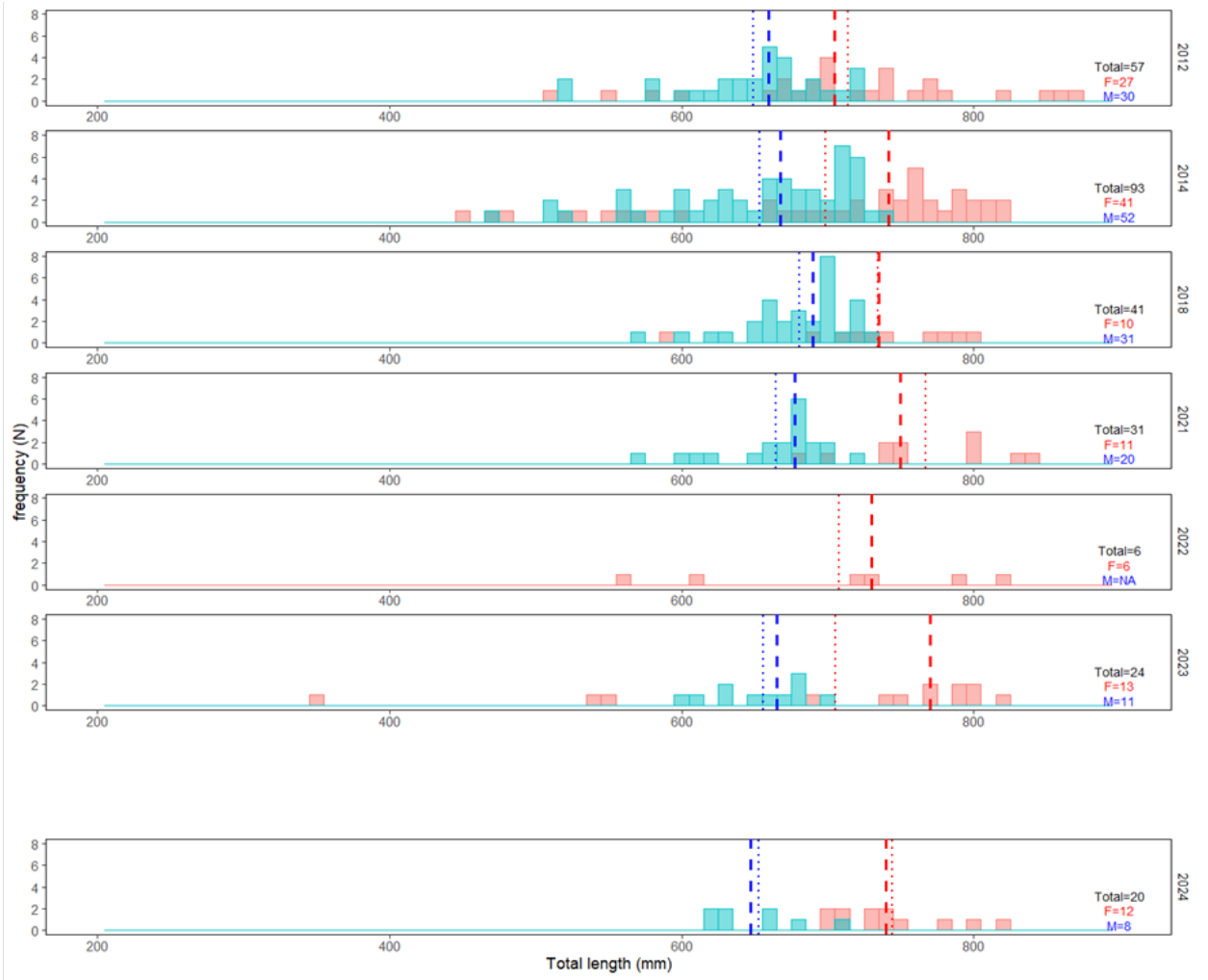


Figure 3. Size distribution of male (blue) and female (red) Maugean skate sampled from Table Head/Liberty Point during 2012 (top panel; FRDC 2010-016), 2013-14 (second panel; FRDC 2013-008), 2017-18 (third panel; FRDC 2016-068), 2021-2023 (fourth to sixth panels; SMRCA study), and 2024 (bottom panel; current NRE study). Note that this panel is separated from the other panels to highlight that 2024 sampling is currently incomplete. Vertical dashed and dotted lines indicate median and mean lengths of males (blue) and females (red), respectively. Sample sizes are indicated (Total = sexes combined, M = males, F = females).

Catch Per Unit of Effort (CPUE)

In 2014, CPUE was 0.17 N/m/hr for the three reference sites combined (Figure 4). While not directly comparable due to methodological inconsistencies, catch rates from 2017 and 2018 were relatively consistent with 2014 values (Moreno et al., 2020). In 2021, CPUE declined to 0.09 N/m/hr (Figure 4). This observed decline in relative abundance was likely the result of two high impact environmental events that occurred in 2019 that resulted in high mortality (~44%) of individuals being electronically tracked at the time (Moreno et al., 2020) combined with longer-term demographic effects resulting from changes in the size structure of the population driven by an ageing population and an absence of recruitment for a protracted period. This decline in relative abundance triggered substantial concerns for the population as it indicated a 47% decline across the Harbour.

In 2022, CPUE decreased further to 0.04 N/m/hr, however, given the lack of recruitment in previous years and the increase in CPUE in subsequent years, this may be related to a lack of skate in the three sampling regions in this year at the time of sampling. In 2023 and 2024 (noting partial sampling in the latter), CPUE increased to 0.11 N/m/hr and 0.13 N/m/hr respectively. This translates to an adjustment

of the point-to-point decline against the baseline year of 2014 to 2021 of 47% presented in the previous interim report, to 35% and 23% when the baseline year is compared to 2023 and 2024 respectively.

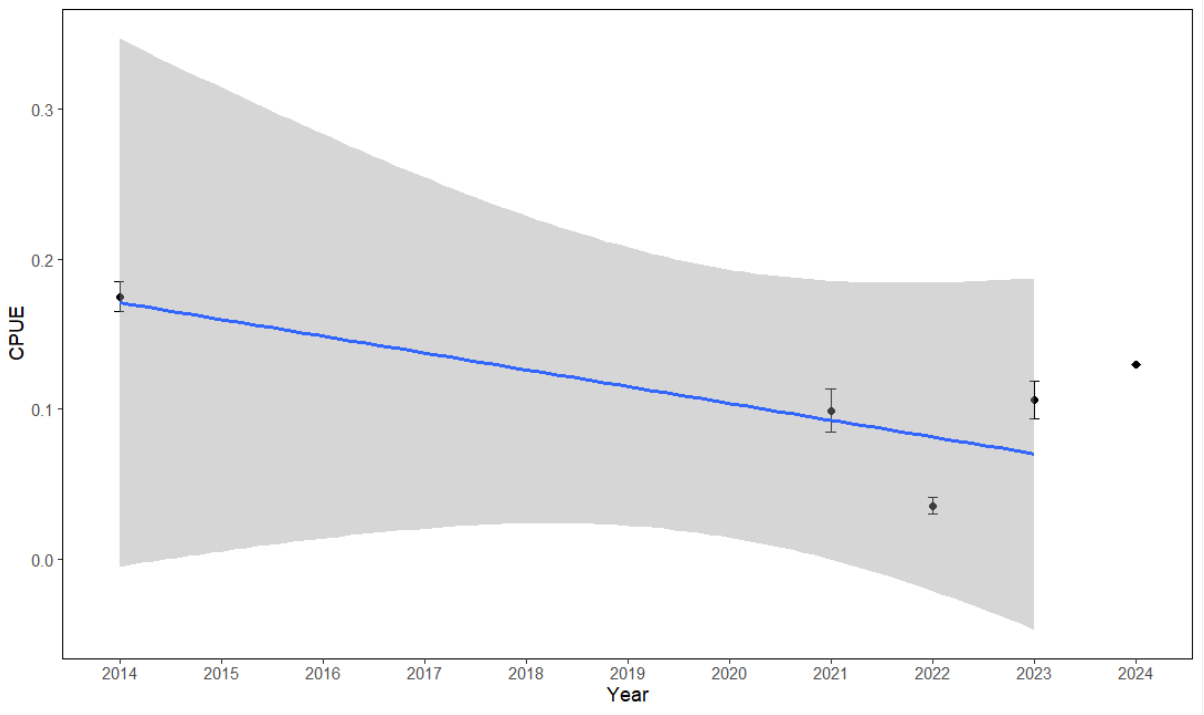


Figure 4. Catch Per Unit of Effort (CPUE) of Maugean skate caught from the three reference sites in Macquarie Harbour. The error bars represent an approximate standard error calculated based on variability in skate per net hour caught between individual deployments. The blue line is a fitted linear regression, and the grey shading indicates the variance around the regression line.

While the decline in relative abundance of adults between 2014 and 2021 was significant (Figure 5), representing a 47% reduction, the decline in relative abundance of juveniles and sub-adults was greater (87%) and the lack of recruitment was a substantial contributor to the overall decline in relative abundance presented in Figure 4.

The influence of recruitment also contributed disproportionately to the increase in relative abundance since 2021 with CPUE for skate less than 600 mm TL now being at comparable levels to the baseline year of 2014 (Figure 6). The linear regression indicates a negative slope, driven by data collected in 2021 and 2022 which were still influenced by the protracted absence of recruitment through the mid-2010s, confounded by the selectivity of the sampling method masking the presence of this cohort due to their small size leading to net avoidance in those two years.

The adult biomass declined between 2014 and 2021 (Figure 5), however, not at the same rate as juveniles and sub-adults (Figure 6). This suggests that natural age-based mortality was reducing the population at a lower rate than the absence of recruits. Except for 2022, CPUE of adults has stabilised since 2021 (Figure 5).

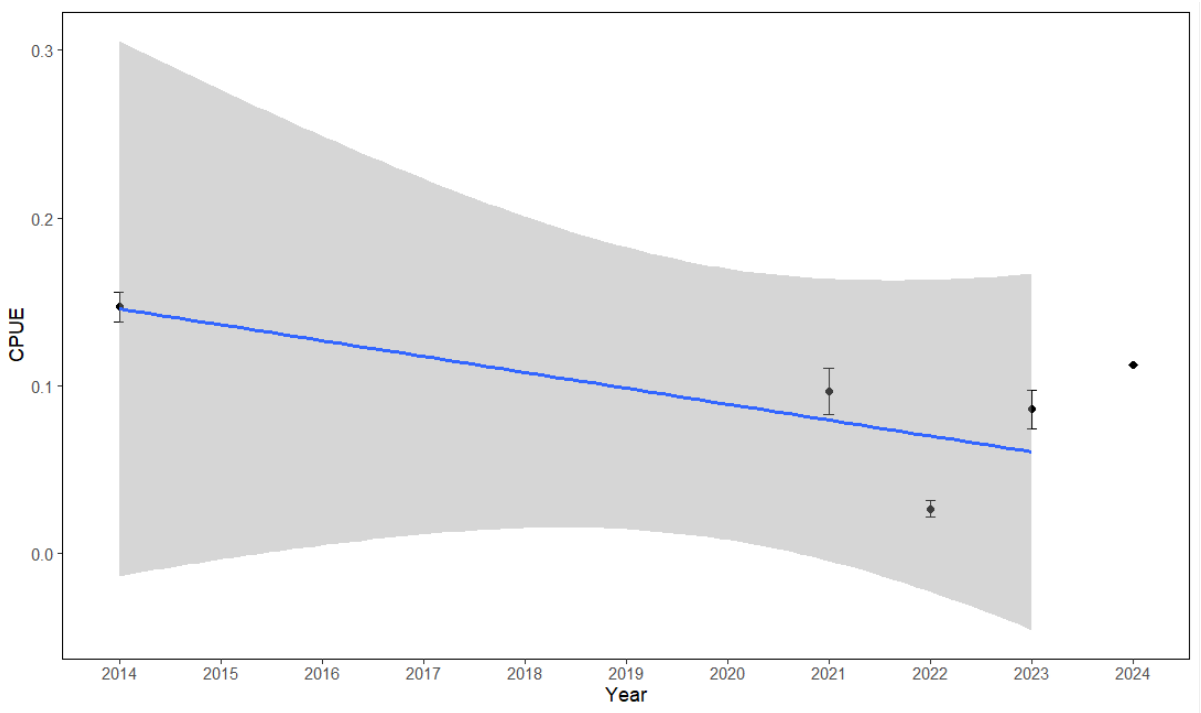


Figure 5. Catch Per Unit of Effort (CPUE) of adult (greater than 600 mm in total length) Maugean skate caught from the three reference sites in Macquarie Harbour. The error bars represent an approximate standard error calculated based on variability in skate per net hour caught between individual deployments. The blue line is a fitted linear regression, and the grey shading indicates the variance around the regression line.

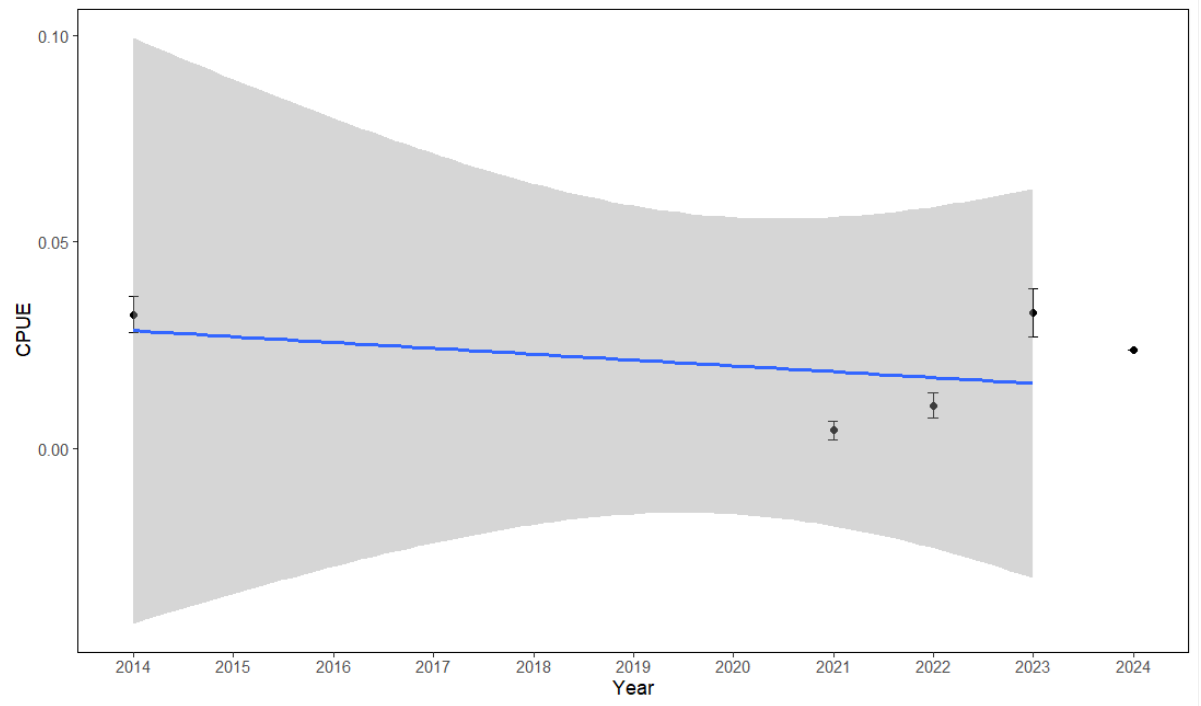


Figure 6. Catch Per Unit of Effort (CPUE) of juvenile and sub-adult (less than 600 mm in total length) Maugean skate caught from the three reference sites in Macquarie Harbour. The error bars represent an approximate standard error calculated based on variability in skate per net hour caught between individual deployments. The blue line is a fitted linear regression, and the grey shading indicates the variance around the regression line.

Site specific CPUE

Previous investigations into the distribution, movement, and habitat use of the Maugean skate show that Table Head and Liberty Point are a critical habitat for the species within the harbour. As such it is a focal sampling site with over 47% of all skate sampled from the area. The CPUE trend through time between Table Head and the whole system (based on the three reference sites) remained consistent, with the site being an important driver in the relative abundance from the Harbour due to the substantial contribution of skate catch from the area.

In 2014, CPUE was reported at 0.25 N/m/hr for the THLP area. In 2021, CPUE decreased to 0.14 N/m/hr representing a decline in relative abundance of 44% at the site. In 2022, CPUE decreased further to 0.02 N/m/hr before increasing to 0.11 N/m/hr in 2023, and to date in 2024, 0.14 N/m/hr (Figure 7B).

The decline in relative abundance was also evident in CPUE at the Swan Basin site (2014 = 0.12, 2021-2023 = 0.04, 2024[1] = 0), although the slope of the linear regression (-0.009; Figure 7A) was less than that fitted to the THLP data (-0.02; Figure 7B). In contrast to the decline reported in the previous two sites, the linear regression fitted to the data collected from the site within the World Heritage Area reported a positive slope (0.002) indicating an increase in relative abundance in this area compared to 2014, particularly in 2023 and the partial survey data from 2024 (Figure 7C).

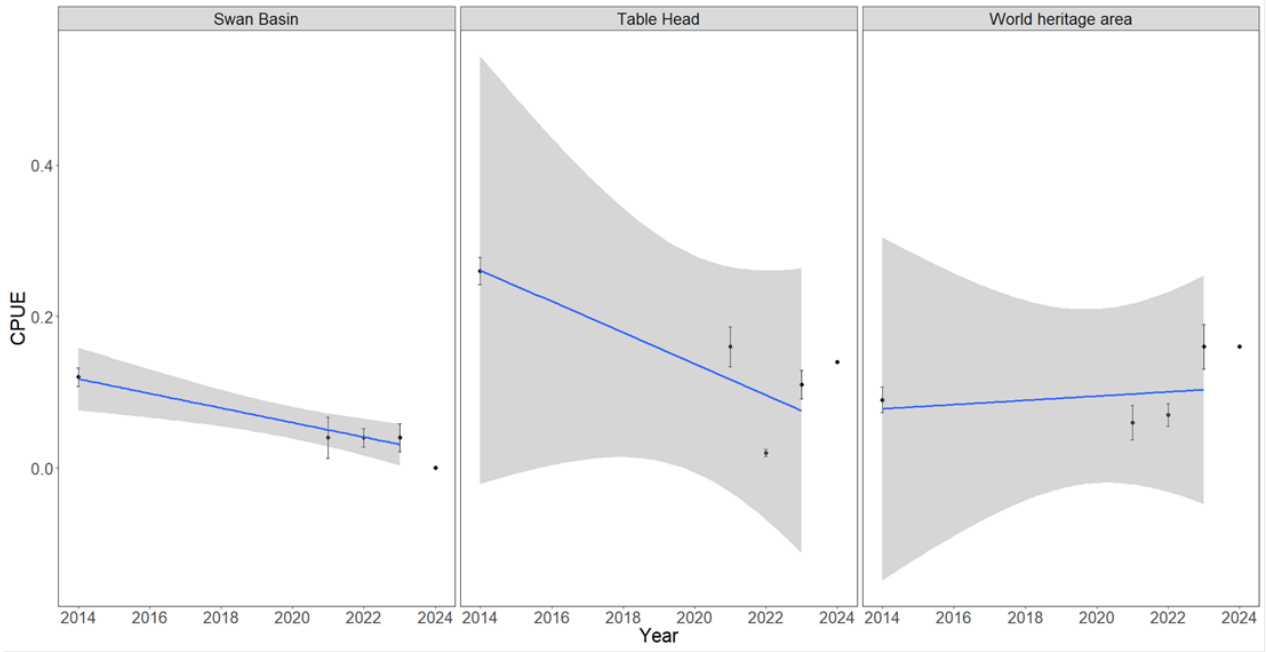


Figure 7. Catch Per Unit of Effort (CPUE) of Maugean skate caught from the three reference sites in Macquarie Harbour. The error bars represent an approximate standard error calculated based on variability in skate per net hour caught between individual deployments. The blue line is a fitted linear regression, and the grey shading indicates the variance around the regression line.

Conclusion

This updated interim report identifies the importance of continued monitoring of the Maugean Skate population. While there was evidence of significant decline in the population of the Maugean Skate between 2014 and 2021 based on CPUE and a lack of recruitment observed, recent surveys indicate a capacity for recovery and at least one recruitment event in the last 3 years. The decline in population

[1]Survey incomplete for 2024.

observed to 2021 appears to have stabilised. Although, skate are still at very low levels and potentially subject to major environmental events leading to mortality as observed in 2019.

Monitoring of the Maugean Skate population should be considered a cornerstone of any conservation actions going forward to ensure contemporary in-situ data is available to assess trends in the population, particularly as substantial work is being conducted to determine the causative links to factors that may affect the population and conservation actions are being considered. This advice is consistent with the first listed priority, '*Continued population monitoring of the Maugean skate to support evaluating effectiveness of conservation actions and to underpin conservation planning decisions',* under the 'Urgent action' category of the 'Survey and monitoring priorities' in the *Zearaja maugeana* (Maugean Skate) Conservations Advice (DCCEEW, 2024).

Gear selectivity is limiting early detection of recruitment events and alternate monitoring methods should be considered to complement netting surveys. A recently tested method using sonar-based systems to detect skate has shown great promise (Moreno et al. *In review*). The sonar-based method can identify skate to species and identify juveniles. This method could be used in a random stratified transect experimental design methodology to provide an alternate population size estimate to complement other model-based assessments. This advice is consistent with the first listed priority, '*Continued population monitoring to include the development of a robust, non-harmful, and logistically feasible sampling method to effectively assess the Maugean skate population size, structure, status and trend…including through techniques such as video sonar (ARIS)',* under the 'Medium-term actions' category of the 'Survey and monitoring priorities' in the *Zearaja maugeana* (Maugean Skate) Conservations Advice (DCCEEW, 2024).

It is recommended that any population models, including Population Viability Assessment (PVA) models are updated routinely as new data comes to light. This recommendation is consistent with the first listed priority, '*Fine tune the PVA to assess extinction risk and assist with prioritising management, conservation and research actions'* under the 'Urgent action' category of the 'Information and research priorities' in the *Zearaja maugeana* (Maugean Skate) Conservations Advice (DCCEEW, 2024).

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