Stock Status Summary – 2021/22

NSW Stock Status Summary – Beachworms (Onuphidae)

Assessment Authors and Year

Chick, R.C., Barnes, T. C. and Fowler, A. M. 2022. NSW Stock Status Summary 2021/22 – Beachworms (Onuphidae). NSW Department of Primary Industries, Fisheries. 12 pp.

Stock Status

Current stock status	On the basis of the evidence contained within this assessment, Beachworms are currently assessed as **sustainable**.

This stock status summary outlines the more detailed information available in the NSW stock assessment report for Beachworms (Chick et al. 2022).

Stock structure & distribution

Beachworms are polychaete worms in the family Onuphidae. In NSW, they are predominantly *Australonuphis teres* (stumpy or kingworm) and are harvested for bait from intertidal sandy beaches. Their distribution ranges from South Australia to Queensland (Dakin et al. 1952; Paxton 1979). Other species of beachworms that occur in NSW and that are recognised as different species by fishers include *A. parateres* (slimy) and *Hirsutonuphis mariahirsuta* (wiry or white headed wiry), but they are less abundant than kingworms (Paxton 1996). A genomic study on *A. teres*, sampled from along 900 km of NSW coast, identified six genetic groups with no clear geographic pattern to their distribution, suggesting considerable gene flow among populations (Padovan et al. 2020). Little is known about the genetic structure of the other species of beachworms. However, it is likely they represent broad, interconnected populations. For the purposes of this assessment, beachworms in NSW are considered a multi-species stock.

Biology

Beachworms are dioecious i.e. separate male and female individuals. Sexual maturity is reached at 42 cm in length for *A. teres*, and 39 cm for *A. parateres* and they are presumed to be repeat spawners throughout their lifespan (Paxton 1979). Mature gametes have been observed throughout the year, with *A. teres* containing >100,000 eggs (Paxton 1986). As the size of beachworms increases, the number of gamete-bearing segments and fecundity also increases. Beachworms are broadcast spawners. Spawning occurs throughout the year (Paxton 1986) with possible reproductive peaks in February and October (Fielder and Heasman 2000). Ontogenetic changes in morphology have been observed throughout juvenile development of various onuphid species, but not in detail for beachworms (Paxton 1986).

Rates of growth of beachworms have not been recorded, but Paxton (1979) found *A. teres* grew up to 100 cm and *A. parateres* grew up to 300 cm in length. The smallest beachworms that have been collected were 30 mm in length (Paxton 1979). Independent surveys of *A. teres* from along the NSW coast included beachworms between 91 and 954 mm long and ranging in age from <1 year to 9 years old. Population size structure appeared to be normally distributed, with individuals weighing between <1 g and 35.5 g (DPI unpublished).

FISHERY STATISTICS

Catch information

Commercial

State-wide fishery catch increased between 1984/85 and 1996/97 during an apparent developmental phase in the fishery, reaching a peak >35 t in 1996/97 (Figure 1). From 1997/98, catch generally decreased from >20 t.yr^{-1} to about 10 t.yr^{-1} between 2006/07 – 2009/10. The pattern of declining annual catches continued from 2009/10 (1.3 t; noting this was the time of transition to the current reporting system) to 2015/16 (~5.5 t). Since 2015/16, catches have averaged about 6 t.yr^{-1} including a total catch of 7.3 t in 2018/19 (the last year prior to implementation of a TAC). Total catch in 2020/21 was 4.9 t, the lowest catch since 1984/85, 1.1 t below that in 2019/20, and 3.6 t below the 2020/21 TAC (8.5 t; Figure 1). Importantly, these relatively recent (since 2009/10) patterns of change in catch for the state-wide fishery are not necessarily consistent with patterns at smaller spatial scales.

Since 2009/10, catches of beachworms have been reported from all Regions defined within the EGHG Fishery (Regions 1-7), and all Regions had catch reported during 2020/21, with the exception of Region 5. In Region 1, catches in 2009/10 and 2010/11 exceeded 1 t.yr^{-1}. In 2020/21, catch was 0.5 t (Figure 2). Region 3 has regularly supported the majority of the fishery's total catch. Catches declined from >5 t in 2009/10 and 2010/11. In 2020/21, catch was 3.2 t (Figure 2). Annual catch in Region 4 is more volatile than other regions. It increased between 2009/10 and 2012/13, to a peak of 3.6 t (as catches in Region 3 decreased substantially) and has generally decreased thereafter, albeit with lower peaks of ~2 t in 2016/17 and 2017/18, to <1.5 t within the last 3 years and the lowest catch reported in 2020/21 (0.8 t) since 2009/10 (Figure 2). Since 2009/10, catches in Region 6 have averaged 300 kg.yr^{-1} (~5% of total state-wide catch), peaked at ~700 kg in 2013/14 and have ranged between 200-400 kg.yr^{-1} since 2015/16. Catch in 2020/21 was 300 kg (Figure 2).

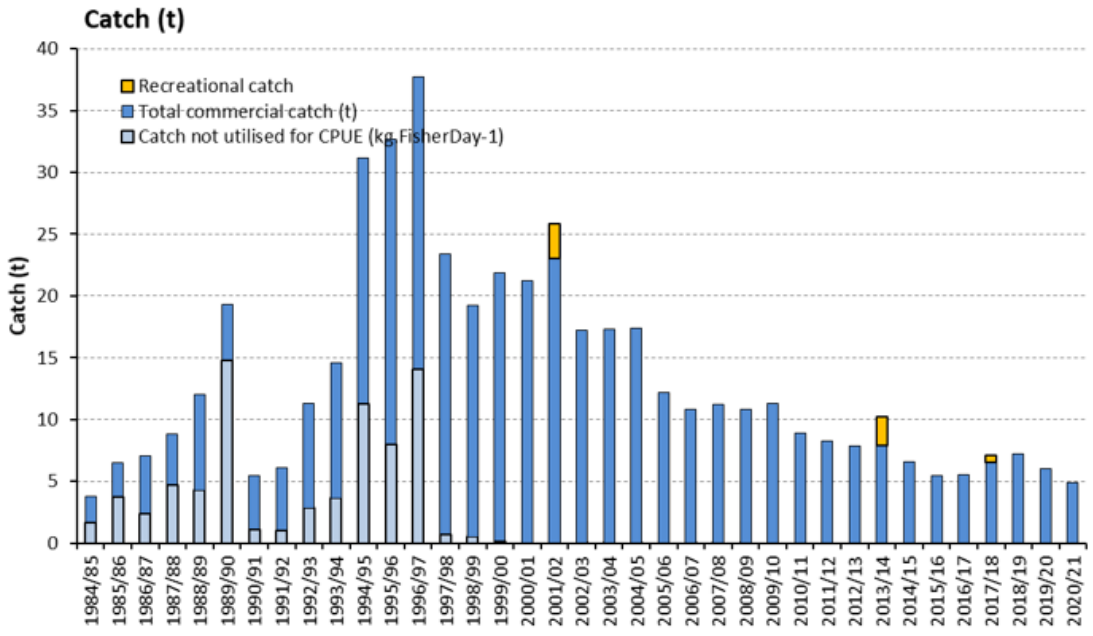

Figure 1. Total annual commercial catch (t) of Beachworms from 1984/85 to 2020/21 and survey estimates of recreational catch (t) in 2000/01, 2013/14 and 2017/18.

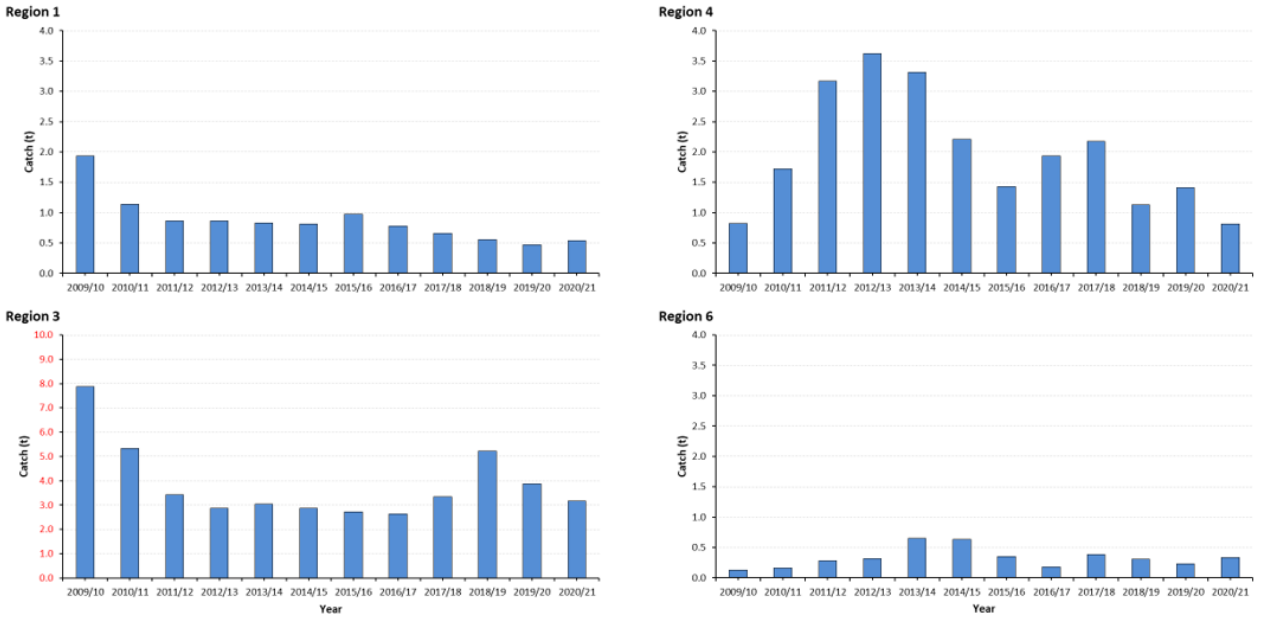

Figure 2. Annual commercial catch (t) from 2009/10 – 2020/21 for the top four regions (by catch). Note: Y-axes in red are greater than others.

It is notable that the pattern of change in the levels of annual catch, effort and CPUE for the state-wide fishery are not necessarily consistent with patterns of catch at finer spatial scales (e.g. Regions).

Recreational & Charter boat

In 2000/01, the recreational harvest (kept numbers) was estimated to be 285,663 ± 72,697 worms (mean ± SE). At an average weight of 10 g (as defined for the conversion of commercial numbers of beachworms to weight), the 2000/01 estimate equates to a total recreational harvest of ~2.9 ± 0.7 $t.yr^{-1}$. In 2013/14 and 2017/18 the state-wide survey estimated the retained recreational catch of beachworms at 239,085 ± 85,662 and 54,046 ± 20,044 beachworms (i.e. ~2.4 ± 0.9 $t.yr^{-1}$ and ~0.5 ± 0.2 $t.yr^{-1}$), respectively (Figure 1). However, corrections made to the 2013/14 survey outcomes, to account for differences in survey designs, indicate the comparable recreational catch was 1.5 t ± 0.8 t (Murphy et al. 2020). Notably, beachworm estimates from surveys in 2013/14 and 2017/18 were from a low sample size and the estimate from 2013/14 was associated with relatively high standard error (i.e. >40%; Murphy et al. 2020). Estimates of recreational catch from the raw survey outputs represent 13%, 30% and 8% of the reported commercial catch for those years, respectively.

The 2017/18 state-wide survey data also allows for estimates of the spatial distribution of the estimated recreational catch into each of the coastal zones described in the survey. Approximately half (230 kg; 42%) of the recreational catch in 2017/18 was harvested from Zone 5 (Mid-South Coast), which overlaps almost entirely with Region 6 of the EGHG.

Indigenous

The benefits (and costs) of fishing generally and professional fishing to the cultural, broader social, health, wellbeing and economic value to Indigenous people and communities are substantial (Voyer et al. 2016). Schnierer and Egan (2012) described a case study in NSW of the impact of

management changes on the viability of Indigenous commercial fishers and the contribution commercial fishing and aquaculture makes to Indigenous communities. Included in this case study are estimates of the contribution Indigenous commercial fishers make to Indigenous communities, including the contribution of between 5% - 20% of their annual commercial catch. The contribution made to Indigenous communities by Indigenous commercial fishers was, on average, 9.8% of annual catch and the contribution from broader Indigenous commercial fishers was greater than that made by fishers in the EGHG Fishery, with this being a consequence of hand gathering being a "…traditional skill that is widely practiced by coastal families so they can fulfil their own needs." (Schnierer and Egan 2012). Moreover, Schnierer and Egan (2012) reported substantial harvests of hand gathered species (principally Pipi) by Aboriginal fishers that were either not reported in commercial catch records, or reported as 'other' species and went unrecorded as species specific catches and were utilised for personal and community use.

Synthesis of catch composition from Indigenous cultural fishing in NSW indicated that there are at least 18 species in the Estuary General Fishery that overlap with Indigenous fisheries (Schnierer and Egan 2016). In a survey based in the Tweed region, annual catch of beachworms by Indigenous fishers was estimated at between 1,869 and 4,350 worms (Schnierer 2011). Based on an average weight of 10 g, the catch from Aboriginal fishers in the Tweed region in NSW is estimated at <0.5 $t.year^{-1}$. Schnierer (2011) described beachworms as among the top 10 culturally most important species but they consisted of less than 5% of the total cultural catch in terms of total numbers of species. Total effort estimated from this area for the Aboriginal fishery was 542 hours or 92 days (Schnierer 2011). Cultural catch of bait including beachworms was also seen to be important in delivering economic benefits to the community (Schnierer 2011).

Illegal, Unregulated and Unreported

The level of Illegal Unregulated and Unreported (IUU) fishing has not been quantified.

There are anecdotal reports of IUU fishing occurring at the scale of beaches, related to minor incidents in both the commercial and recreational fishing sectors. NSW Fisheries Compliance provide annual summaries of seizures of fish and invertebrates due to non-compliance. These reports do not indicate IUU activity related to seizures of beachworms (https://www.dpi.nsw.gov.au/fishing/compliance/fisheries-compliance-enforcement).

Fishing effort information

Commercial

Reported effort in days fished ($effort_{dy}$) has generally reflected that of catch over the history of the fishery. It has increased from 945 FisherDays in 1984/85 to a peak of 7,442 FisherDays in 1996/97 (Figure 2). Noting that during this period fishers were required to report their catch monthly and effort (in days fished) by gear type, not linked to catch unless only a single gear type was used and then not linked to species catch within a gear type. Therefore, prior to 1997/98 total $effort_{dy}$ reported within the EGHGF cannot be allocated to a species catch and is the total $effort_{dy}$ reported by EGHG fishers for each month where one method (hand gathering) was reported. From 1997/98 to 2008/09, $effort_{dy}$ generally decreased from >6,000 fisher days to about 4,000 fisher days. Since 2009/10, $effort_{dy}$ has continued to decline from ~3,000 fisher days to 1,486 fisher days, reported in 2020/21, the lowest $effort_{dy}$ since 1984/85 (Figure 2). Similarly, effort in hours fished ($effort_{hr}$) generally declined from >10,000 hours in 2009/10 to 4, 268 hours in 2020/21, again, the lowest level since 1984/85 (Figure 2).

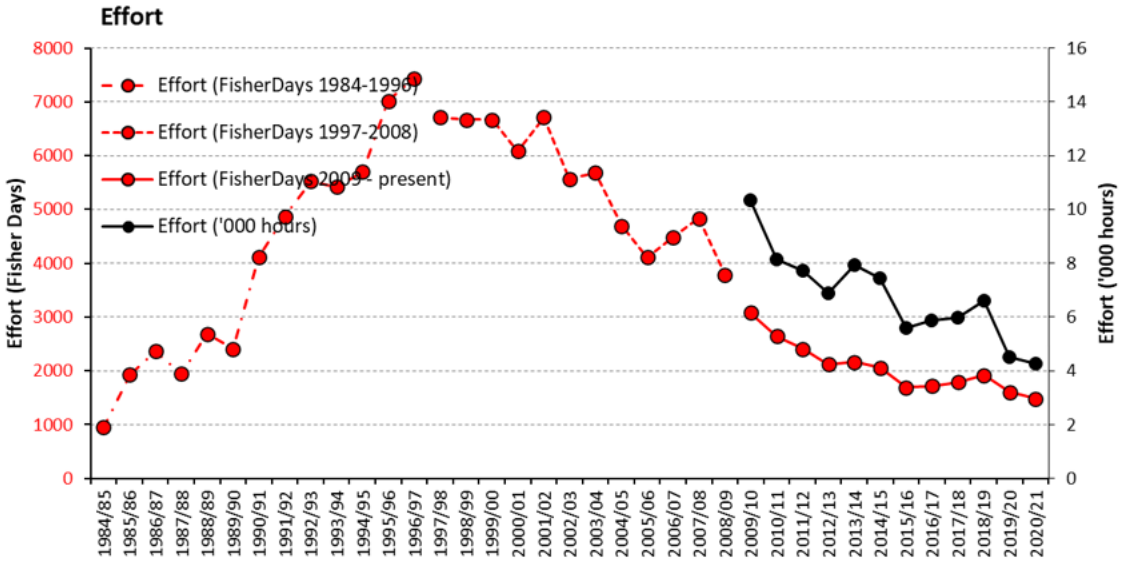

Figure 3. Total annual commercial effort on fishing for Beachworms from 1984/85 to 2020/21.

Catch Rate information

Catch per FisherDay ($CPUE_{dy}$) is a problematic index to estimate and interpret prior to 2009/10, for reasons outlined for the $effort_{dy}$ time series. Using daily effort calculated as explained above, three distinct time periods, with clearly different CPUE trends, can be distinguished (Figure 3). $CPUE_{dy}$ increased from less than 10 $kg.day^{-1}$ (1984/85–2000/01) to a maximum of 33 $kg.day^{-1}$ in 2005/06, probably due to fewer multispecies catches per month and substantially less allocated daily effort. Between 2005/06 and 2008/09, daily catch rate declined substantially, reflecting substantially lower catches and sustained levels of relatively low effort, again likely a function of the challenges in allocating effort to catches during this period. Since 2009/10 (the first year of current commercial fisher reporting requirements), daily catch rate has been relatively stable (with substantial within year variation), reflecting similar increasing levels of catch and effort and has averaged 9 $kg.day^{-1}$ (range 6.4 – 11.4 $kg.day^{-1}$). In 2020/21, the average daily catch rate was 8.9 $kg.day^{-1}$ (Figure 3).

Since 2009/10, annual estimates of catch (kg) per hour ($CPUE_{hr}$) have averaged 2.4 $kg.hr^{-1}$ (range 1.52–3.2 $kg.hr^{-1}$), with substantial within year variation and has remained relatively stable, despite exceptions in 2010/11 and 2013/14 when $CPUE_{hr}$ was 1.4 and 1.5 $kg.hr^{-1}$, respectively (Figure 3). These anomalous $CPUE_{hr}$ levels coincide with and partially reflect changes in the composition of fishers between years, the spatial distribution of catch and effort among estuaries. Importantly, and as similarly described for fishery-wide levels of catch, change in levels of fishery-wide effort and $CPUE_{hr}$ are not necessarily consistent with patterns at smaller spatial scales.

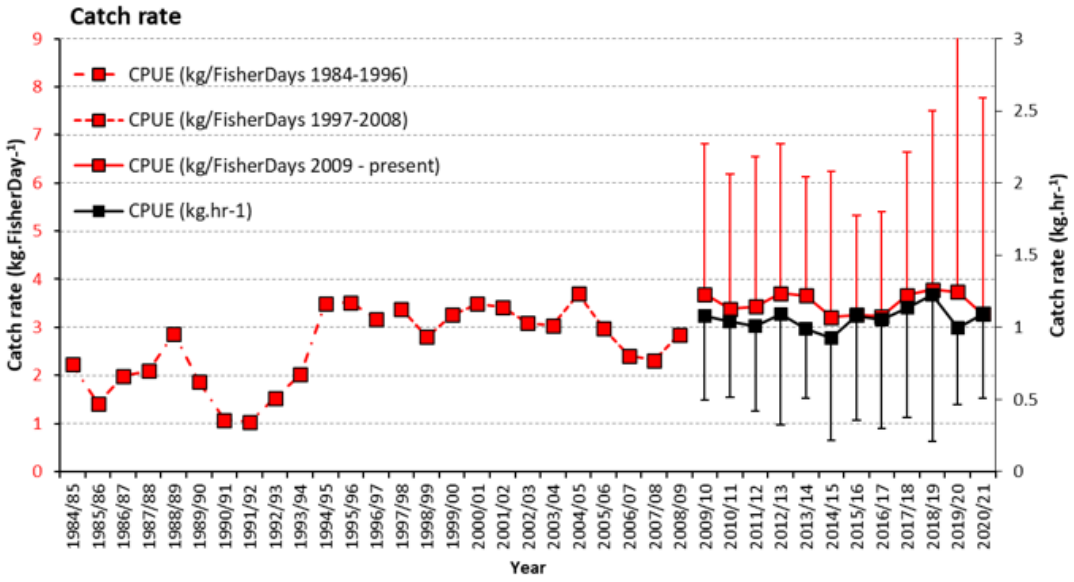

Figure 4. Average annual catch rate (kg.hr^{-1} and kg.FisherDay^{-1}; plus or minus one standard deviation, respectively from 2009/10) from 1984/85 to 2020/21.

In Region 1, $CPUE_{hr}$ (kg.hr^{-1}) has decreased substantially, from 0.85 kg.hr^{-1} in 2009/10, to an average of 0.53 kg.hr^{-1} over the last 5 years, 0.51 kg.hr^{-1} in 2020/21 and below the long-term average (0.64 kg.hr^{-1}) from 2009/10. $StdCPUE_{hr}$ has reflected that of nominal $CPUE_{hr}$ and remained below the long-term average since 2014/15 (Figure 5). In Region 3, $CPUE_{hr}$ has averaged 1.26 kg.hr^{-1} since 2009/10 and annual measures have been relatively stable around the average. In 2020/21, $CPUE_{hr}$ was 1.26 kg.hr^{-1}. $StdCPUE_{hr}$ demonstrates less volatility but generally reflects the long-term stability of the nominal $CPUE_{hr}$ series (Figure 5). In Region 4, , $StdCPUE_{hr}$ and $CPUE_{hr}$ show similar patterns through time and general stability around the long-term average (~1 kg.hr^{-1}), with the exception of a significant decline in 2014/15 and a smaller but significant decline in 2019/20. $StdCPUE_{hr}$ and $CPUE_{hr}$ have increased in 2020/21 to levels similar to the long-term average (Figure 5). In Region 6, $StdCPUE_{hr}$ has remained stable or marginally increased at levels consistent with the long-term average since 2009/10, although that in 2020/21 substantially increased to above the long-term average (Figure 5).

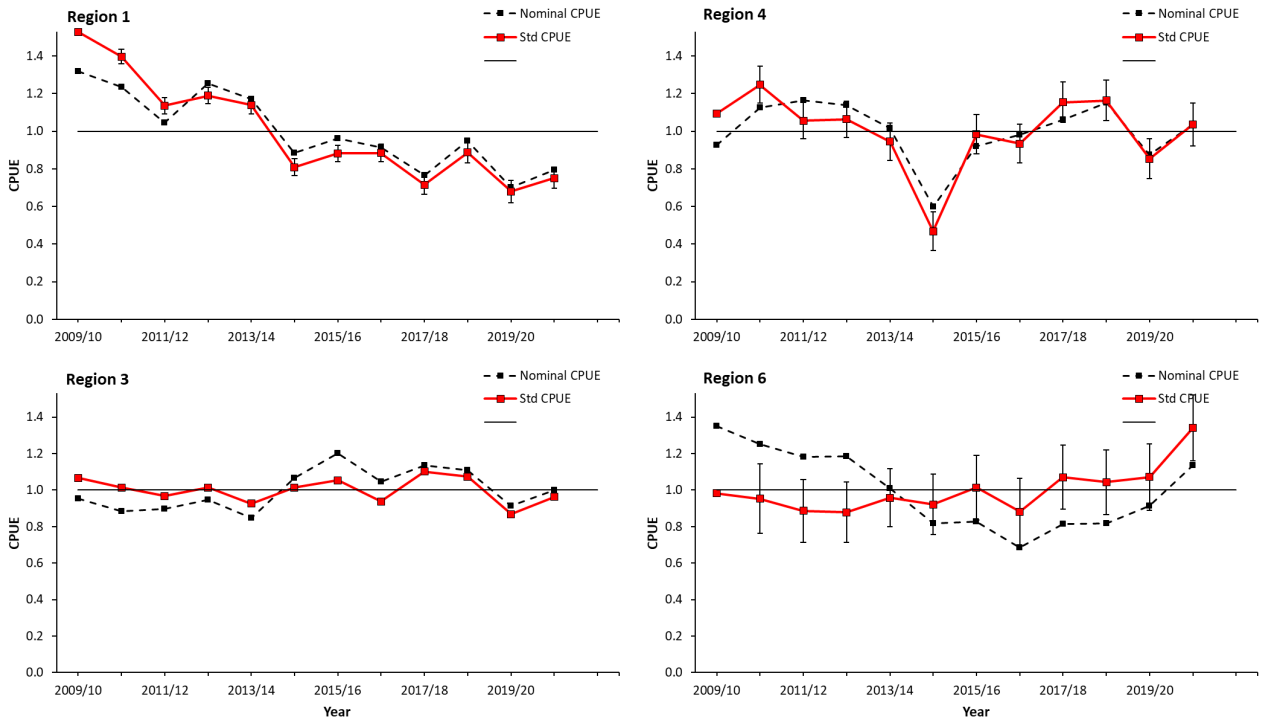

Figure 5. Standardised commercial catch rates (red lines with 95% confidence intervals) and nominal catch rates (dashed black lines) scaled to the 12-year average (horizontal solid black line) for each of the top 4 regions (by catch) from 2009/10 to 2020/21.

STOCK ASSESSMENT

Stock Assessment Methodology

Year of most recent assessment:

2021/22 (using data to end of June 2021)

Assessment method:

A review of indicators (weight-of-evidence approach) was used to assess the status of the NSW Beachworm stock. Included in this approach are: knowledge of biology and population structure; patterns of catch and standardised catch rate across the fishery and within key regions, respectively; and outputs from a Catch-MSY model assisted catch only assessment.

Main data inputs:

- Catch (commercial) (t) – 1984/85 to 2020/21
- Catch (recreational) (t) 2000/01, 2013/14, 2017/18
- Commercial CPUE (kg.day^{-1}) – 2009/10 to 2020/21
- Commercial CPUE (kg.hr^{-1}) – 2009/10 to 2020/21

Data interpreted at state-wide and estuary scales.

Key model structure & assumptions:

- Standardised catch rates (using cede v. 0.04) (Haddon, 2018). Assumption: annual catch rates are a relative index of abundance not unduly influenced by factors other than those accounted for through standardisation.
- Catch-MSY model-assisted catch-only assessment (Martell and Froese, 2013) using the 'datalowSA' R package (Haddon et al. 2019), updated from the 'simpleSA' R package (Haddon et al. 2018). This uses population productivity (r) and carrying capacity (K) parameters of an underlying Schaefer production model, applied to total annual catches, to estimate the ranges in biomass and harvest rate that could could lead to the annual catches realised in the fishery. Assumptions: Estimated ranges of the population growth rate parameter (r) and carrying capacity (K) of the stock are pre-determined through an assumed resilience (set to low in this case); the underlying population biomass model is very generic and simplistic.

Sources of uncertainty evaluated:

General data limitations and uncertainty was considered in the weight-of-evidence approach.

The assessment is for the species complex of NSW beachworms, principally utilising data related to *A. teres*, and assuming they represent the broader species complex. State-wide total catches within the last two years have been substantially below the TAC determined for the commercial fishery. Patterns of catch and catch rate among key regions are inconsistent, indicating beachworm populations functioning within these scales may be responding differently to different pressures, including fishing pressure.

The use of catch rates to inform relative change in biomass though time becomes more uncertain when processes other than changes in population biology influence them. It is possible that there has been some inconsistent reporting of effort (searching time included or excluded with actual time catching) and also some operating practices of fishers targeting beachworms has been influenced by market or economic factors.

There are inconsistencies in the methodology used to estimate recreational fishing catch through the time series that provides some uncertainty around direct comparison of catch estimates from different times (noting, estimates from 2013/14 have been modified to provide direct comparison with those from 2017/18). Levels of Indigenous cultural fishing are not well quantified.

The effect of three different constant catch scenarios on the projections of estimated biomass and harvest rate trajectories from Catch-MSY analyses.

Factors other than fishing, including global disruptions (e.g. COVID-19 pandemic and associated social impacts (FAO 2021)), large scale, state-wide disruptions (e.g. natural disaster bushfires in 2019/20) and also, more local factors (e.g. land-use influences and environmental factors), may affect change in the abundance and productivity of beachworms and/or the operations of the fishery. How these factors may influence the reliability of the available data is not well known and are not considered in this assessment beyond their acknowledgement.

Despite and whilst including consideration of these uncertainties, the weight of evidence provided is sufficient to support an understanding that the biomass of Beachworms is at a level sufficient to ensure that on average, future levels of recruitment are adequate and fishing mortality is at a level to avoid the stock being recruitment impaired, resulting in a classification of the Beachworm stock status of **sustainable**.

Status Indicators - Limit & Target Reference Levels

Biomass indicator or proxy	None specified in a formal harvest strategy. This assessment used a weight-of-evidence approach, with data including: • Nominal $CPUE_{hr}$ (state-wide and estuary) • Nominal $CPUE_{dy}$ (state-wide) • Standardised $CPUE_{dy}$ (key Regions) • Biomass depletion as a function of unfished biomass from viable K and r pairs from Catch-MSY analyses
Biomass Limit Reference Point	None specified in a formal harvest strategy. For the purpose of the Catch-MSY analyses, 20% of defined unfished biomass was accepted as the Limit.
Biomass Target Reference Point	None specified in a formal harvest strategy. For the purpose of the Catch-MSY analyses, 48% of defined unfished biomass was accepted as the Target.
Fishing mortality indicator or proxy	None specified in a formal harvest strategy. This assessment used a weight-of-evidence approach, with data including: • Catch (state-wide and estuary scale) • mean annual relative fishing mortality from Catch-MSY analyses.
Fishing mortality Limit Reference Point	None specified in a formal harvest strategy.
Fishing Mortality Target Reference Point	None specified in a formal harvest strategy.

Stock Assessment Results

The NSW stock status of beachworms is classified as **sustainable**.

The weight of evidence provided supports an understanding that the biomass of beachworms is at a level sufficient to ensure that on average, future levels of recruitment are adequate and fishing mortality is at a level to avoid the stock being recruitment impaired.

A weight-of-evidence approach has been taken to support a stock status classification of ‘sustainable’, including, i) patterns of catch and catch rate from across the fishery and within key regions; ii) recently reduced knowledge gaps regarding population size and structure and commercial size structure from ongoing research; and iii) outputs from a catch-MSY model assisted catch-only assessment, indicating that current biomass is depleted to between 6% – 55% (95^{th} percentiles describing the distribution of trajectories; Figure 6) of virgin biomass and

maximum sustainable yield (from lower bound of MSY was 9.0 t). The stock status trajectory, in terms of predicted mean biomass and harvest rate indicates mean biomass is above the 0.2B0 biomass limit reference level and at a harvest rate around the fishing mortality target level of F_{targ} (FMSY; Figure 6).

The 'sustainable' classification of the NSW beachworm stock is made with greater certainty from that in the previous assessment. This is due to: i) continued high levels of commercial fishery logbook reporting, including fields for catch (that closely match quota usage reports), associated reporting of effort (<1.5% of catch records with no effort) and codes describing spatial distribution; ii) relatively stable proportions of catch across Regions and most beaches within the fishery as well as continued monthly catches demonstrating consistent availability of beachworms albeit at lower total catches in recent years; and iii) regional catch rates having increased from levels in 2019/20, and in 2020/21 to levels at or above long-term averages for most key regions.

A balanced interpretation of the weight of evidence provided supports an understanding that the biomass of beachworms is at a level sufficient to ensure that on average, future levels of recruitment are adequate and fishing mortality is at a level to avoid the stock being recruitment impaired – and hence the NSW Beachworm stock is classified as **sustainable**.

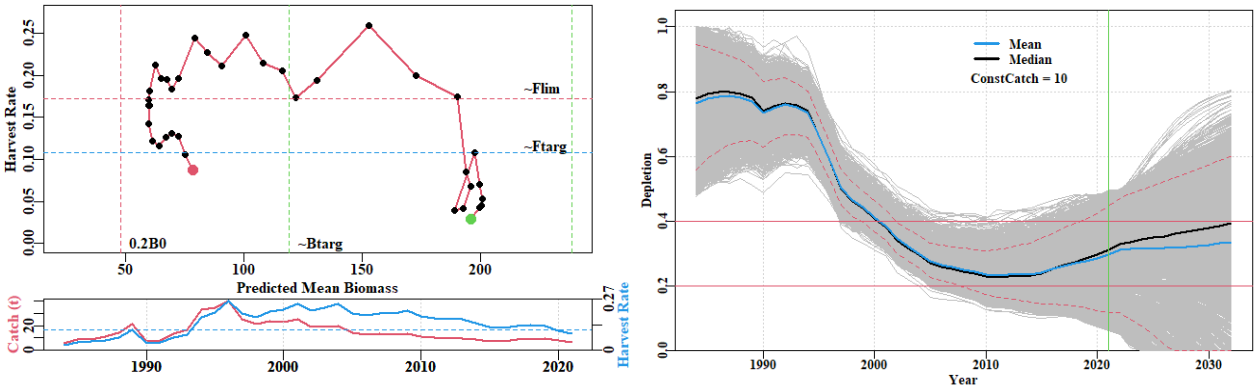

Figure 6. Phase plot (top left) and predicted mean biomass (bottom left, red line, tonnes) and harvest rates (blue line) in each year for a modified Catch-MSY model fitted to Beachworm total catch (15% of reported commercial harvest defined recreational harvest). The first year of data is indicated by the green dot and the last by the red dot. Limit reference points (red dashed lines) of 20% maximum biomass (0.2B0) and corresponding harvest rate (~F_{lim}), default 40% target biomass (~B_{targ}, green dashed line) and corresponding harvest rate (~F_{targ}, blue dashed line) also indicated. Right figure shows viable depletion trajectories in each year for constant catch projections of 10 t.

Stock Assessment Result Summary

Biomass status in relation to Limit	NA – no biomass limits has been set. Weight-of-evidence provided is sufficient to support an understanding that the biomass of Beachworms is at a level sufficient to ensure that on average, future levels of recruitment are adequate.
Biomass status in relation to Target	NA – no biomass target has been set.

Fishing mortality in relation to Limit	NA – no fishing mortality limit has been set. Weight-of-evidence provided is sufficient to support an understanding that fishing mortality is at a level to avoid the stock being recruitment impaired.
Fishing mortality in relation to Target	NA – no fishing mortality target has been set.
Current stock status	**Sustainable**

Fishery interactions

Fishing for Beachworms in the EGHG Fishery is done by hand with hand collection of individuals. There are limited, if any interactions with other fisheries and no interactions have been reported between the EGHG Fishery and species protected under the Environment Protection and Biodiversity Conservation *Act 1999*.

Qualifying Comments

There is uncertainty in the determination of stock status presented in this report. The assessment is for the species complex of NSW beachworms, principally utilising data related to A. teres, and assuming they represent the broader species complex. State-wide total catches within the last two years have been substantially below the TAC determined for the commercial fishery. Patterns of catch and catch rate among key regions are inconsistent, indicating beachworm populations functioning within these scales may be responding differently to different pressures, including fishing pressure. Uncertainty in the data contribute to uncertainty in understanding changes in biomass and fishing mortality at relevant scales.

Factors other than fishing, including global disruptions (e.g. COVID-19 pandemic and associated social impacts (FAO 2021)), large scale, state-wide disruptions (e.g. natural disaster bushfires in 2019/20) and also, more local factors (e.g. land-use influences and environmental factors), may affect change in the abundance and productivity of beachworms and/or the operations of the fishery. How these factors may influence the reliability of the available data is not well known and are not considered in this assessment beyond their acknowledgement. Influences at local scales are likely to be spatially and temporally variable. Identifying and quantifying (where possible) the likely effect of these otherwise unaccounted for factors in limiting the potential of the beachworm fishery (e.g. through a risk assessment) would inform the relative effects of fishing.

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