TASMANIAN OCTOPUS FISHERY ASSESSMENT 2019/20

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February 2021

This assessment of the Tasmanian Octopus Fishery is produced by the Institute for Marine and Antarctic Studies (IMAS).

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The Tasmanian Octopus Fishery (TOF) operates off the north coast of Tasmania and in the Bass Strait, primarily targeting Pale Octopus (*Octopus pallidus*), with Maori Octopus (*Macroctopus maorum*) and Gloomy Octopus (*Octopus tetricus*) landed as by-product. The Scalefish Fishery Management Plan (revised in 2015) provides the management framework for the fishery. The commercial fishery has been a sole operator fishery since its commencement in 1980, with two vessels. The main management controls for the fishery include gear and spatial restrictions and limited access via licensing.

The status of Pale Octopus in the TOF area is assessed annually using data on catch, effort and catch per unit effort (CPUE). These data now cover the period from 2000/01 to 2019/20. Fishing pressure on Pale Octopus is assessed using catch as a proxy for absolute mortality and effort (number of potlifts) as a proxy for exploitation rate.

The total catch of Pale Octopus in 2019/20 was 120 tonnes (t), representing the third highest recorded catch. Records of by-product species, in contrast, revealed less than 20 kg for Gloomy Octopus and no catch for Maori Octopus (a decrease from 1 t in 2018/19). Total effort in the fishery decreased slightly from last year's total, with 327,500 potlifts recorded in 2019/20. This is below a total limit reference point of 350,000 potlifts proposed in previous reports.

The high total catch of 120 t in 2019/20 was similar to previous peaks of 127 t recorded in 2012/13 and 132 t recorded in 2018/19. These catches are well above (1) the average of 88 t observed over the last decade, and (2) a previously proposed limit reference point of 106 t. Notably, the current fishing season represents the first instance of two consecutive years during which catch exceeded 100 t, and almost all of the catch in 2019/20 (90%) occurred in only two fishing blocks east of King Island.

Biomass, as indicated by broad-scale trends in CPUE, has decreased from 2005/06, albeit with annual fluctuations. CPUE derived from logbook data was 12.6% lower in 2019/20 than the recent peak in 2018/19, but remains above reduced values recorded in previous years (2011/12 to 2017/18). The 50-pot research sampling data was unavailable for this assessment, such that 50-pot sample based CPUE, as an additional index of abundance, could not be calculated. In 2018/19, the 50-pot sample derived CPUE was 89% of the reference year.

Importantly, these outcomes based on broad-scale analyses outlined above do not account for recent shifts in the distribution of fishing effort and catch beyond traditionally fished areas. To address this issue, we introduced more in-depth analyses of local trends in CPUE into this assessment, delineating the "traditional" TOF fishing ground by identifying fishing blocks that have been fished (i.e. any effort or catch recorded) in most of the first ten years since the reference year. We then highlighted areas where declining trends in CPUE indicated that biomass might be depleting or depleted. The results revealed that depletion might have occurred in multiple traditionally fished areas, specifically in the eastern portion of the fishery around

Bridport and north-east off Flinders Island, where the fishery used to be more productive. Notably, CPUE trends in the single most important fishing block (4E1), which is situated several kms north of Stanley, did not reveal evidence of decline. However, with a significant risk that CPUE trends are insensitive to population declines, because octopus actively seek pots as refugia and are targeted at putative breeding aggregation areas, declining CPUE in blocks surrounding 4E1 might be indicative of more widespread declines of the breeding population in this area.

To assess potential biomass depletion and estimate sustainable catch limits while accounting for recent shifts in fishing effort and catch, we introduced a data-poor stock assessment approach ("CMSY") that was focused exclusively on the putatively consistent time series data for the traditional TOF fishing ground. CMSY results indicated that Pale Octopus biomass in this region might be depleted to 30-31% of unfished levels, with lower 90% confidence limits of 18-23% of unfished levels. The maximum sustainable yield (MSY) in traditionally fished areas was estimated at 64-69 t, with lower 90% confidence limits of 53-65 t. This level of catch is close to the average catch landed from this region in the preceding five fishing seasons (63 t). Catches from areas outside of the traditional TOF fishing ground used to be low (median of less than 1 t over the first ten years from 2004/05) but have frequently exceeded 40 t over the last five fishing seasons (105 t in 2019/20). The area from which these recent catches are harvested is considerably smaller than the traditional TOF fishing ground (primarily east of King Island), but the MSY for this smaller region cannot meaningfully be estimated until a more comprehensive time series is available.

To complement quantitative assessments of biomass depletion and sustainable catches, we further introduced a risk analysis for the TOF. The risk assessment approach used procedures established by the Marine Stewardship Council based on CSIRO's "Ecological risk assessment for the effects of fishing". The outcomes highlighted that the TOF is a high-risk fishery, failing the pass mark for sustainable fishing in three assessment categories. Key concerns included (1) an energy-intense reproductive strategy (active brooding of eggs), (2) the high probability of capture, specifically of breeding females, who seek pots as refugia, and (3) a high associated risk of recruitment impairment.

In summary, trends in broad-scale CPUE remain relatively stable, with no clear indication that stock biomass is depleted. However, the high-risk nature of the fishery coupled with high total catches and evidence of localised and total biomass depletion in traditionally fished areas indicate that current levels of fishing mortality are unlikely to be sustainable. On the basis of this evidence, the Pale Octopus stock in northern Tasmania is classified as depleting.

Acknowledgements

We would like to thank Frances Seaborn and the Hardy family for their valuable contributions to this report.

1. Introduction

The Tasmanian Octopus Fishery

The Tasmanian Octopus Fishery (TOF) has been operating since 1980. Until December 2009, access to the commercial fishery was provided to holders of a fishing licence (personal), a vessel licence and a scalefish or rock lobster licence with a trip limit of 100 kg. Since December 2009, a specific octopus licence was required to participate in the Bass Strait fishery. Two licences were issued, belonging to the same operator.

Since 1996, under the Offshore Constitutional Settlement (OCS) with the Commonwealth of Australia, Tasmania has assumed management control of the TOF.

The TOF primarily targets the Pale Octopus (*Octopus pallidus*), but also includes the Gloomy Octopus (*Octopus tetricus*) and the Maori Octopus (*Macroctopus maorum*) albeit taken in much lower numbers as by-product. The main fishing method is unbaited moulded plastic pots (volume 3,000 ml) with no doors, which are attached to a demersal longline that is 3–4 km long and set on the sea floor at variable depths of 15–85 m (Leporati *et al.*, 2009). Currently, a maximum of 1,000 pots per line is allowed (Table 1.1; Table 1.2). Octopus are attracted to these pots as a refuge, which are generally hauled after 3–6 weeks soak time. An abundant food supply may support a large population of octopus and when combined with a shortage of suitable shelters results in high catch rates. Commercial octopus fishing is presently restricted to the East Bass Strait and West Bass Strait fishing zones (Figure 1.1). While no further octopus licences can be issued for the Bass Strait area, the remaining State waters are classified as developmental and could be opened to fishing provided necessary research is undertaken. The assessment period covered in this report includes a single permit for the east and south coasts of Tasmania restricted to 4,000 unbaited pots (from south of Eddystone Point and East of Whale Head).

From 2000/01 to 2005/06 catches of Pale Octopus in the TOF increased substantially and since then have fluctuated around 80 tonnes, ranging from 55t to 132t. Gloomy Octopus has only been reported in the fishery since 2010/11, with catches concentrated predominantly around Flinders Island. Recently increasing catches of this species, which peaked at 17 t in 2017/18, are indicative of range expansion (Ramos *et al.* 2015, 2016). However, no notable catches of Gloomy Octopus were reported in the last two seasons. The catch of Maori Octopus in the fishery has continued to fluctuate since 2000/01 with approximately 1 tonne landed in 2018/19, and zero tonnes recorded in 2019/20.

Table 1.1 Summary of the management and reporting changes for the Tasmanian Octopus Fishery.

Date	Management changes
Pre December 2009	Access provided to holders of personal fishing licence, a vessel licence and a scalefish (or rock lobster) licence. Trip limit of 100 kg applied.
December 2009	Two licences issued for the operation of two vessels (sole operator).
2004 / 2005	50-pot sampling program implemented
2016 / 2017	Two developmental permits issued (no reportable catches)
2017 / 2018	Single developmental permit issued (reportable catches)

Table 1.2 Summary of the management systems for the Tasmanian Octopus Fishery.

Fishery characteristics	Management changes
Fishing methods	Access provided to holders of fishing licence (octopus), a vessel licence and a scalefish (or rock lobster) licence. Trip limit of 100 kg if not the holder of a fishing licence (octopus).
Octopus licences	Two licences issued for the operation of two vessels by a single operator (family business).
Management methods	**Input control:** - Fishing licence (octopus) allows the use of 10,000 pots (maximum of 1,000 pots per line) to target *Octopus pallidus*, *O. tetricus* and *O. maorum.* - Fishing zone restriction (East and West Bass Strait Octopus zones only).
Main market	Tasmania and mainland Australia
Active vessels	3 (2 operating the licences; 1 operating the permit)

Recreational fishery

Small amounts of Octopus are also targeted by recreational fishing. As of 1 November 2015, recreational fishers have been subject to a bag limit of 5 octopus and a possession limit of 10 octopus (all species combined).

Data on the recreational catch of octopus in Tasmania is sparse. Surveys of the recreational fishery conducted in 2000/01, 2007/08, 2012/13 and 2017/18 provide the only comprehensive snapshots of the Tasmanian recreational fishery (Lyle, 2005; Lyle *et al.*, 2009; Lyle *et al.*, 2014; Lyle *et al.*, 2019). The recreational fishery surveys did not differentiate between cephalopod species with the exception of Southern Calamari and Gould's Squid. It is, however, understood that the majority of the catch reported as "cephalopods, other" are octopus, the remaining portion being cuttlefish. These surveys suggest that Octopus species are not a key target for the recreational fishery and appear as a bycatch caught predominantly by line fishing, gillnets and, to a lesser extent, rock lobster pots, with the majority not retained (Table 1.3).

Table 1.3 Estimated total recreational harvest numbers, numbers kept and % released for cephalopods taken by Tasmanian residents (refer to Lyle *et al.*, 2009). Note that survey periods do not necessarily correspond to octopus fishing years; details can be found in respective survey reports (weblink).

Cephalopod, other	Number fished	Number kept	% released
2000/01	6,264	<1,000	85.3
2007/08	5,605	1,149	79.5
2012/13	3,773	1,443	61.8
2017/18	101,500 (99% squid; ~500 other)	<1,000	67.2

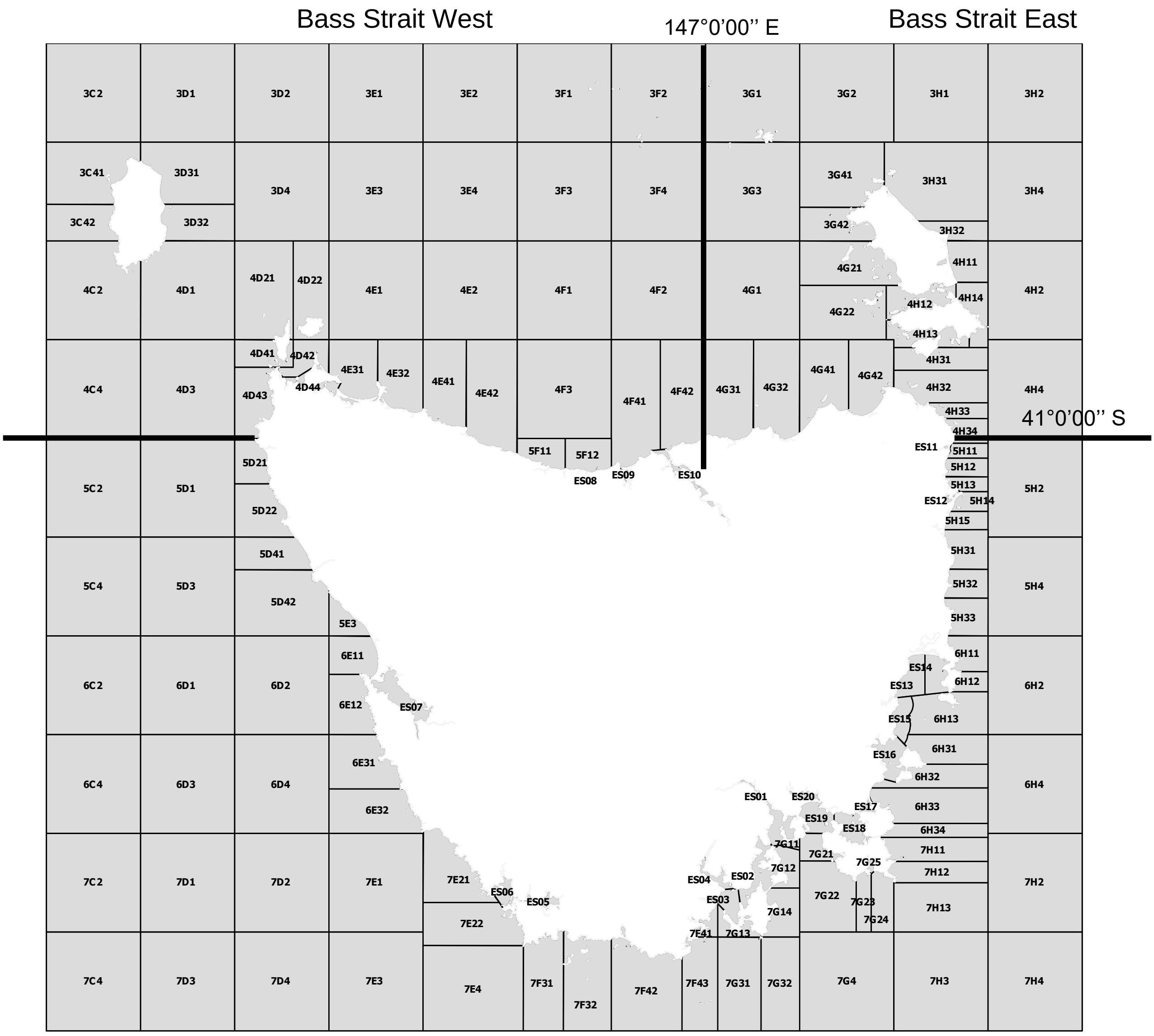
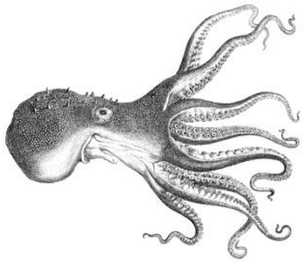


Figure 1.1 East and West Bass Strait octopus fishing zones and blocks. The octopus fishery reports in latitude and longitude but for the purpose of this report, fishing areas will be reported in fishing blocks.

Species Biology

All three octopus species harvested in Tasmania are short lived and fast growing. Table 1.4 summarises the biology of each species.

Table 1.4 Life history and biology of Pale Octopus (*Octopus pallidus*), Gloomy Octopus (*Octopus tetricus*) and Maori Octopus (*Macroctopus maorum*). In the 'Source' column, [1] refers to *O. pallidus,* [2] to *O. tetricus and* [3] to *M. maorum.*

Species	**Pale octopus** *Octopus pallidus*	**Gloomy octopus** *Octopus tetricus*	**Maori octopus** *Macroctopus maorum*	**Source**
Illustration	 (William Hoyle)	 (Angustus Gould)	 (Peter Gouldthorpe)	
Habitat	Sand and mud habitats to depth of 600m.	Rocky reefs and sand habitats in shallow waters, up to 30 m depth.	Rocky reefs, beds of seagrass or seaweeds, sand down to 549 m.	Norman (2000)[1,2,3] Edgar (2008)[1,2,3]
Distribution	South-east Australia, including Tasmania.	Subtropical eastern Australia and northern New Zealand, increasingly found in Tasmania.	Temperate and sub-Antarctic waters of New Zealand and southern Australia.	Norman (2000)[1,2] Stranks (1996)[3]
Diet	Crustaceans and shellfish (bivalves).	Crustaceans (crabs, lobster) and shellfish (gastropods, bivalves).	Crustaceans (crabs, lobsters), fish, shellfish (abalone, mussels) and other octopuses.	Norman and Reid (2000)[1,2] Norman (2000)[1,2,3]
Movement and stock structure	Limited movement and dispersal from natal habitat. Eastern and western Bass Strait populations likely to be two discrete sub-populations.	Undefined.	• Several genetically distinct populations. • At least 2 populations in Tasmania: North-east Tasmanian population and South-west Tasmanian populations (which extends to South Australia). • Adults of the species aggregate all year-round in Eaglehawk Bay in the Tasman Peninsula).	Doubleday *et al*. (2008)[1] Doubleday *et al*. (2009)[3]
Natural mortality	Undefined but potentially high	Undefined.	Undefined.	

Maximum age	Up to 18 months.	Maximum of 11 months	Maximum of 7.3 months from ageing study but lifespan potentially up to 3 years.	Leporati *et al*. (2008b)[1] Doubleday *et al*. (2011)[3] Grubert and Wadley (2000)[3] Ramos *et al* (2014)[2]
Growth	• Highly variable, partly dependant on water temperature and hatching season. • Max weight: 1.2 kg • Growth is initially rapid in the post-hatching phase, before slowing down. Growth has been represented by a 2-phase growth model with an initial exponential growth phase followed by a slower growth phase. Average growth in the first 114 days was estimated at $W = 0.246e^{0.014t}$ in spring/summer and $W = 0.276e^{0.018t}$ in summer/autumn, where *W* is the weight in g and *t* is the age in days.	• Max weight: up to 2.6 kg • Growth between 49 g to 2.64 kg described by the growth equation: $W = 3.385(1 - e^{-0.07642t})^3$ where *W* is the weight in kg and *t* is the age in days. Growth in the field might however only be about 40% of growth in aquarium.	• Max weight: 15 kg • Growth equation undefined	Leporati *et al*. (2008a)[1] André *et al*. (2008)[1] Joll (1977, 1983)[2] Stranks (1996)[3]
Maturity	Size at 50% maturity for females reached at 473g. Males appear to mature earlier (<250 g).	• Size-at-50% maturity was 132g for females and 92g for males • Age at 50% maturity 224 days for females and 188 days for males	• Size-at-50% maturity undefined. • Female mature between 0.6 to 1 kg. • Weight-specific fecundity range from 6.82 to 27.70 eggs/gram body. • Mating activity is independent of female maturity.	Leporati *et al*. (2008a)[1] Grubert and Wadley (2000)[3] Ramos *et al* (2015)[2]
Spawning	• Semelparous (i.e. reproduces only once before dying). • Spawns all year round with peaks in late summer/early autumn	• Semelparous (i.e. reproduces only once before dying). • Spawning season undefined but likely all year round.	• Semelparous (i.e. reproduces only once before dying). • Spawning season: spring-summer in New Zealand but appear to mate and lay all year round in Tasmania.	Leporati *et al*. (2008a)[1] Joll (1983)[2] Anderson (1999)[3]

	• Around 450-800 eggs per spawning event. • Egg length: 11-13 mm.	• Average fecundity is 278,448 eggs ± 29,365 se • Average size (maximum length) of ripe eggs is 2.2 mm ± 0.1 se	• Lay around 7,000 eggs in captivity but up to 196 000 eggs in ovaries of wild caught animals. Egg length: 6.5-7.5 mm.	Grubert and Wadley (2000)[3] Ramos *et al* (2015)[2]
Early life history	Large benthic hatchlings (0.25g) settling directly in the benthos.	Planktonic hatchlings (2-5mm length) settling at 0.3g (8 mm).	Planktonic hatchlings (5 mm length).	Leporati *et al*. (2007)[1] Joll (1983)[2] Anderson (1999)[3]
Recruitment	Variable.	Variable. No stock-recruitment relationship defined.	Variable. No stock-recruitment relationship defined.	

2. Methods

Data sources

Commercial data

Commercial catch and effort data used in this assessment are based on that recorded in TOF Commercial Catch, Effort & Disposal Record logbook returns. Octopus catches are reported as weight, and effort is reported as the number of potlifts. Additional data of octopus catch are reported from the Rock Lobster and Scalefish fisheries (tonnages of by-catch), but not included in CPUE calculations specific to the TOF.

Since November 2004, a 50-pot sampling program has been conducted, where fishers are required to collect all octopus caught in 50 randomly selected pots from a single line, representing 10% of a standard commercial line. From these 50-pot samples, the numbers of males and females of each species and the percentage of pots with eggs are recorded. The total and gutted weight of the catch was also recorded from 2004 to 2010. Fishers are required to sample at least 50 pots per line from at least one line per fishing day, and at least one line per distinct area fished in each day. Areas are distinct when lines are located entirely on different substrates or are separated by more than 10 nautical miles.

Weight-at-age is highly variable in octopus due to a high individual variability and a rapid response to environmental factors (Leporati *et al.*, 2008b; André *et al.*, 2009). This introduces stochasticity in catch weight so that it becomes difficult to use when interpreting trends in population size. The 50-pot samples provide numbers of octopus, which is more representative of the state of the stock. This practice aims to enhance the understanding of the stock status, particularly at a finer spatial scale (i.e. block level). New logbook requirements recently implemented will lead to improved data collection for the 50-pot samples.

In the 2019/20 season commercial data also exists for the developmental permit for the east coast of Tasmania. This fishing is outside of the TOF assessed here, hence it has not been included in the above analysis and has been summarised separately below.

Data analysis

Catch, Effort and CPUE

For the purpose of this assessment; catch, effort and CPUE analyses were restricted to commercial catches of Pale Octopus for the period March 2000 to February 2020.

A fishing year from 1st March to the last day of February has been adopted for annual reporting, which reflects the licensing year. Catches have been analysed fishery-wide and by fishing blocks (Figure 1.1).

Data on logbook returns include gutted and non-gutted (i.e. whole) weights. All gutted weights were converted to whole weight as follows:

$$Whole\ weight = 1.233472 * Gutted\ weight$$

where *Whole weight* and *Gutted weight* are in kilograms. This relationship between *Whole* and *Gutted* weight was estimated from 8,510 individuals recorded in the 50-pot sampling dataset between December 2004 and April 2010.

The number of pots pulled (potlifts) was used as a measure of effort in this assessment. Catch returns for which effort information was incomplete were flagged and excluded when calculating effort or catch rates. However, in recent years the amount of incomplete logbook entries has been negligible to nil. All records were included for reporting catches.

The impact of soak time (the time during which the fishing gear is actively in the water) was determined by analysing CPUE trends (in catch number per pot) through time for the 50-pot sampling data. Exploration of this influence was discussed in detail in the 2015/16 stock assessment (Emery & Hartmann, 2016), where no relationship between soak time and CPUE was apparent. Therefore, soak time was not considered in the resultant catch standardisation process below.

CPUE of Pale Octopus has been standardised using a generalised linear model (GLM) to reduce the impact of obscuring effects such as fishing year or season on the underlying trends in biomass (Kimura, 1981, 1988). However, while standardised catch rates are preferred over the simple geometric mean, other factors may remain unaccounted for that obscure the relationship between standardised catch rates and stock size, such as increasing fisher efficiency or spatial shifts in fishing effort from areas of low to higher catch rates.

There is currently only one family business representing the TOF, which operates from two different vessels. The depth fished is variable and the two vessels cooperate, with the vessel pulling the gear not necessarily being the same vessel that set it. Consequently, depth, vessel and skipper were not included in the GLM. Factors considered in the GLM were year, month and block. A lack of spatial block data for a number of trips from 2003/04 to 2007/08 led to 115t of catch data being omitted from the subsequent catch standardisation process. The GLM was applied to weight per pot for the whole commercial dataset and number per pot for the 50-pot sampling dataset (up to 2018/19). This process removes the effect of season and location so that trends in CPUE are more accurately reflective of change in octopus abundance.

Assessment of stock status

Stock status definitions

To assess the status of Pale Octopus in the TOF in a manner consistent with the national approach (and other jurisdictions), we have adopted the national stock status categories used in the 2018 Status of Australian Fish Stock (SAFS) report (Table 2.1) (Stewardson et al., 2018). These categories define the assessed state of the stock in terms of recruitment overfishing, which is often treated as a limit reference point. If a stock falls below this limit reference point, it is deemed that recruitment is impaired and its productivity reduced. Fisheries are ideally also managed towards targets that maximise benefits from harvesting, such as economic yield or provision of food. The scheme used here does not attempt to assess the fishery against any target outcomes. Determination of stock status into the below categories was based on temporal and spatial trends in commercial catch, effort and standardised CPUE data from the TOF.

Table 2.1 The stock status classifications that were adopted for this assessment.

Stock status	Description	Potential implications for management of the stock
SUSTAINABLE	Biomass (or proxy) is at a level sufficient to ensure that, on average, future levels of recruitment are adequate (recruitment is not impaired) and for which fishing mortality (or proxy) is adequately controlled to avoid the stock becoming recruitment impaired (overfishing is not occurring)	Appropriate management is in place.
RECOVERING ↑	Biomass (or proxy) is depleted and recruitment is impaired, but management measures are in place to promote stock recovery, and recovery is occurring.	Appropriate management is in place, and there is evidence that the biomass is recovering.
DEPLETING ↓	Biomass (or proxy) is not yet depleted and recruitment is not yet impaired, but fishing mortality (or proxy) is too high (overfishing is occurring) and moving the stock in the direction of becoming recruitment impaired.	Management is needed to reduce fishing mortality and ensure that the biomass does not become depleted.
DEPLETED	Biomass (or proxy) has been reduced through catch and/or non-fishing effects, such that recruitment is impaired. Current management is not adequate to recover the stock, or adequate management measures have been put in place but have not yet resulted in measurable improvements.	Management is needed to recover this stock; if adequate management measures are already in place, more time may be required for them to take effect
UNDEFINED	Not enough information exists to determine stock status.	Data required to assess stock status are needed.

Table 2.2 Summary of the proposed performance indicators and reference points.

Performance indicators and reference points

We note that no performance indicators and reference points haven been formally adopted for the Tasmanian Octopus Fishery. In all previous assessments, the determination of stock status was based on the consideration of commercial catch and effort data, which were assessed by calculating fishery performance indicators and comparing them with reference points (Table 2.2). Total commercial catch and effort, and CPUE (available both in weight and in numbers per pots derived from the 50-pot samples) were used as proxies for trends in fishing mortality and biomass using a reference period of 2000/01 to 2009/10 for catch and 2004/05 for CPUE (corresponding to the start of the 50-pot sampling program). We note that the validity of these performance metrics relies on the assumption of “negligible shifts in the distribution of fishing effort” (see Table below). This assumption did not apply in 2019/20, leading to the introduction of additional analyses and assessment approaches, including CMSY and the Risk-Based Framework, which are described further below.

Performance indicators	Reference points
Fishing mortality	• Catch (120 t) > highest catch value from the reference period (106.3 t) • Effort (327,000 potlifts) < Approximate effort required to achieve highest catch from the reference period (106.3 t); This reference point assumes average (unstandardised) catch rates across the period 2004/05 to 2009/10 (0.306 kg per pot) (=350,000 potlifts) and negligible shifts in the distribution of fishing effort
Biomass / Abundance	• Catch rate (0.62 octopus/pot) in 2018/19 > lowest value from the reference period (0.40 octopus/pot). No 50-pot sampling data was available for the 2019/20 season.

CMSY

In addition to analysing temporal trends in catch and effort data, we introduced the "CMSY" approach to estimate stock depletion and the maximum sustainable yield (MSY) from trends in catch (Martell and Froese, 2013; Froese *et al.*, 2017) as implemented in the R-package "datalowSA" (Haddon *et al.*, 2019). CMSY is a model-assisted stock assessment approach suitable for data-poor conditions. The approach relies on the Schaefer production model, which assumes that the biomass delivering MSY is equal to 50% of the unfished biomass and uses a Monte-Carlo based form of stock reduction analysis to estimate management reference points according to the assumed resilience of the target species and a time series of catch records. In the absence of empirical data on intrinsic population growth rates (r), but considering both a short life span (up to 1.5 years) and reproductive behaviour (active breeding of eggs), the CMSY approach was run by assuming that the resilience of Pale Octopus is likely to be "high" (r = 0.6-1.5) or "medium" (r = 0.2-0.8). In agreement with the precautionary principle, it is recommended that the lower 90% margins of MSY estimates are used as reference points for management.

Risk-Based Framework

We further introduced a risk analysis following protocols established by the Marine Stewardship Council (MSC) based on an approach established by the CSIRO (Hobday *et al.*, 2011). The MSC is globally recognised and produces a widely used Fisheries Standard for assessing if a fishery is well managed and sustainable. The Risk-Based Framework (RBF) described within the MSC Standard is suitable for assessing fisheries with limited data and for which primary indicators may be unavailable or problematic. If the TOF were assessed under the MSC Fisheries Standard, it is likely that there would be sufficient information to use the default assessment method. However, application of the RBF is straight-forward and provides an alternative perspective.

The RBF draws on information about the productivity of a target species and its susceptibility to fishery-related impacts (Productivity Susceptibility Analysis) as well as the consequence of this susceptibility (Consequence Analysis). Application of the RBF approach culminates in an overall score, which is indicative of the relative sustainability of the fishery. Scores >80 are regarded as passing the assessment with a low risk of stock damage. Scores of 60 – 80 are also regarded as passing the assessment, but with a moderate risk of stock damage. Scores <60 fail the assessment with a substantial risk of stock damage. It should be noted that the RBF is more precautionary and will likely result in a lower score than the default assessment method.

Given that the RBF framework is designed for data-poor fisheries, a cautious (worst plausible) approach is recommended in the absence of credible information, meaning that limited species information likely results in a lower final score. The RBF approach assumes that fisheries operating at relatively high levels of exploitation inherently pose a greater risk to ecological components with which they interact than under-utilised fisheries. Therefore, lower scores will be derived for highly utilised species unless credible information is available to indicate otherwise.

3. Results

Broad scale patterns in catch, effort and CPUE

Catch and effort within the Tasmanian Octopus Fishery

Influence of soak time

As per the 2015/16 report (Emery & Hartmann, 2016), an analysis of the 50 pot samples indicated that soak time had no discernible relationship with CPUE by number or weight and was disregarded when standardising CPUE. The number of pots continues to be used as the measure of effort when calculating catch rates.

Sex ratio

No difference in the ratio of male to female Pale Octopus was observed on a licencing year basis since the start of the 50-pot sampling program (Figure 3.1). However, this information was not available to be analysed for the 2019/20 licensing year.

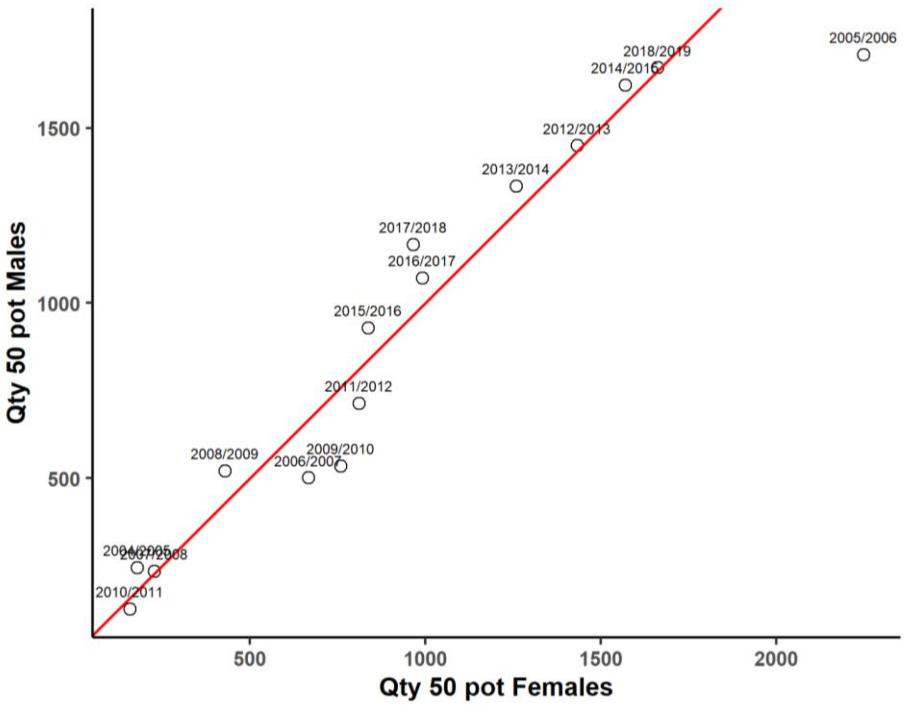


Figure 3.1 Ratio of Male to Female Octopi for 50-pot samples. Note: There was no 50-pot sample data recorded in 2019/20.

Catch and effort

The total catch of Pale Octopus in the TOF in 2019/20 was 120t, a slight decline from the previous year's record catch of 132t (Figure 3.2). This year's catch represents the third highest catch value in the history of the TOF. This is the first occurrence of two consecutive years of catches greater than 100t occurring within the TOF. Usually, a low catch year follows an unusually high catch year which occurred in 2011/12 and 2012/13. Catches in the fishery have varied between ~60t and ~120t since 2003/04. This catch occurred despite a small decline in effort and a large catch in 2018/19, which is atypical. This suggests multiple strong recruitment years, favourable conditions that led to increased vulnerability to fishing gear, or improved fishing efficiency.

Catches also vary seasonally within the fishery (Figure 3.3). In 2019/20, catches peaked during winter constituting 36% of this year's catch, followed by autumn which constituted 30.6% of catches. The high percentage of catch in winter is atypical to the usual autumn peak in catch recorded in previous years. Spring and summer landings constituted 18.3% and 15.1% of the total annual catch, respectively.

Fishing effort in 2019/20 was 320,000 pot lifts, a slight decrease from 2018/19 effort of 347,000 pot lifts, and was the equal eighth highest level of effort recorded for the fishery (Figure 3.4). Effort was concentrated in Autumn and Winter and was largely consistent with the previous three years (Figure 3.5). However, there was a decline in effort spatially, with less effort expended in the eastern region of the fishery.

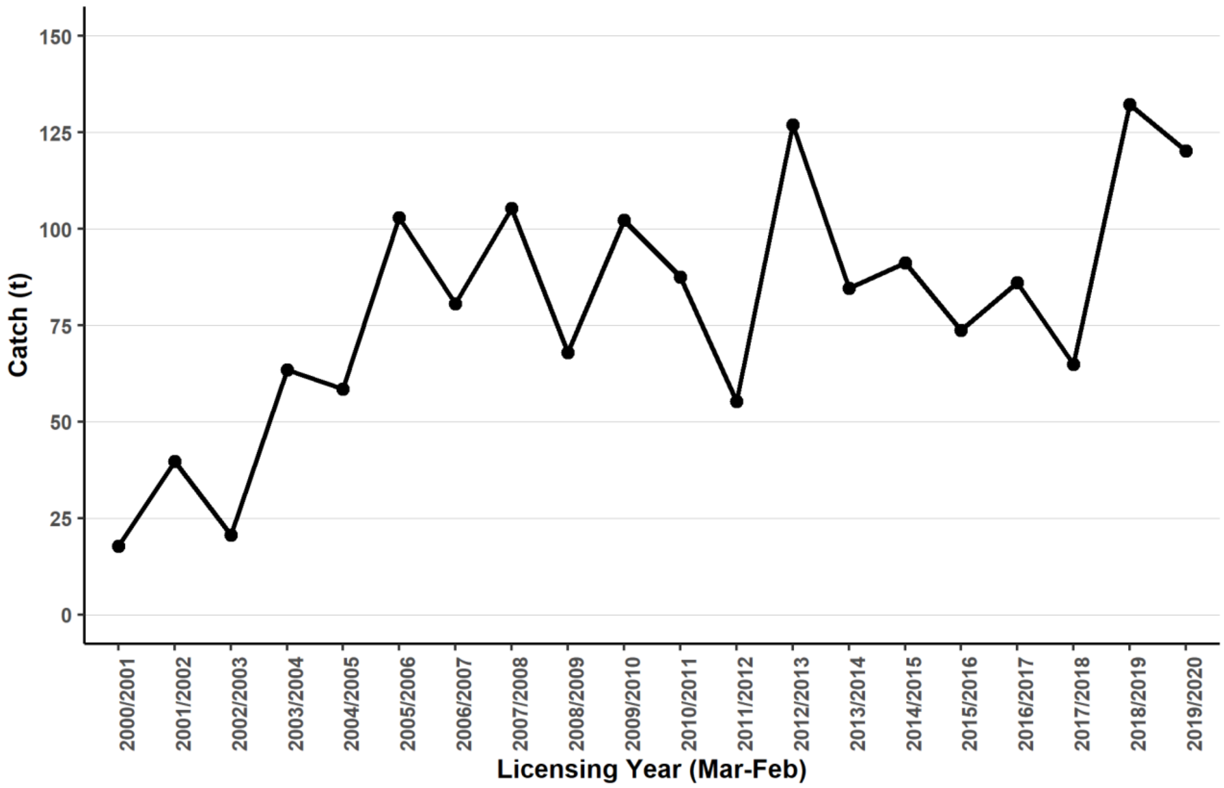


Figure 3.2 Total catches of Pale Octopus in the Tasmanian Octopus Fishery since 2000/01.

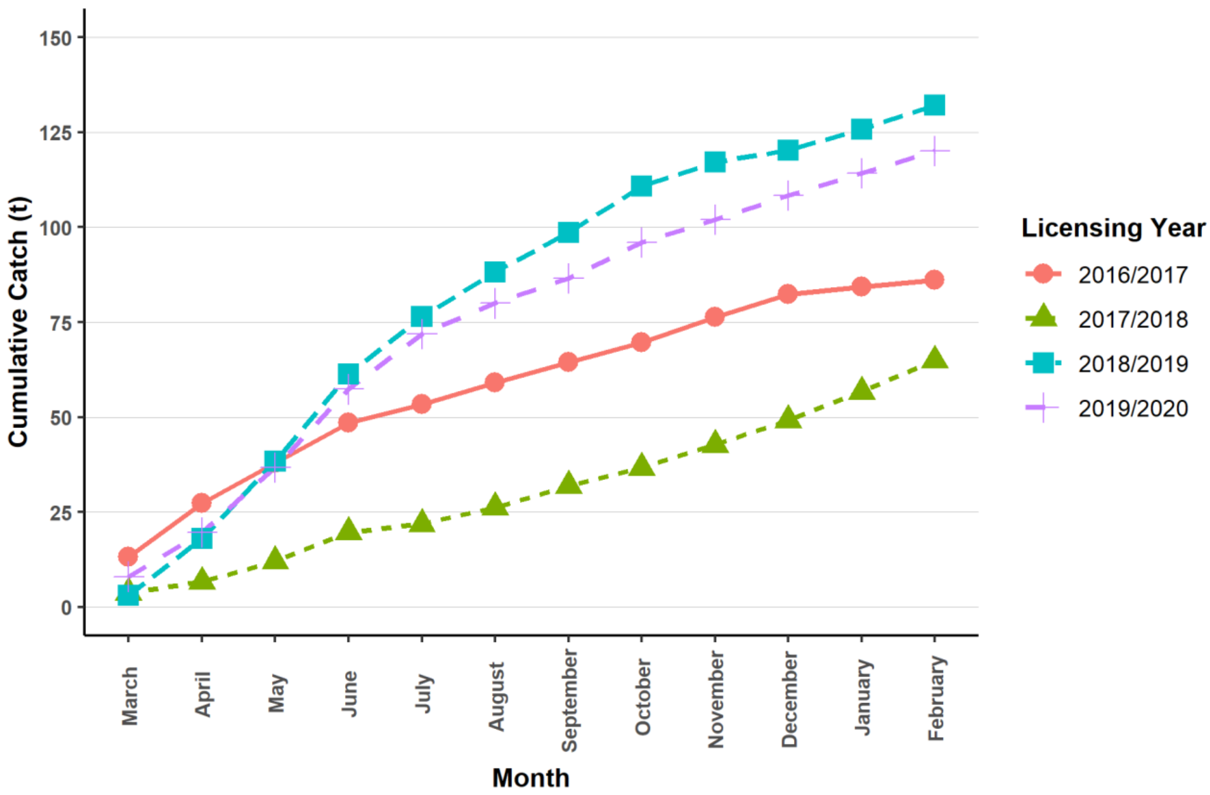


Figure 3.3 Cumulative catches of Pale Octopus landed over the last four licensing years showing seasonal trends.

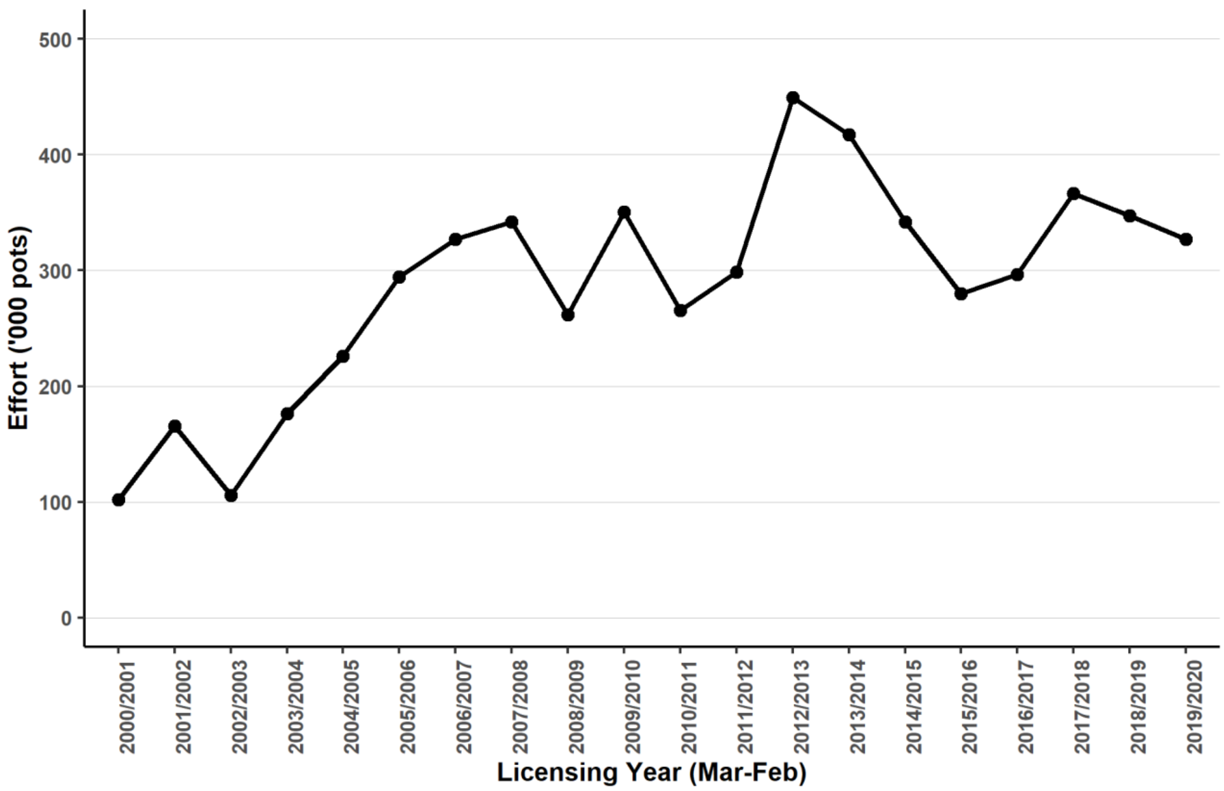


Figure 3.4 Effort (thousands of pot lifts) for Pale Octopus in the Tasmanian Octopus Fishery

since 2000/01.

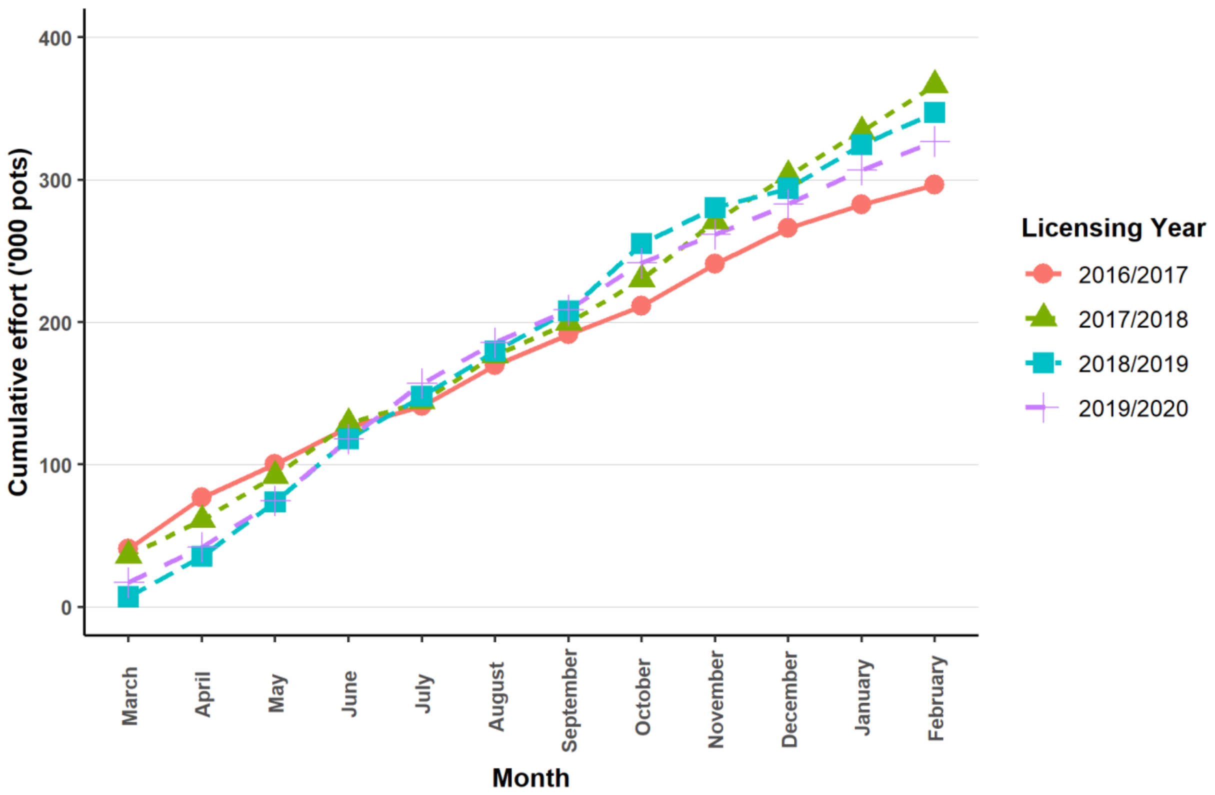


Figure 3.5 Cumulative effort (thousands of pot lifts) of Pale Octopus landed over the last four licensing years showing seasonal trends.

Catch per unit effort

In 2019/20, as with previous assessments, CPUE peaked in autumn and winter (March-August, Figure 3.6), coinciding with the brooding peak for the species (Leporati *et al.*, 2009).

The licensing year 2004/05 was chosen as a reference year for CPUE as the 50-pot sampling commenced in that year (Figure 3.7). The CPUE standardisation, with removed seasonality shows inter-annual variability in CPUE and a steady decline in CPUE from both the total commercial catch data and 50-pot sampling since 2004/05 to 2010/11 until 2018/19 where a noticeable increase was recorded. The inter-annual variation to some extent is likely due to the biological characteristics of Pale Octopus, which are inherently linked to environmental conditions, influencing hatching success and timing, larval mortality, recruitment, growth and spawning success. Stocks may be relatively abundant in one year but decline in the following year due to less favourable environmental conditions and/or changes in fishing pressure (Boyle, 1996; Rodhouse *et al.*, 2014). Notably, the fishery is removing brooding females, which use fishing pots as shelters to deposit their eggs. As Pale Octopus is a holobenthic species (i.e. they produce egg batches in the hundreds with benthic hatchlings) there is limited dispersal and the stock is highly structured (Doubleday *et al.*, 2008). Genetic studies corroborate these findings, identifying at least two differentiated sub-populations of Pale Octopus across the northern Tasmanian coast, which suggests limited movements of benthic hatchlings and adults (Higgins *et al.*, 2013) and a high associated potential for localised depletion if fishing effort becomes concentrated.

The ability to use CPUE based on total commercial catch data to help detect declines in local abundance is limited by spatial shifts in fishing effort from areas of low to high productivity. Given that octopus are known to seek pots for breeding and are likely to be targeted most effectively at breeding aggregation sites, there is also a notable risk of “hyperstability” in this fishery, whereby CPUE remains high despite potentially significant declines in population size. Research pot sampling data is an important source of information to assess trends in CPUE in addition to logbook-derived CPUE trends alone, but were not available for the current assessment.

The standardised catch rate for the total commercial catch from logbooks has fluctuated at around 60% of the reference year since 2011/12. In 2018/19, CPUE peaked, increasing from 52% of the reference year in 2017/18 to 86%. In 2019/20, CPUE decreased from this 2018/19 peak to 87% of the reference year. This remains above the ~60% average from 2011/12 to 2017/18 and is the third highest in ten years Estimates of CPUE from the 50-pot sampling program have largely remained stable since 2011/12, but also showed a similar peak in 2018/19, increasing from 67% of the reference year in 2017/18 to 89% in 2018/19 (Figure 3.7). Data for this index was not supplied for the 2019/20 season.

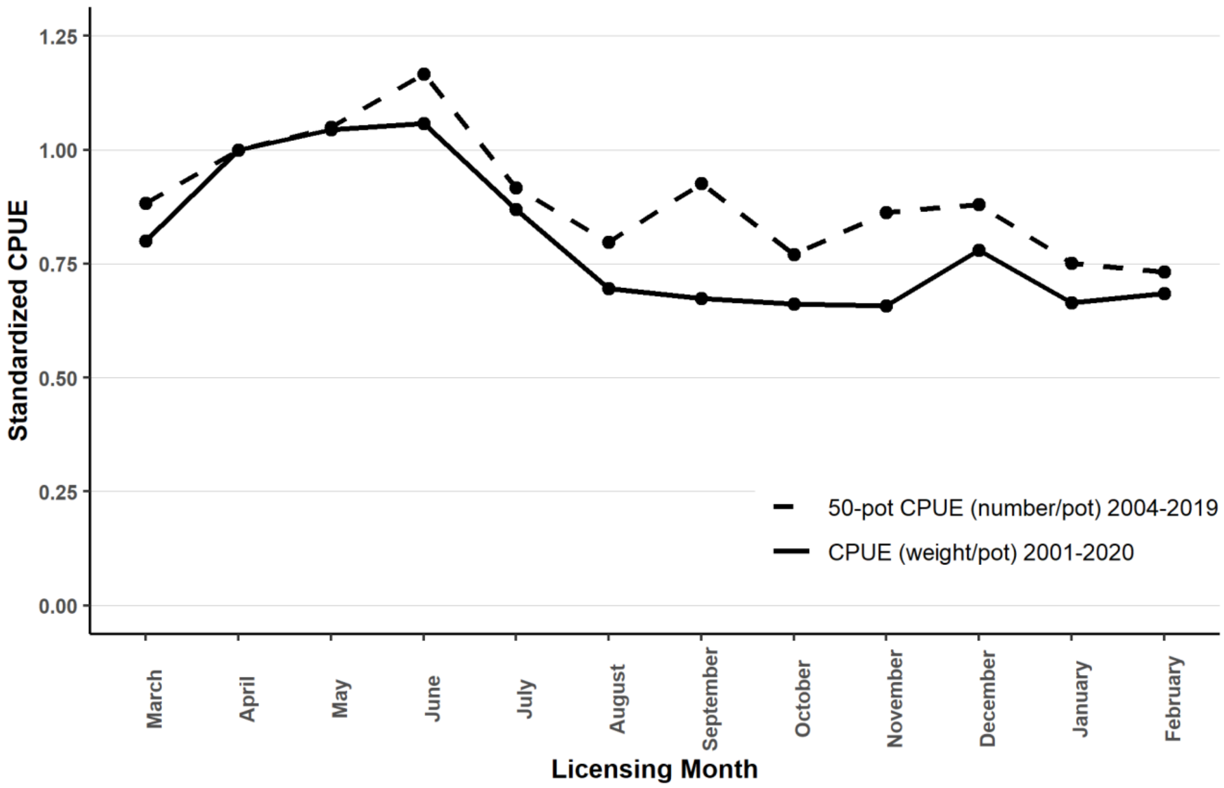


Figure 3.6 Pale Octopus standardised catch per unit effort (CPUE) relative to March levels in weight per pot (total commercial) and in number per pot (50-pot sampling).

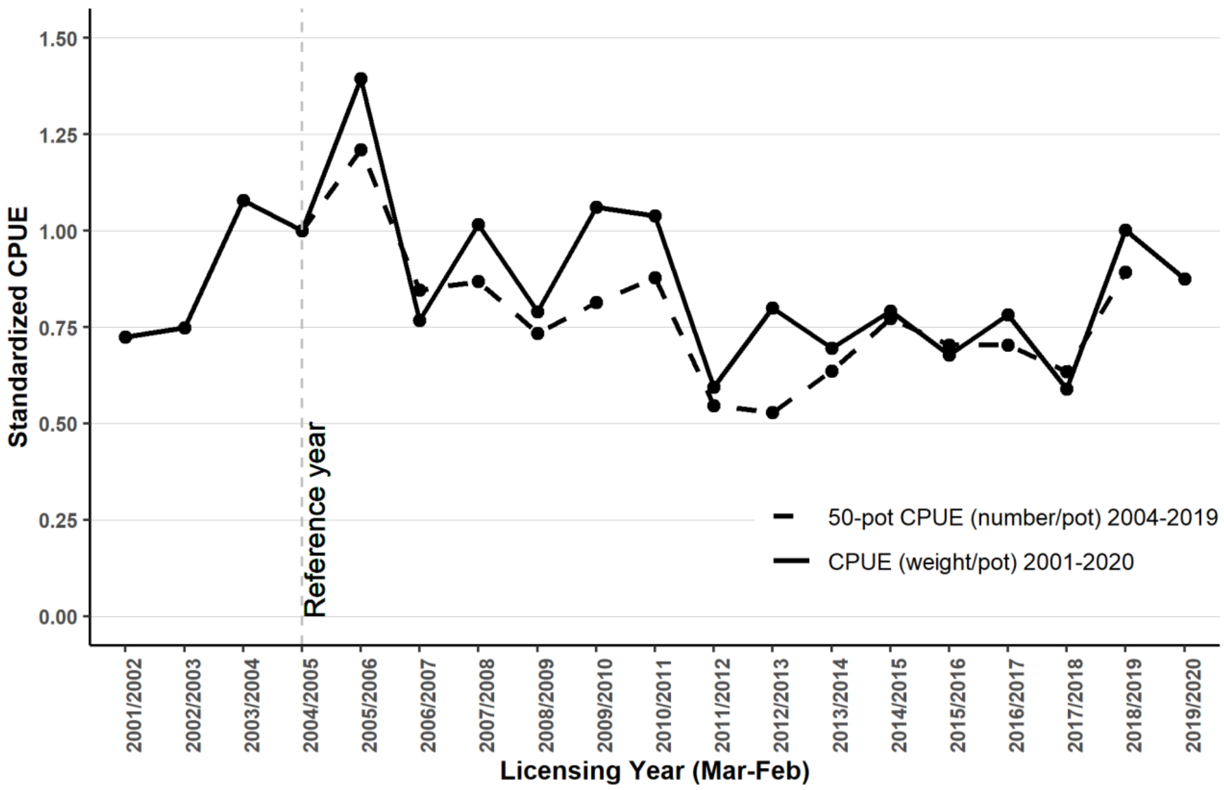


Figure 3.7 Pale Octopus standardised catch per unit effort (CPUE) relative to 2004/05 levels in weight per pot (total commercial) and in number per pot (50-pot sampling). Note: There was no 50-pot sample data recorded in 2019/20.

Commercial catch from developmental fishing permits

The single fishing permit, allowing access along the east coast below latitude 41° 0’ 00’’ South, resulted in a total catch of 5.7 t of Pale Octopus from a total of 31,500 potlifts. The catch of non-target species totalled 11.8 kg for Gloomy Octopus and 0 kg of Maori Octopus, respectively.

Commercial catch from other fishing methods

Although historical total octopus bycatch has reached up to 30 tonnes in the early 2000’s, recent records are indicating a stable, albeit lower value, with a total of 11.7 tonnes recorded in 2019/20 (Figure 3.8). Individuals are often not identified to the species level, with 65% of the bycatch from the rock lobster and scalefish fisheries detailed as “unspecified octopus” species. It is generally accepted that the rock lobster fishery octopus bycatch is predominantly Maori Octopus.

Most of the octopus bycatch in recent years originated from the rock lobster commercial fishery, with an average bycatch of 6.2 tonnes per annum over the last six licensing years, which is probably an underestimate (Figure 3.8). In 2019/20 the reported catch was 10 tonnes, which is above the long-term average. The commercial scalefish fishery provided the other source of octopus bycatch with an average of 2.7 tonnes per annum over the last six licensing years (Figure 3.8), with the 2019/20 catch totalling 1.7 tonnes. Gears that produce most of the octopus catch are hand collection and gillnets. Hand collected octopus was once a targeted fishery in

Eaglehawk Neck but declined after DPIPWE stopped the use of gillnets as a barrier in late 2009. The current pressure on the Octopus Fishery from other commercial fisheries does not appear excessive and indicates stability. The impact of bycatch from these fisheries on octopus stocks is therefore considered low.

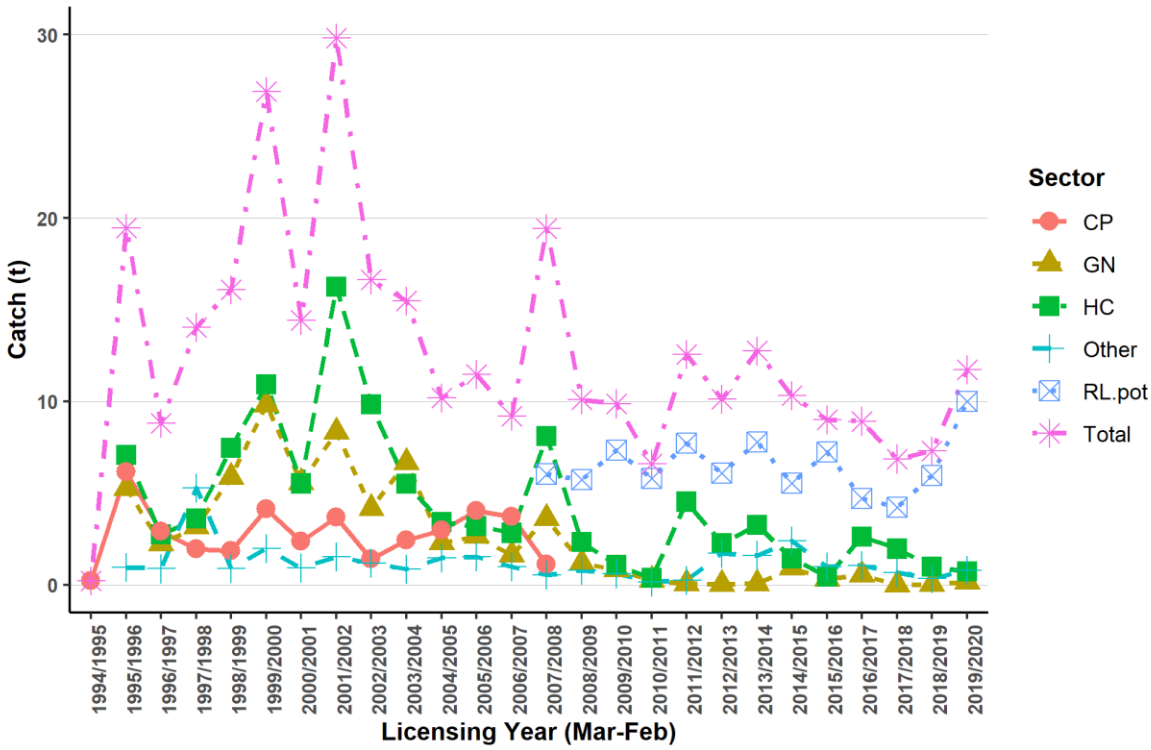


Figure 3.8 Octopus bycatch (tonnes) in other commercial fisheries. HC = hand collection, GN = gillnet, RL pot = Rock lobster pot, CP = crab pot.

Local patterns in catch, effort and CPUE

Notably, all results presented above, including estimates of MSY, implicitly assumed that fishing activities are comparable over the period from the reference year in 2004/05 to the current assessment year in 2019/20. This assumption does not hold given that both fishing effort and catches have expanded to previously unexploited areas further offshore. Thus, to examine signs of localised depletion, previous assessment reports visualized recent trends in catch, effort and CPUE by fishing block (0.5 x 0.5 degree). Furthermore, trends in each fishing block have been calculated as the difference in catch, effort and nominal CPUE between the current assessment year and previous years, as well as between the current assessment year and the average of the five previous years (Figures 3.9 and 3.10).

Most notable is a shift in effort, and subsequently catch, from the north-east coast off Bridport, to areas north-west off Flinders Island and east off King Island (Figures 3.9 and 3.10, A and B). These shifts in effort and catch might have been caused by reductions in CPUE closer to port – i.e. Stanley this year and Bridport over the previous five years (Figure 3.10 C) – suggesting that octopus in these areas might be depleted.

In 2019/20, an exceptionally high concentration of fishing effort and catch was evident in only two fishing blocks - east of King Island in the western portion of the fishery (3D4 and 3E3). These two blocks accounted for approximately 90% of the catch and > 60% of effort in 2019/20. Such a high local concentration of effort and catch is unlikely to be sustainable and might indicate a lack of productivity elsewhere, given that in contrast to increases in these two blocks further away from Stanley, declines were apparent in several traditionally fished blocks. However, with only two vessels in operation, fleet behaviour is likely to be influenced also by individual decisions that might be independent of catch rates.

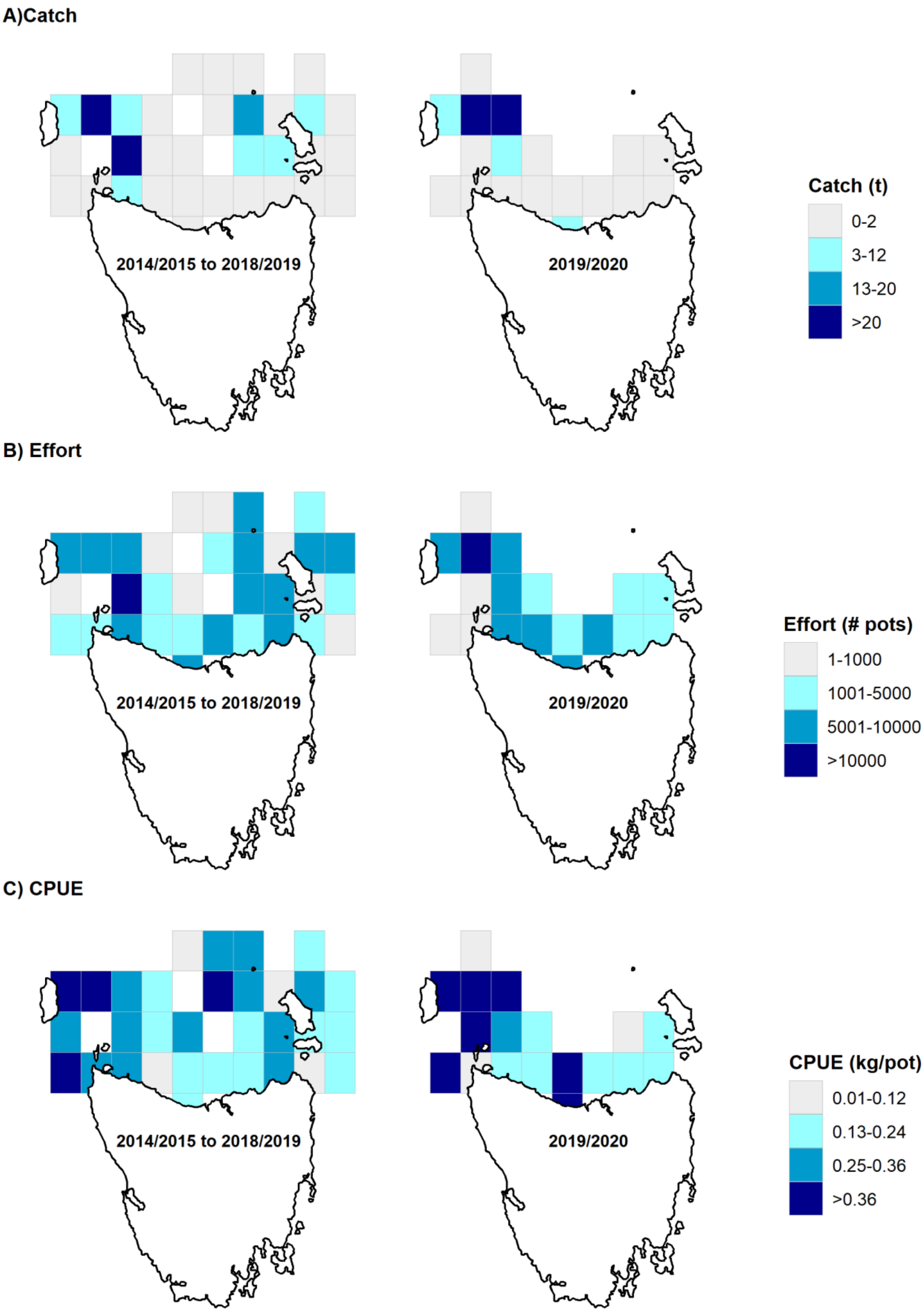


Figure 3.9 (A) Catch, (B) effort (pot lifts) and (C) nominal CPUE averaged over the last 5 years (left) and for the current licensing year 2019/20 (right).

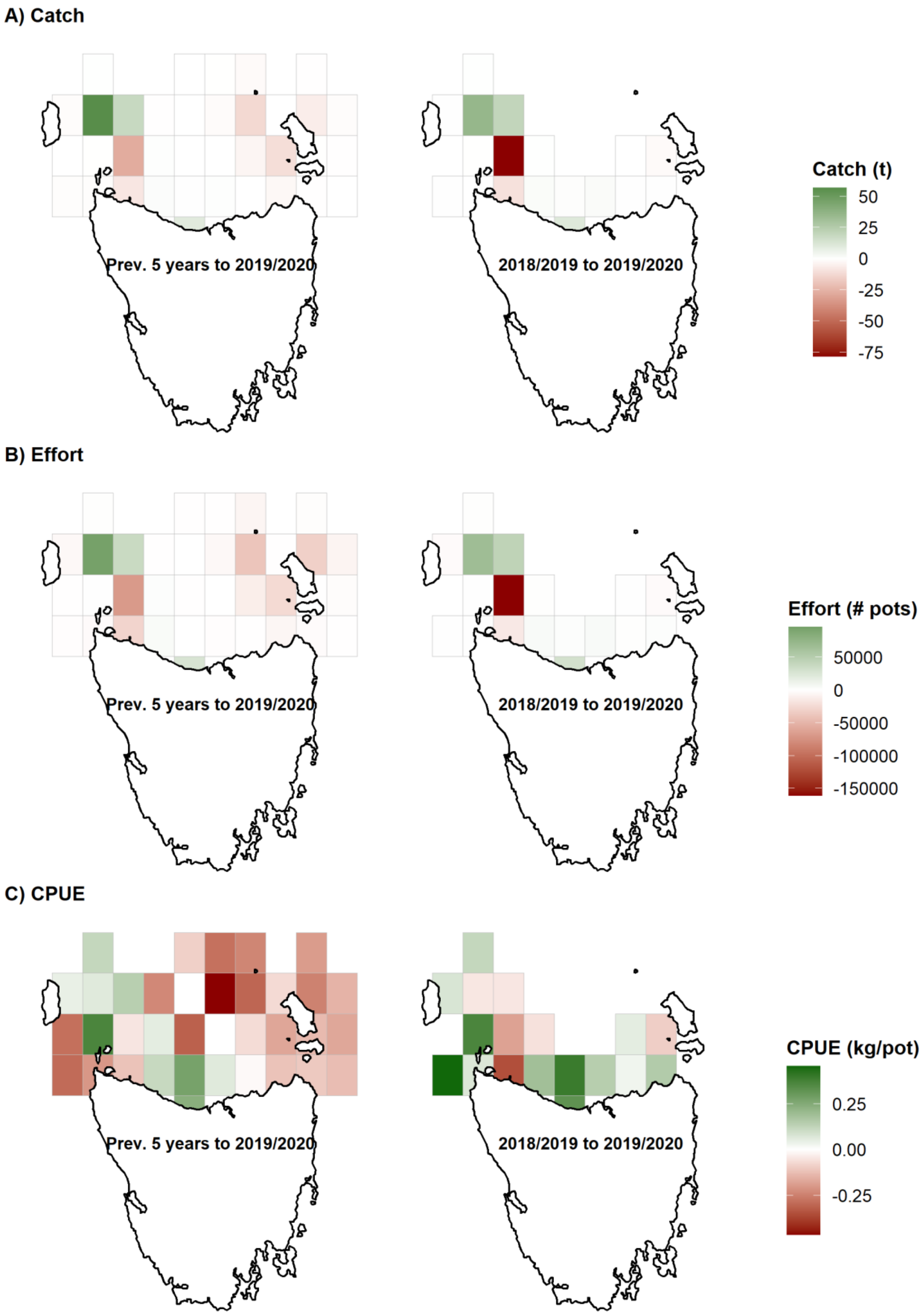


Figure 3.10 Change in (A) catch, (B) effort (pot lifts) and (C) CPUE by blocks between 2018/19 and the current year 2019/20 (right), and between 2019/12 and the previous 5 years average (2014/15 to 2018/19) (left). A positive value (green) indicates that the catch, effort or CPUE increased in 2019/20, a negative value (red) indicates a decrease.

Localised depletion was investigated in more detail using maps that visualized trends in catch, effort and CPUE across the TOF area in a higher temporal and spatial resolution (Fig. 3.11). The maps indicated that current catch rates are lower where effort and catch were concentrated in the first 5-10 years after the reference year (2004/05). To investigate further, we defined the "traditional" TOF fishing ground by identifying all fishing blocks that had been fished (any effort or catch recorded) in more than 50% of the first ten years since the reference year in 2004/05. Intentionally, this definition includes fishing blocks where effort and catch might have been comparatively low, but which might therefore serve as more sensitive indicators of declines in population density around breeding aggregation areas. Declining trends were identified based on temporal trends in CPUE by quantifying the slope of linear regressions. All blocks showing a negative slope were highlighted to visualize the spatial extent of potentially depleting or depleted biomass (Fig. 3.12). In combination, these analyses suggested that localised depletion is a matter of concern in multiple traditionally fished areas, specifically on the eastern side of Bass Strait and north-east off Flinders Island, where the fishery used to be more productive. Notably, the single most important fishing block in terms of both effort and catch, which is situated next to Three Hummock Island to the north of Stanley (4E1, see Fig. 3.12), did not reveal evidence of depletion. However, under consideration of the high risk of hyperstable CPUE in this fishery, signs of depletion in the periphery of block 4E1 (blocks 4E2, 4E3 and 4E4) could be indicative of an overall decline in the size of a breeding population that is concentrated in 4E1.

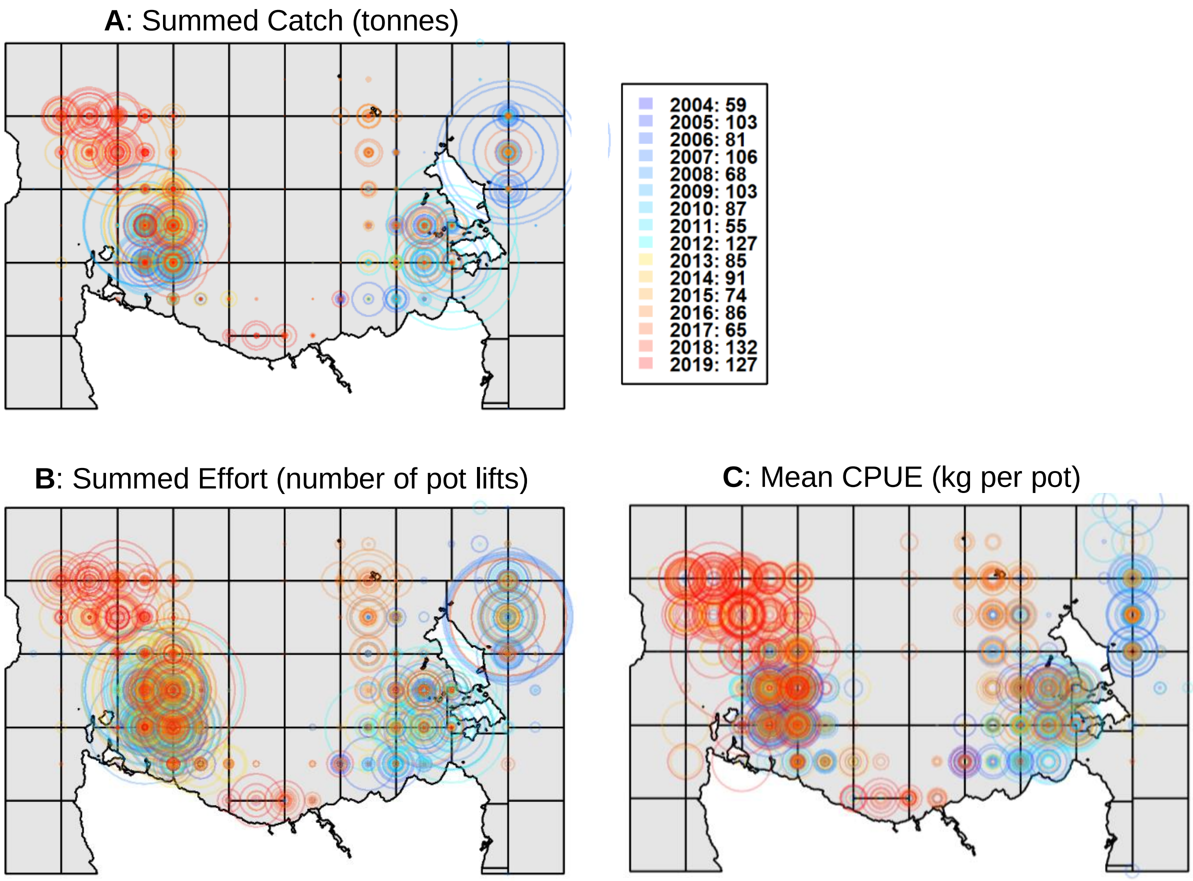


Figure 3.11 Change in monthly catch (A), effort (B) and CPUE (C) rounded to a spatial resolution of 0.25 degrees from the reference year (2004/05, blue) to the current assessment year (2019/20, red). Circle sizes are scaled by observed maxima, with largest circles indicating highest catch, effort and CPUE. Circle colours indicates the fishing season. Note that for clarity the maximum mean catch rate of 0.56 kg/pot recorded in April 2004 in the eastern portion of the fishery was removed from (C).

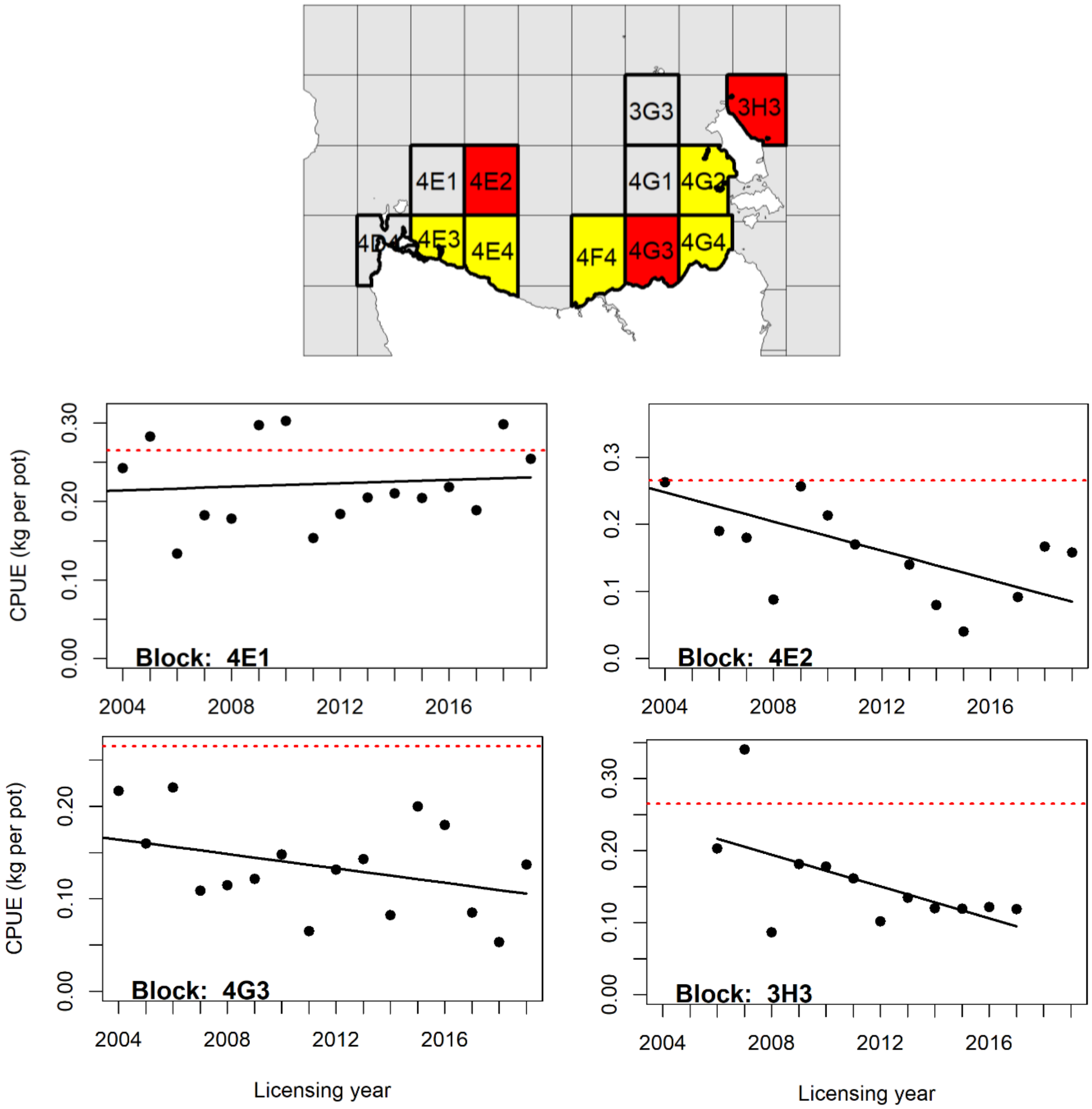


Figure 3.12 Map of fishing blocks delineating the “traditional” TOF fishing ground with thick boundaries (see text on page 27 for definition). Blocks where CPUE showed a declining trend are highlighted in yellow and red. Strongest declines are highlighted in red and detailed in regression plots below relative to the mean CPUE across all blocks in the reference year (0.26 kg per pot). CPUE in the most important fishing block in terms of both effort and catch (4E1) was found to be relatively stable.

Over the first ten fishing seasons since the reference year, a median catch of less than 1 t was recorded in blocks outside of the traditional TOF area, accounting for approximately 1% of the total catch. In contrast, over the last five fishing seasons, the catch from blocks outside of the traditional TOF area has increased to a median of more than 40 t, accounting for almost 40% of the total catch. Unprecedented peaks in catches taken outside of the traditional TOF area started with 28 t in 2014/15, increasing to 42 t in 2015/16, 48 t in 2018/19 and 105 t in 2019/20. Thus, in 2019/20, only 15 t out of a total of 120 t of the TOF catch was taken from traditionally fished areas. This is the lowest catch (both total and proportionally) from this area recorded to date.

CMSY results

CMSY simulations were run based on a subset of the TOF data that included only traditionally fished blocks (map in Fig. 3.12), intending to account for recent shifts in the distribution of fishing effort and ensuring that estimates of biomass depletion and maximum sustainable yield (MSY) were based on a spatially consistent time series of catch data. The outcomes indicated that the biomass of Pale Octopus in the traditional TOF area might have been depleting below 50% of unfished levels when the stock was firstly classified as "Transitional-Depleting" in 2012/13. Over the following seasons from 2013/14 to 2018/19, estimated biomass depletion in the traditional TOF area fluctuated between 32% and 40% of unfished levels before declining to an estimated 30-31% (lower 90% confidence interval = 18-23% of unfished biomass) in 2019/20 (Fig. 3.13).

While no reference points have been formally implemented, biomass fluctuating around 50% of unfished levels is a commonly defined target (Btarget = BMSY = 0.5 B/B0) (Fig.3.13), but has also been used as a threshold in precautionary Australian harvest strategies to initiate reductions in catch of data-poor stocks so that biomass remains above target levels (B > 0.5 B/B0) (see e.g.DPIRP, 2020). Biomass depletion below 20% (at the lower 90% confidence limit) is an internationally applied limit reference point (Blimit), beyond which directed fisheries under Australian harvest strategies are closed (Rayns, 2007; Smith *et al.*, 2009; Punt *et al.*, 2014).

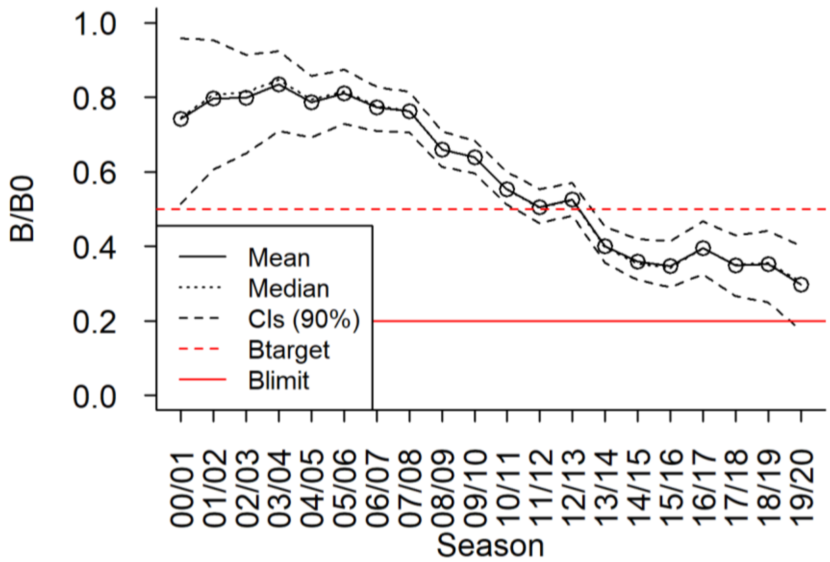


Figure 3.13 Trend in estimated depletion (biomass divided by unfished biomass, including 90% confidence intervals) in traditionally fished blocks. Results assume "medium" resilience, given that the assumption of "high" resilience produced few credible scenarios. The red line marks a common economic performance threshold, which is the biomass assumed to deliver the maximum sustainable yield (Bthreshold).

CMSY simulations further indicated that the maximum sustainable yield of Pale Octopus in the traditional TOF area ranges between an estimated 64 t ("medium" resilience) and 69 t ("high" resilience), with lower 90% CIs of 53 t and 65 t, respectively. This level of catch is close to the mean catch over the preceding five fishing seasons from that area (63 t, see Fig. 3.14).

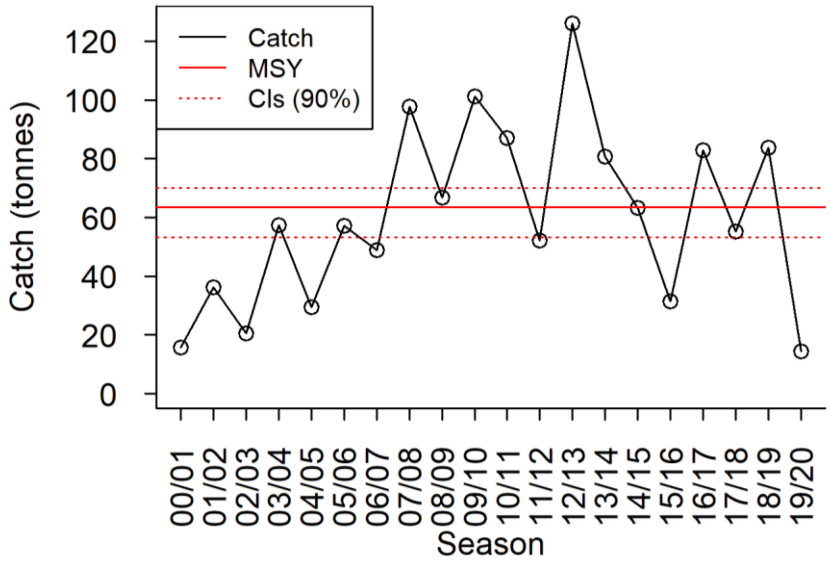


Figure 3.14 Trends in catch from traditionally fished blocks relative to the estimated maximum sustainable yield (MSY) and associated 90% confidence intervals (CIs). Results assume "medium" resilience, given that the assumption of "high" resilience produced few credible scenarios.

As outlined above, catches from outside the traditional TOF commonly exceeded 40 t over the last five fishing seasons. The region east of King Island, where most of these catches came from (see Fig. 3.9 and Fig. 3.11), is considerably smaller than the traditional TOF area (3 vs 12 blocks). However, in the absence of a more comprehensive time series of catch data, CMSY simulations cannot meaningfully be run to estimate MSY for this more recently targeted area.

Risk-Based Framework

The Pale Octopus fishery within the TOF scored < 60 in the MSC-RBF analysis, failing assessment with high risk of stock damage. The Productivity Susceptibility Analysis score was based on the assumption that Pale Octopus is a moderately productive secondary consumer, with a short generation time (< 1 year), and a relatively energy-intense reproductive strategy whereby females actively brood egg clutches. Pale Octopus is highly susceptible to capture and damage by the fishery. Fishing effort overlaps with > 30% of the stock distribution in Tasmania, suggesting that the stock is readily available to the fishery. The major risk factor identified by the analysis was the high probability of individual octopus encountering and being captured by fishing gear, given that octopus actively seek out fishing gear (pots) as refugia. This risk is exacerbated by the behaviour of female octopus, which use pots as sheltered habitats to lay and brood eggs.

In consequence, commercial fishery CPUE and other catch data (e.g. sex ratio) are unreliable metrics of stock status over time, as octopus might be caught effectively largely regardless of population density. That is, population depletion might occur even if only minor or no declines in CPUE are evident. Furthermore, the attraction of brooding females to fishing gear indicates a high likelihood of damage to recruitment. The Consequence Analysis indicated full exploitation of the stock, with population size representing the most vulnerable subcomponent. Although there is no clear evidence of damage to recruitment, the frequent capture of brooding females suggests that without suitable management there is a high risk of stock damage and recruitment impairment by this fishery.

Table 1 Risk-Based Framework scoring of the Pale Octopus fishery for the consequence analysis, productivity susceptibility analysis, and the combined total
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Consequence Analysis		
Most vulnerable subcomponent	**Score**	**Score interpretation**
Population size	60	Full exploitation rate but long-term recruitment dynamics not adversely affected
Productivity Susceptibility Analysis		
Productivity attribute	**Score**	**Score interpretation**
Average age at maturity	1	< 5 years
Average maximum age	1	< 10 years
Fecundity	2	100 – 20 000 eggs per year
Reproductive strategy	2	Demersal egg layer
Trophic level	2	2.75 – 3.25
Density dependence	3	Depensatory dynamics at low population sizes (Allee effects) demonstrated or likely
Susceptibility attribute	**Score**	**Score interpretation**
Availability (areal overlap of fishing effort with stock distribution)	3	> 30% overlap
Encounterability (position of stock/species in water column or on habitat relative to position of gear)	3	High overlap with fishing gear. Default score for target species.

Selectivity (potential of gear to retain immature individuals)	3	a) Individuals < size at maturity a frequently caught. b) Individuals < half size at maturity are retained by gear.
Post-capture mortality (the chance that captured individuals will be released, and their chance of survival if released)	3	All individuals are retained, or the majority are dead if released due to damage (e.g. legs missing). Default score for target species.
Total Productivity Susceptibility Score **Total RBF Score**	**< 60** **< 60**	

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4. Stock status

STOCK STATUS	DEPLETING

In 2019/20, the catch of Pale Octopus in the Tasmanian Octopus Fishery remained high (120 t). This is the first instance in the TOF in which catches were above 100 tonnes over two consecutive years. Effort was recorded at 327,000 potlifts in 2019/20, representing a slight decrease from last year and remaining below the proposed limit reference point of 350,000 potlifts.

Broad-scale trends in catch per unit effort (CPUE) show a decrease from 2005/06, albeit with annual fluctuations. Historically, CPUE declined after a peak in the mid-2000s but has been fluctuating around 60% of the reference CPUE (corresponding to the start of the 50-pot sampling) since 2011/12. In 2019/20, a slight decrease in logbook derived CPUE from the recent peak in 2018/19 was recorded, with estimates in 2019/20 at 87.5% of the reference year. No 50-pot sample data was available for 2019/20, which is why 50-pot based CPUE, as an additional index of abundance, could not be calculated for this assessment. High levels of fishing effort have previously preceded declines in fishery-wide CPUE, yet the magnitude of this effect is likely to be masked by notable shifts in the distribution of fishing effort and catch away from traditionally fished areas.

Uncertainty about recent shifts in effort distribution, local biomass depletion and sustainable catch limits initiated more in-depth analyses of both ecological risks and local trends in catch, effort and CPUE as part of this assessment. Results revealed evidence of localised depletion across multiple traditionally fished areas, even if CPUE in a single highly productive block appeared to be stable. Data-poor stock assessment methods further indicated that the biomass in traditionally fished blocks might be depleted beyond desirable levels and that peak catches from this area are unlikely to be sustainable. While there is no clear evidence that the total biomass of Pale Octopus is already depleted to critical levels, there is a considerable risk that recruitment might be impaired even if broadscale CPUE remains relatively stable.

On the basis of this information, Pale Octopus is classified as depleting.

5. Environmental interactions

Bycatch

Bycatch in the octopus pot fishery is historically low. While Pale Octopus is the main target, pots also attract other octopus species such as Gloomy Octopus and Maori Octopus as by-product. Catches of Gloomy Octopus decreased from their peak in 2017/18 of 16.9t, to zero in 2018/19 and just 11.8kg in 2019/20. No catch of Maori Octopus was recorded for 2019/20, a decline from 1 t in the 2018/19 season, which might be related to shifts in effort distribution in 2019/20. Both by-product species were considered to be at negligible risk from octopus potting in the 2012/13 Ecological risk assessment (ERA) of the Tasmanian Scalefish Fishery due to their low historical catches (Bell *et al.*, 2016).

Protected and threatened species interactions

In general, the nature of the fishery and the gear used make interactions with bycatch or protected species unlikely. Boats do not operate at night hence seabirds are not attracted to working lights. There is no bait discarding issues since the pots are unbaited. Surface gear is minimal (two buoys and two ropes for each demersal line). The 2012/13 ERA considered that risks from octopus potting to protected species were negligible (Bell *et al.*, 2016).

Entanglement of migrating whales in ropes of pot fisheries have been reported in Western Australia (WA Department of Fisheries, 2010). While the Tasmanian Octopus Fishery operates in Bass Strait, part of which is in the migratory route of southern right whales (TAS Parks and Wildlife Service), no such interactions have been reported in Tasmania. Furthermore, the limited amount of surface gear, typically 40 buoys in the entire fishery at any one time is negligible in contrast to other pot fisheries. For example in the Tasmanian Rock Lobster Fishery a single operator may set up to 50 sets of pots and ropes and there are approximately 1.3 million potlifts set annually, or in the Western Australia Rock Lobster Fishery where there are approximately 2 million potlifts set annually (De Lestang *et al.*, 2012; Hartmann *et al.*, 2013).

Ecosystem and habitat interactions

The octopus pots currently used in the fishery are lightweight and set in a sandy bottom environment, which is the preferred substrate for Pale Octopus. The impact of commercial potting has been found to have little impact on benthic assemblages (Coleman *et al.*, 2013) and the 2012/13 ERA considered that octopus potting was of low risk to both the ecosystem and habitat (Bell *et al.*, 2016).

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