TASMANIAN OCTOPUS ASSESSMENT 2020/2021

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Octopus are caught commercially in Tasmanian waters across multiple fisheries using a range of gear types. The three recorded species are Pale Octopus (*Octopus pallidus*), Gloomy Octopus (*Octopus tetricus*), and Māori Octopus (*Macroctopus maorum*). Most catch comes from a targeted unbaited trap fishery for Pale Octopus in northern Tasmania, primarily Bass Strait, by fishers operating under the fishing licence (octopus). This fishery is referred to as the Tasmanian Octopus Fishery (TOF) in this report, and by the Department of Natural Resources and Environment Tasmania (NRE Tas). Holders of the fishing licence (octopus) also retain low quantities of Māori Octopus as by-product and take occasional landings of Gloomy Octopus in years when the fishery extends towards eastern Bass Strait. Given that the TOF targets Pale Octopus and represents the majority of octopus catches in Tasmania, it is the focus of this report. Developmental permits for targeting Pale Octopus on the east coast of Tasmania have also been issued in recent years, but operators retain substantially smaller quantities than in the Bass Strait.

The Scalefish and Rock Lobster fisheries take octopus as by-product. The Giant Crab fishery operates using similar gear to the Rock Lobster fishery; however, no octopus are recorded in Giant Crab fishery returns data. Species information is not always recorded for octopus landed within the Scalefish and Rock Lobster fisheries, but the majority is Māori Octopus. Based on the low incidence of Gloomy Octopus and Pale Octopus in observer sampling from these fisheries, landings are considered negligible.

Until late 2009, a targeted fishery for Māori Octopus existed in Eaglehawk Bay using hand collection and barrier nets. Catches in this local fishery declined significantly and remained very low after the permit ceased to allow the use of barrier nets.

Aboriginal cultural catch and recreational catch of octopus species is known to occur, mainly as bycatch from line fishing or diving, but catches appear negligible based on survey data from recreational fishers.

Pale Octopus – TOF

The Scalefish Fishery Management Plan (revised in 2015) provides the management framework for the northern Tasmanian commercial unbaited trap fishery targeting Pale Octopus (the TOF). The TOF has been a sole operator fishery since its commencement in 1980, with two vessels operating in Bass Strait and on the eastern side of Flinders Island. The main management controls for the fishery include limited access via licensing and gear restrictions.

Pale Octopus are found in southeast Australian waters, including Tasmania. The reproductive biology of Pale Octopus suggests low resilience to fishing pressure as small numbers of eggs are actively brooded by females producing large, benthic hatchlings.

The status of Pale Octopus in the TOF area is assessed annually using data on catch, effort, and catch per unit effort (CPUE) as well as catch-only assessments of maximum sustainable yield (MSY) and biomass depletion. Catch and effort data now cover the period from 2000/01 to 2020/21. Fishing pressure on Pale Octopus is assessed using catch as a proxy for absolute mortality and effort (number of pot-lifts) as a proxy for exploitation rate.

The total catch of Pale Octopus in 2020/21 was 154 tonnes (t), representing the highest recorded catch.

Total effort in the fishery decreased slightly from last year's total, with 311,500 pot-lifts recorded in 2020/21.

These catches are well above the average of 100 t observed over the last decade. Notably, the current fishing season represents the first instance of three consecutive years during which catch exceeded 100 t, and almost all the catch in 2020/21 (72%) occurred in only three fishing blocks – two east of King Island and one inshore adjacent to Stanley.

CPUE was the highest on record in the 2020/21 season; CPUE derived from fishers' logbook data was 132% of the reference year (2004/05), substantially higher than the 2019/20 season, in which CPUE was 72% of the reference year. CPUE derived from the 50-pot research sampling programme — data collected in addition to standard logbook data — was also the highest on record in the 2020/21 season, at 156% of the reference year.

To assess potential biomass depletion and estimate maximum sustainable yield (MSY) while accounting for recent shifts in fishing effort and catch, we utilised catch-only stock assessment approaches developed for data-poor fisheries like the TOF. Catch-only stock assessment approaches were run based on regional trends in catch and estimates of stock resilience or natural mortality. The results indicated that Pale Octopus biomass in the traditionally fished regions west and east of Flinders Island might be depleted below desirable levels (50% of biomass delivering MSY) while biomass in the key traditional fishing ground offshore from Stanley could be close to 50% of unfished levels, which is common target reference point in fisheries management. While climate change-driven factors may have influenced shifts in the distribution of productivity within the fishery, further investigation will be required to understand how and to what extent the apparent declines in the eastern regions of the Bass Strait have been driven by climate and environmental factors vs. fishing effects.

To complement quantitative assessments of biomass depletion and sustainable catches, we incorporated 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 that seek pots as refugia, and (3) a high associated risk of recruitment impairment.

In summary, broad-scale trends in CPUE give no indication that stock biomass is depleted. However, the high-risk nature of the fishery coupled with high total catches and evidence of regional biomass depletion in some traditionally fished areas indicate that current levels of fishing pressure might be unsustainable. On the basis of this evidence, the Pale Octopus stock in northern Tasmanian waters is classified as Depleting

Gloomy Octopus – TOF

Catch for Gloomy Octopus within the TOF was only 0.3 t in the most recent year and has remained close to zero since a peak of 20.8 t in 2017/18. Gloomy Octopus catch seems to be driven by the distribution of effort in the TOF, because Gloomy Octopus are caught primarily around Flinders Island. Unless TOF effort is moved into this region, catches are generally close to zero.

Gloomy Octopus are found along the eastern Australian coastline, with Tasmania at the southern end of the species' distribution and catches from the TOF coming from only a small part of the range. Effort and catch in eastern Bass Strait have been close to zero over the last 3 years. Considering this minimal catch, and the reproductive biology of Gloomy Octopus, with large numbers of small planktonic larvae produced from active benthic brooding by females suggesting greater resilience to fishing pressure than Pale Octopus, the Tasmanian Gloomy Octopus stock is classified as Sustainable.

Māori Octopus – multiple fisheries

A total of 14.7 t of Māori Octopus were landed by Tasmanian commercial fishers in 2020/21. This comprised 4.1 t of by-product from the TOF, 9.3 t of by-product from the Rock Lobster fishery, 0.9 t of by-product from the Scalefish fishery, and 0.4 t from the formerly productive Eaglehawk Bay targeted Māori Octopus fishery. These totals are based on the assumption that all records of landed octopus without species identification from these fisheries are Māori Octopus.

Rock Lobster and Scalefish fishing licences have a trip limit of 100 kg of retained octopus. In the Rock Lobster fishery, octopus are captured in crustacean traps where they prey on the target species, Southern Rock Lobster (Brock and Ward 2004). Unidentified octopus is a dominant by-product 'species' in the Rock Lobster fishery (León et al. 2019), and additional unknown quantities of captured octopus are killed and discarded by rock lobster fishers to prevent future lobster depredation. Data presented here represent the retained, landed by-product only, rather than total fishing mortality.

Uncertainty about discard mortality in the Rock Lobster fishery challenges reliable estimates of total catch and sustainability for Māori Octopus. However, observer sampling and comparison of landed by-product tonnage with total numbers of rock lobster trips suggest that discard mortality may be low. Unpublished IMAS data from video observation suggests selectivity of rock lobster gear for octopus may also be low.

The life-history of Māori Octopus suggests this species may be moderately resilient to fishing pressure. Māori Octopus are found along the southern Australia coastline, including the whole Tasmanian coast. Large numbers of small planktonic larvae are produced after females actively brood benthic egg clutches. In a risk-assessment of common bycatch and by-product species in the Southern Rock Lobster fishery, using only productivity/life history traits of a species and its susceptibility to capture without considering catch or population size, Māori Octopus returned a low-risk ranking (León et al. 2019).

Thus, the Tasmanian Māori Octopus stock is classified as Sustainable.

1. Introduction

History of octopus harvesting in Tasmania

Development of commercial Māori Octopus harvesting

Pre-colonial harvesting of seafood by Tasmanian Aboriginal communities involved hand collection of shellfish. Frijlink and Lyle (2013) were unable to find historical reports of octopus catch from the pre-colonial or colonial period, even if it is likely that catches occurred.

There was a large expansion of rock lobster fishing from vessels using rings and pots in the late 19th century, which led to depletion and concern about the sustainability of rock lobster harvests. There was controversy around the use of lobster pots relative to rings because of their greater effectiveness in depleting reefs, and the problem that lobsters in the pots were vulnerable to depredation by Māori Octopus. Pots were first legalised in the north of the state in 1903 and then in the rest of the state in the 1920s. Octopus were caught as bycatch throughout this period but were generally not retained until consumption patterns changed with greater immigration from Mediterranean Europe after the second world war.

Commercial landings of octopus from the lobster fishery are currently constrained by management imposing a landing limit of 100 kg per trip. Annual recorded landings for the fleet generally fluctuate between 5 and 10 t. As a consequence of the trip limit, the fishing mortality of Māori Octopus will exceed the landed catch because commercial lobster fishers always kill octopus rather than release them to reduce lobster depredation.

A targeted octopus fishery has operated in Eaglehawk Bay since the 1970s. Most catch came from one operator who used a barrier net that trapped the octopus as they moved along the southern side of the bay although there was also hand collection. When the use of barrier nets was banned under this fishing permit in late 2009, the fishery declined substantially. In fisher reports to IMAS, declines in catch were also attributed to observed increases in seal abundance in the bay, assuming significant octopus depredation by seals.

Development of commercial Pale Octopus harvesting

Targeted fishing for Pale Octopus has occurred since 1980 and operated under permit for many years. The targeted Pale Octopus fishery represents the main focus of this report and is referred to officially by NRE Tas as the Tasmanian Octopus Fishery (TOF). Since 1996, under the Offshore Constitutional Settlement (OCS) with the Commonwealth of Australia, Tasmania has assumed management control of the TOF within state waters. Since December 2009, a specific octopus licence (fishing licence (octopus)) was required to participate in this fishery, which operates within Bass Strait, including waters to the east of Flinders Island. Two licences were issued, both to the same operator.

The TOF primarily targets the Pale Octopus using 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 refugia; pots are generally hauled after 3–6 weeks soak time. An abundant food supply may support a large population of octopus. When combined with a shortage of suitable shelters, this results in high catch rates. TOF geographic regions within the Bass Strait, as discussed in this report, can be seen in Figure 1.1. While no further octopus trap 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 two permits for octopus traps for the east and south coasts of Tasmania (from south of Eddystone Point and East of Whale Head). One permit is restricted to the use of 4,000 unbaited pots, the second to the use of 200 unbaited pots and 50 unbaited trigger traps (trigger traps unused for the duration of this permit).

From 2000/01 to 2005/06 catches of Pale Octopus in the TOF increased substantially and, until the 2020/21 season, fluctuated around 80 tonnes, ranging from 55 t to 132 t.

Commercial Gloomy Octopus harvesting

Gloomy Octopus are uncommon in Tasmania and found only around the northeast, which is at the southern end of their geographic distribution.

Gloomy Octopus are found on both reef and sediment habitat so may be taken by commercial operators in both the rock lobster fishery and the TOF.

Based on observer observations, catch of Gloomy Octopus taken by the rock lobster fishery appears to be negligible and thus difficult to quantify.

Gloomy Octopus has only been reported from the TOF since 2010/11, when effort from that fishery shifted eastwards around Flinders Island.

Catches of Gloomy Octopus peaked at 17 t in 2017/18, which was unprecedented and thus interpreted as evidence of range expansion (Ramos et al. 2014, Ramos et al. 2015). However, annual trends in catch of Gloomy Octopus can more likely be explained by targeted effort in eastern Bass Strait. When effort shifted westward after the 2017/18 season, catches of Gloomy Octopus were reduced back to previously low levels. In the 2020/21 season, where effort was concentrated almost exclusively in western Bass Strait, only 315 kg of Gloomy Octopus was reported. Similarly low catches had been observed already in the two preceding seasons.

Table 1.1 Summary of the management and reporting changes for octopus fishing in Tasmania.

Date	Management changes
1903	Legislation banning the use of rock lobster pots overturned, which enabled increased retention of Māori Octopus
1980-90s	Various modifications made to licencing that affected retention of octopus bycatch including access provided to holders of a personal fishing licence, a vessel licence, and a scalefish (or rock lobster) licence. Trip limit of 100 kg applied which limited by-product from lobster pots of Māori Octopus.
2000/01	Commercial fishing for Pale Octopus and other minor species approved under permit using unbaited traps in Bass Strait (TOF).
December 2009-ongoing	Two licences issued for the operation of two vessels (sole operator) using unbaited octopus traps (TOF).
2004 / 2005	50-pot sampling programme implemented in the TOF Pale Octopus fishery.
2016 / 2017	Two developmental permits issued (no reportable catches) for east coast Pale Octopus fishery.
2017 / 2018	Single developmental permit issued (reportable catches) for east coast Pale Octopus fishery.
2019/2020	Two developmental permits issued (reportable catches) for east coast Pale Octopus fishery.
2020/2021	Three developmental permits issued (reportable catches) for east coast Pale Octopus fishery.

Table 1.2 Summary of the current management systems for octopus fishing in Tasmania.

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.
Management methods	**Input control:** - Fishing licence (octopus) allows the use of 10,000 pots (maximum of 1,000 pots per line) to target Pale Octopus, Gloomy Octopus, and Māori Octopus. - Fishing zone restriction for fishing licence (octopus): East and West Bass Strait Octopus zones only.
Main market	Tasmania and mainland Australia
Active vessels	5 targeting octopus with unbaited traps (2 operating the licences; 3 operating permits); additional ~ 200 vessels taking small tonnage (<15 tonnes total) of by-product, mainly Māori Octopus.

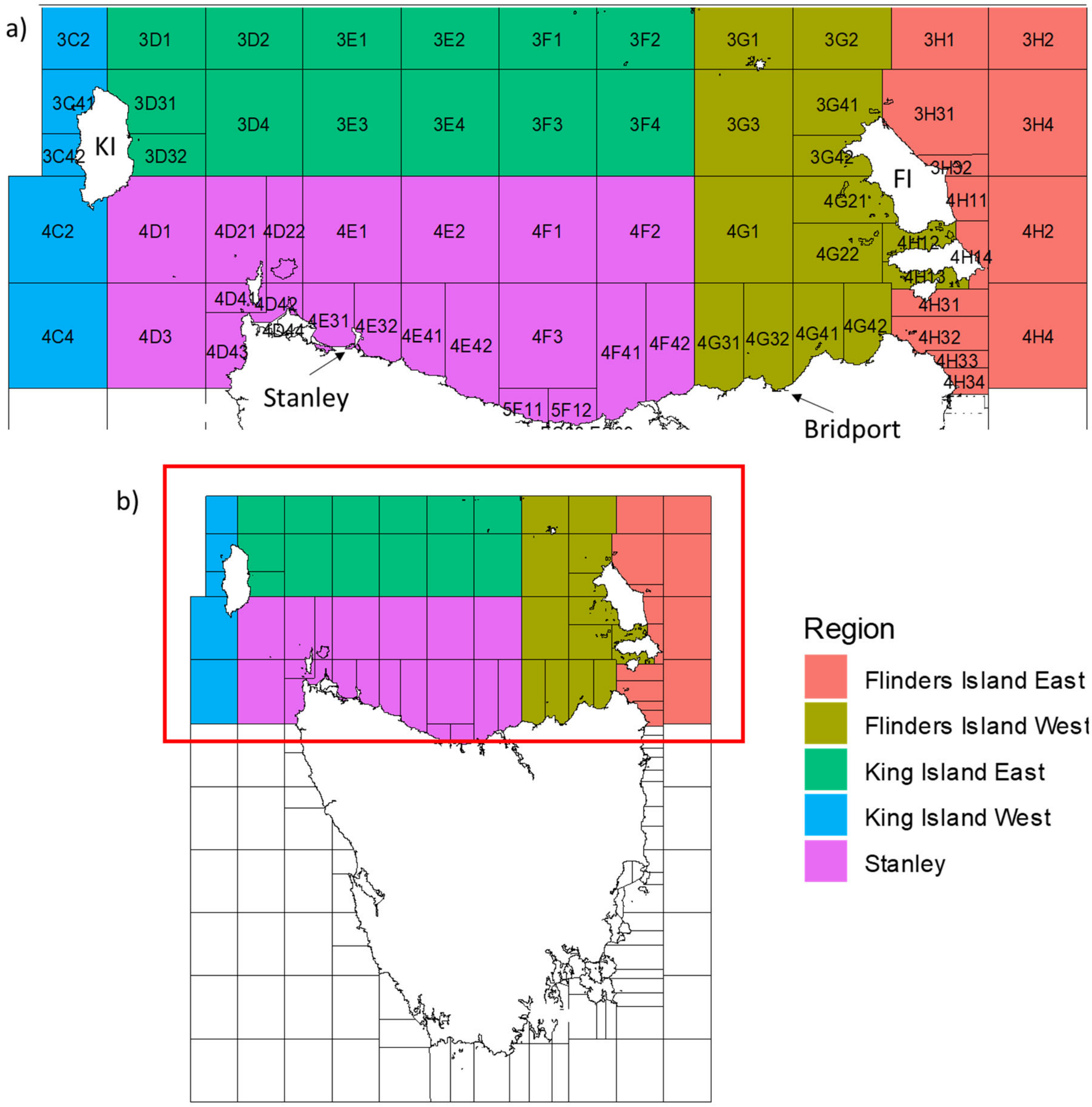

Figure 1.1 Map of fishing blocks in Tasmania highlighting the Bass Strait target area for Pale Octopus within the TOF, including the 50-pot sampling regions: a) fishing blocks within regions – the TOF reports in latitude and longitude but for the purpose of this report, fishing areas are reported in fishing blocks; KI = King Island, FI = Flinders Island; b) red box indicates the area shown in a). Note: no catch or effort data were recorded for the King Island West region during the time series assessed here.

Species Biology

Table 1.3 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	 (Illustration © R.Swainston/anima.fish)	 (Illustration © R.Swainston/anima.fish)	 (Illustration © R.Swainston/anima.fish)	
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. • Females 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

Pale Octopus commercial data from the TOF

Commercial catch and effort data used in the main component of this assessment are based on Pale Octopus landings recorded in TOF Commercial Catch, Effort & Disposal Record logbook returns. TOF fishing records comprise individual demersal unbaited trap longline lifts, with catches per line reported as weight, and effort per line reported as the number of unbaited pots (i.e., ‘pot-lifts’).

Since November 2004, a 50-pot sampling programme has been conducted within the TOF, 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. Data from the 50-pot sampling programme are separated into geographic regions, as indicated in Figure 1.1.

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 2020/21 season, commercial data for Pale Octopus also exist for the developmental permits for the east coast of Tasmania. This fishing is outside of the normal TOF operations analysed here, hence it has not been included in the above analysis and has been summarised separately below.

Māori and Gloomy Octopus commercial data

To assess the status of Māori and Gloomy Octopus we used commercial catch data from the Scalefish and Rock Lobster fishery logbook returns, as well as records of these species in the TOF logbook returns, which include data from the east coast developmental permits. Octopus catch in the Eaglehawk Bay targeted fishery are recorded in the Scalefish logbook returns.

Data analysis

TOF Pale Octopus Fishery

Catch, Effort, and CPUE

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 both fishery-wide and by fishing blocks (Figure 1.1). 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 2021.

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

$$\textit{Whole weight} = 1.23 * \textit{Gutted weight}$$

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 (pot-lifts) 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 et al. 2017), where no relationship between soak time and CPUE was apparent. Therefore, soak time was not considered in the resultant catch standardisation process

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 (Kimura 1981, Kimura 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 operator representing the TOF, which uses two different vessels. The vessels cooperate, with the vessel pulling the gear not necessarily being the same vessel that set it. Consequently, vessel and skipper were not included in the GLM. The depth at which the gear is set is variable and the inclusion of depth in the GLM was not useful for explaining the data. Factors considered in the GLM were year, month, and block. A lack of spatial block data for multiple trips early in the time series led to 228 t of catch data (13.3% of total catch over the time series) 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. An additional GLM was applied to CPUE data from the Stanley region (see 50-pot sampling regions in Figure 1.1). Catch and effort data from all other regions within the TOF did not meet the model assumptions of homogenous and normal distribution of residuals, therefore this analysis was not run for other regions.

Catch-only approach

In addition to analysing temporal trends in catch and effort data, we utilised two “catch-only” approaches to estimate the status of the Tasmanian Pale Octopus stock – “CMSY” (Martell and Froese 2013, Froese et al. 2017) and “OCOM” (Zhou et al. 2017). Results from CMSY were chosen to present as this approach has been consistently applied to data from multiple commercial stocks within Australia (Haddon et al. 2019, Piddocke et al. 2021). CMSY can be used to estimate stock depletion and the maximum sustainable yield (MSY) from trends in catch data, and was implemented for the TOF using the R-package “datalimited2” (Free 2018).

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 brooding 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). OCOM, the “optimized catch-only method”, was run by assuming an instantaneous rate of natural mortality of 1 (63%) and 2 (86%). However, the results were similar, which is why results are shown only for the more widely applied CMSY approach. In agreement with the precautionary principle, lower confidence intervals of CMSY outputs are generally taken into account when making management decisions.

All catch-only simulations were run based on regional subsets of the TOF data, which represented those chosen for the 50-pot sampling programme (Figure 1.1). However, some regions could not meaningfully be analysed given that they have not been consistently fished in the past. Recent shifts in the distribution of fishing effort and, consequently, catch to the King Island East region, for example, meant that catch data from both this region and the entire fishery were not suitable for catch-only simulations. Therefore, results are presented for the Stanley, Flinders Island West, and Flinders Island East regions only.

Risk-Based Framework

We further introduced a risk analysis following protocols 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 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.

Reference points

No reference points have been formally adopted for the TOF. In 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 (fishing mortality and biomass) and comparing them with potential reference points (Table 2.). Total commercial catch, effort, and CPUE (as both weight and as numbers per pot derived from the 50-pot sampling programme) were used as proxies for trends in performance indicators using a reference period of 2000/01 to 2009/10 for catch and 2004/05 for CPUE (corresponding with the start of the 50-pot sampling programme).

Table 2.1 Summary of previously proposed performance indicators and reference points.

Performance indicators	Reference points
Fishing mortality	• Catch > highest catch value from the reference period (106.3 t) • Effort > Approximate effort required to achieve highest catch from the reference period (106.3 t) assuming 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	• Numbers per pot < lowest value from the reference period (0.40 octopus/pot)

In 2019/20, catch and effort data no longer met the assumptions of these fishery-wide performance metrics; that is, the assumption of “negligible shifts in the distribution of fishing effort”. In 2019/20, substantial spatial shifts in fishing effort and catch occurred within the fishery, leading to the introduction of additional analyses and regional assessment approaches, as well as CMSY and the Risk-Based Framework described above (Krueck et al. 2021).

Following this latest assessment of the Tasmanian Pale Octopus stock as Depleting, fishery stakeholders initiated a meeting among representatives of the Institute for Marine and Antarctic Studies (IMAS), the Department of Natural Resources and Environment Tasmania (NRE Tas), and the Tasmanian Seafood Industry Council (TSIC). During the meeting, IMAS presented stock assessment outcomes for the 2019/20 season for extended subsequent discussion. The meeting concluded with the aim to establish potential reference points for future management of effort in all different regions currently monitored in the context of the 50-pot sampling programme (Figure 1.1). Reference points for sustainable effort, rather than catch, were considered desirable in terms of both practical implementation as well as fishery impact. A draft report on potential reference points has been forwarded to NRE Tas for feedback, with principal outcomes based on catch-only simulations that are presented in this document.

Māori and Gloomy Octopus – multiple fisheries

Landed by-product catch of all octopus species from the Scalefish and Rock Lobster logbook returns were assessed spatially and temporally, across fishing blocks and available time series. For Māori and Gloomy Octopus, these catches also included retained by-catch recorded for the TOF. Effort and CPUE data were not included in these assessments because they are unlikely to be informative for by-product species, and because of the high uncertainty about underreported catches and discard mortality of the main species (Māori Octopus). Observer sampling has shown that octopus catch from the Scalefish and Rock Lobster fisheries is almost entirely Māori Octopus. In cases where landed octopus where not recorded to species level, we therefore made the simplistic but realistic assumption that these are primarily Māori Octopus. However, for transparency, data with no species name have been assessed and presented here as 'Octopus, unidentified'. The Risk-Based Framework described above was also used to assess the risk of damage to the stocks of Māori and Gloomy Octopus, with the susceptibility component of the Productivity Susceptibility Analysis based on the fisheries that retained the highest catch of each species in 2020/21: the Rock Lobster fishery for Māori Octopus, and the TOF for Gloomy Octopus.

Assessment of stock status

Stock status definitions

To assess the status of Octopus in a manner consistent with the national approach (and other jurisdictions), we adopted the national stock status categories used in the 2020 Status of Australian Fish Stock (SAFS) report (Table 2.) (Piddocke et al. 2021). 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. However, 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, and catch data from other fisheries.

Table 2.2 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.

3. Results

TOF Pale Octopus fishery and east coast developmental fishery

Broad scale patterns in Pale Octopus catch, effort, and CPUE

Influence of soak time

As per the 2015/16 report (Emery et al. 2017), an analysis of the 50-pot sample data 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, based on raw abundance data, was observed on a licencing year basis since the start of the 50-pot sampling programme (Figure 3.1). This information was not available to be analysed for the 2019/20 licensing year.

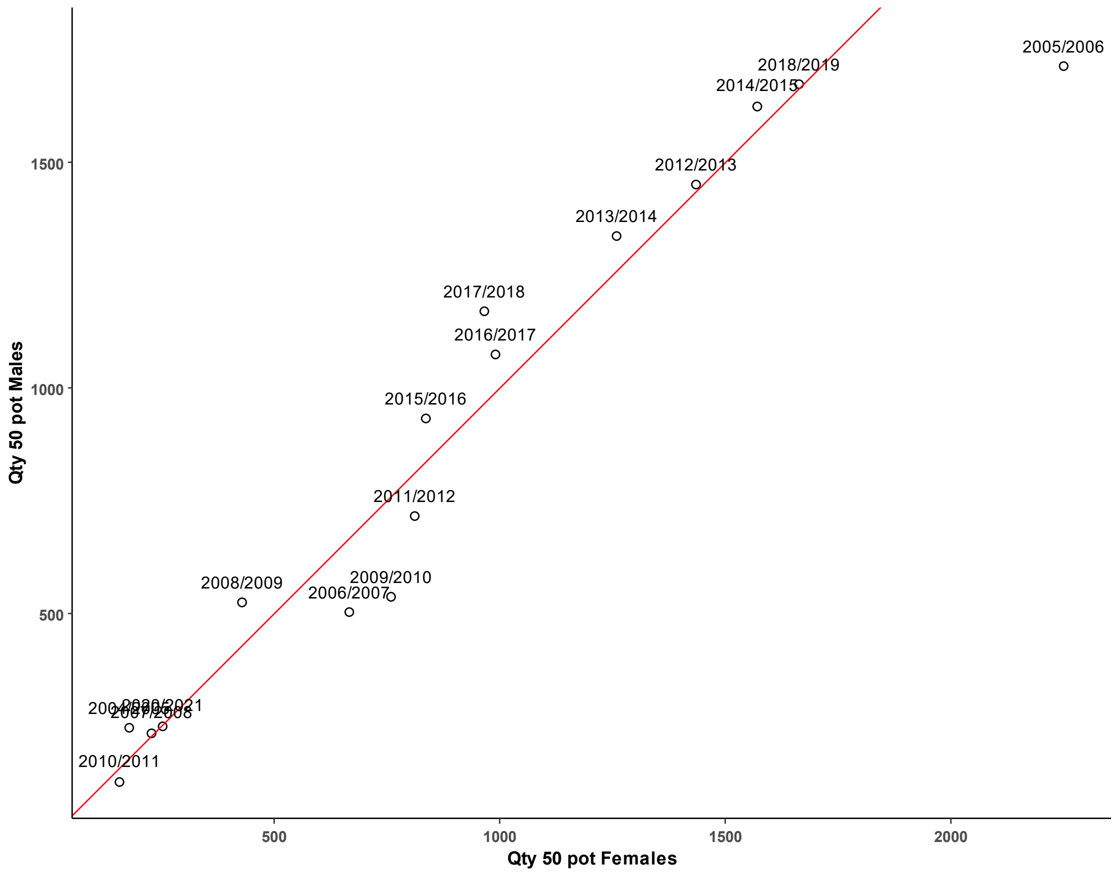

Figure 3.1 Ratio of Male to Female Octopi for 50-pot samples. Note: There was no 50-pot sample data recorded in 2019/20.

Catch and effort

The total catch of Pale Octopus in the TOF in 2020/21 was 154 t (Figure 3.2). This year's catch represents the highest catch value in the history of the TOF. This is the first occurrence of three consecutive years with catches greater than 100 t occurring within the TOF. Catches in the fishery have varied between ~60 t and ~130 t since 2003/04. This season's record high catch, following two seasons of relatively high catch and despite a slight decline in effort, suggests favourable environmental conditions that led to strong recruitment and/or increased vulnerability to fishing gear, or improved fishing efficiency.

Pale octopus catches in the TOF vary seasonally (Figure 3.3). During most years, catches peak in autumn. This was the case in 2020/21, with 35.5% of total catch occurring during autumn. Winter constituted 25.5% of total catch, followed by spring (21.2%) and summer (18%).

Fishing effort in 2020/21 was 311,500 pot-lifts, a slight decrease from 2019/20 effort of 327,000 pot-lifts (Figure 3.4). Effort was concentrated in autumn (34.8% of total effort), which was largely consistent with the previous three years (Figure 3.5). However, effort in the eastern region of the fishery declined to negligible levels in recent years (Figure 3.10).

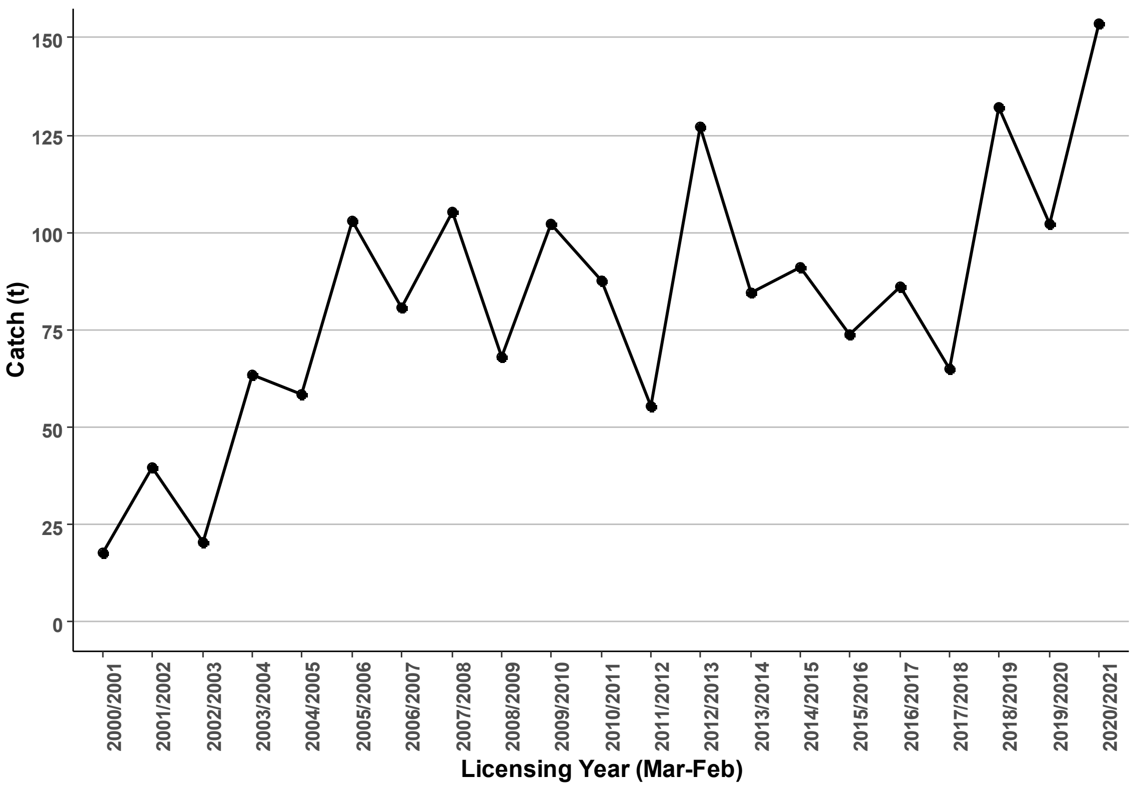

Figure 3.2 Total catches of Pale Octopus in the Tasmanian Octopus Fishery since 2000/01.

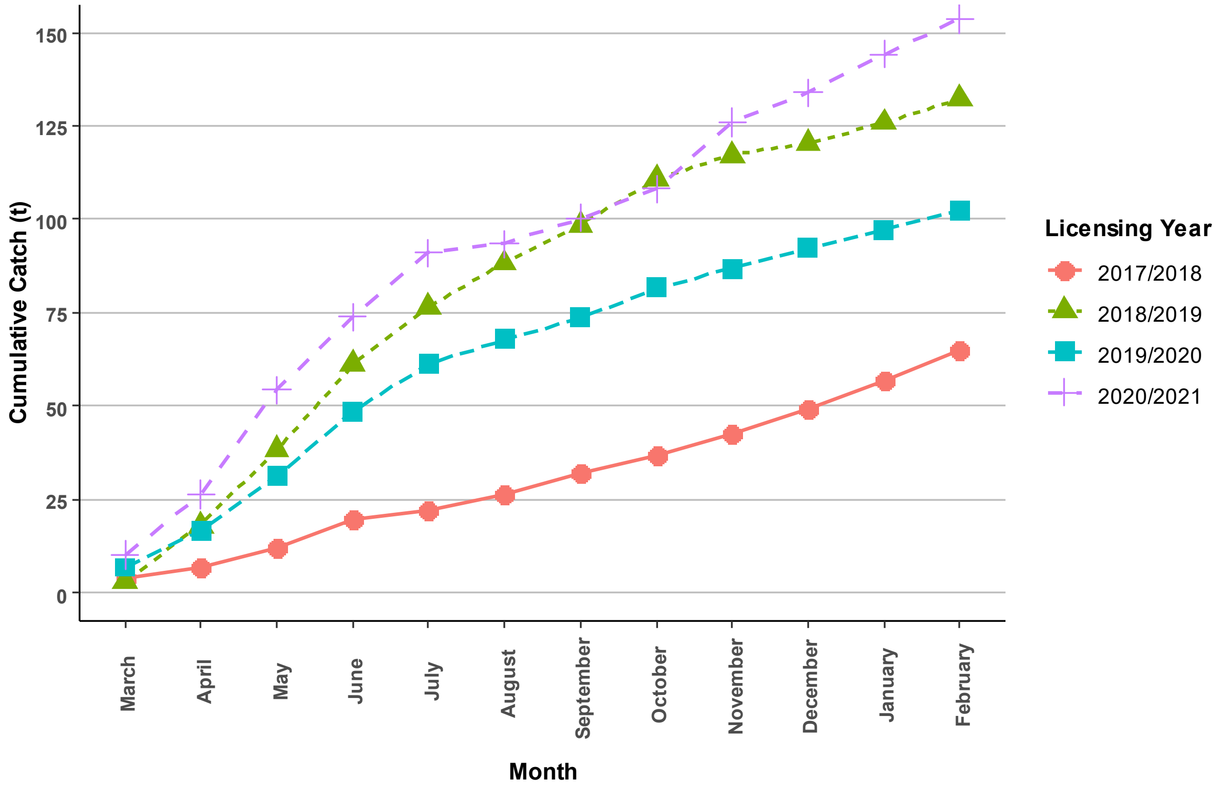

Figure 3.3 Cumulative catches of Pale Octopus landed over the last four licensing years showing seasonal trends.

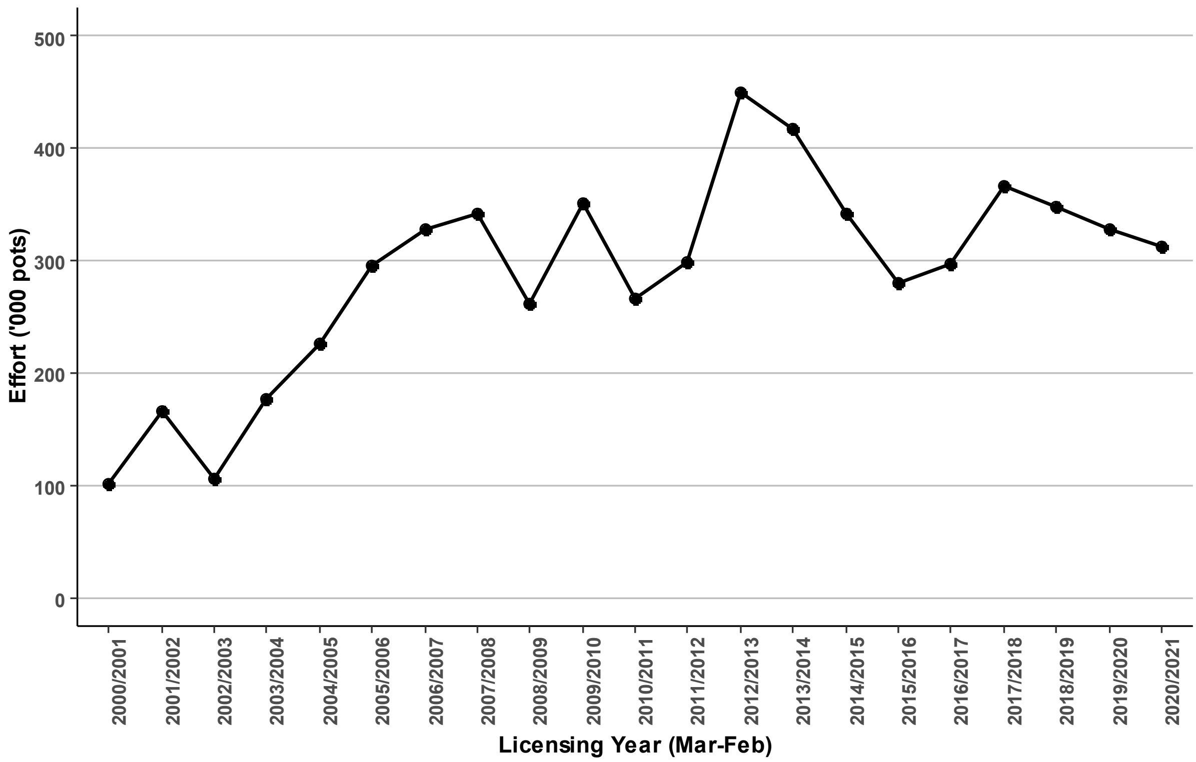

Figure 3.4 Effort (thousands of pot-lifts) for Pale Octopus in the Tasmanian Octopus Fishery since 2000/01.

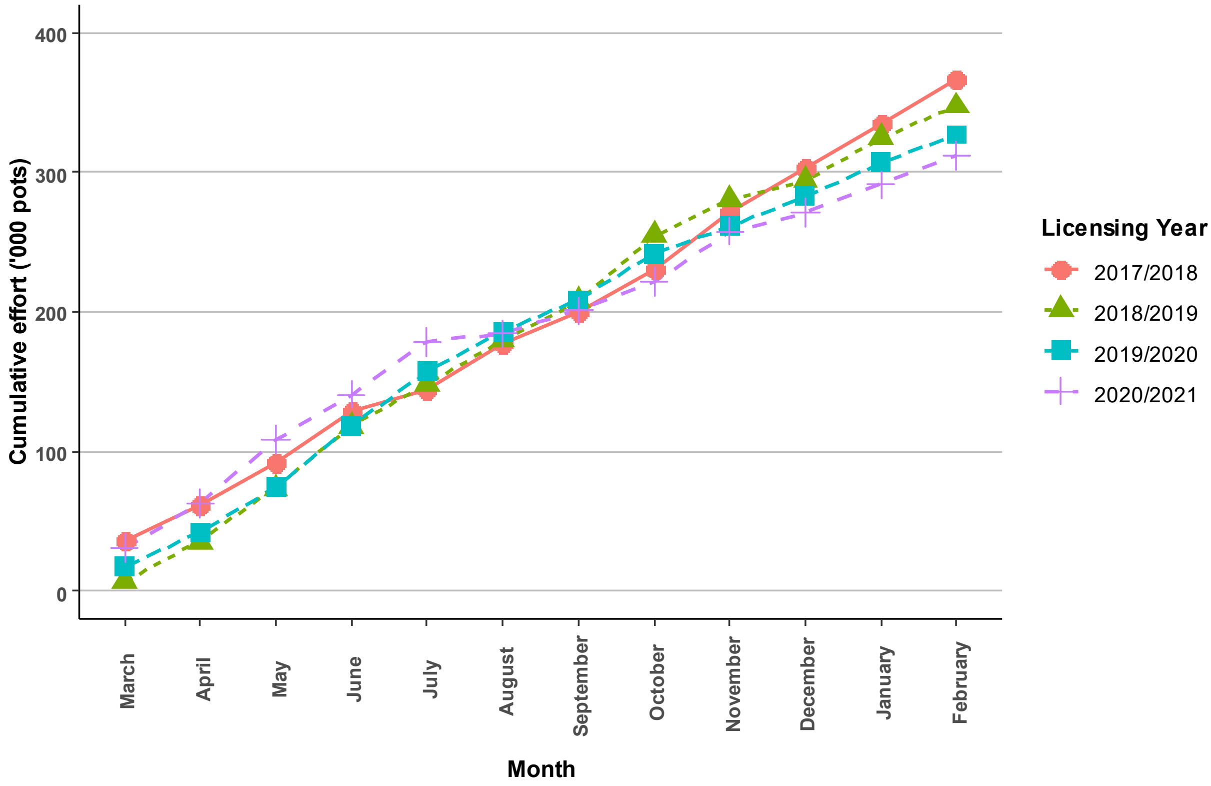

Figure 3.5 Cumulative effort (thousands of pot-lifts) of Pale Octopus landed over the last four licensing years showing seasonal trends.

Catch per unit effort

The final Generalised Linear Model (GLM) used to test variation in catch per unit effort (CPUE) included the terms CPUE ~ Licensing Year + Month + Fishing Block. Catch and effort data for many fishing blocks across multiple years were absent or insufficient for testing the interaction between Licensing Year and Fishing Block (i.e., for testing whether CPUE distribution among fishing blocks varied among licensing years). Standardised catch per unit effort (CPUE) varied significantly among licensing years and months, with less significant variation among fishing blocks (see Appendix Table A1 for model coefficients).

The licensing year 2004/05 was chosen as a reference year for CPUE, in correspondence with the commencement of the 50-pot sampling programme (Figure 3.6). The standardised catch rate for the total commercial catch from logbooks fluctuated at around 60% of the reference year from 2011/12 to 2017/18. In 2018/19, a notable increase in CPUE occurred, reaching 93% of the reference year. Following a slight decline in 2019/20, the highest CPUE on record occurred in 2020/21, at 132% of the reference year. Estimates of CPUE from the 50-pot sampling programme also remained relatively stable from 2011/12 to 2017/18, showing an increase in 2018/19 similar to the logbook data. Data from the 50-pot sampling programme were not supplied for the 2019/20 season, however 2020/21 data showed the highest CPUE on record, at 156% of the reference year. Inter-annual CPUE variability in the Stanley region (the most consistently fished region) reflects CPUE variability across the entire fishery (Figure 3.7).

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 and Boletzky 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 presumably highly structured (Doubleday et al. 2008). Genetic studies corroborate this assumption, 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.

In 2020/21, as with previous assessments (Figure 3.8), CPUE peaked in autumn and winter (March-August, Figure 3.9), coinciding with the brooding peak for the species (Leporati et al. 2009).

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. Although research pot sampling data are an important source of information to assess trends in CPUE in addition to logbook derived CPUE trends alone, the same problems remain for these data, too.

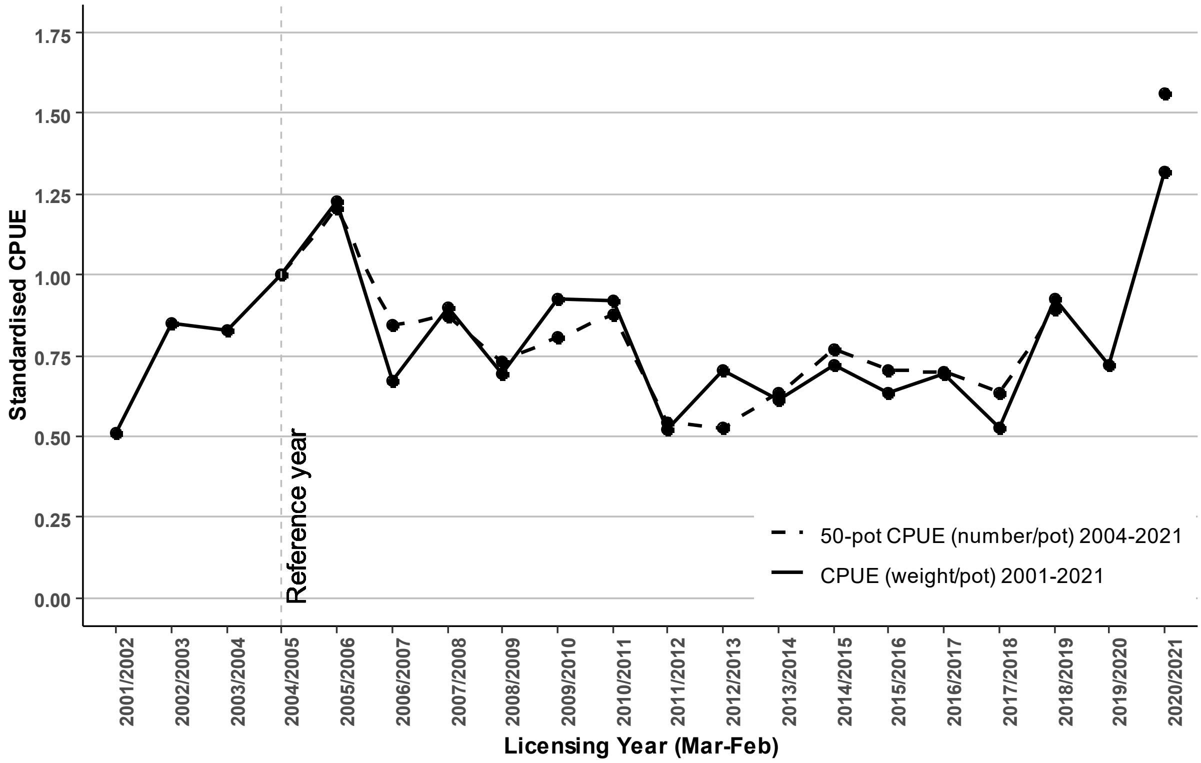

Figure 3.6 Pale Octopus standardised catch per unit effort (CPUE) relative to 2004/05 levels in weight per pot (total commercial) and in number per pot (50-pot sampling). Note that 50-pot sampling data were not collected in 2019/20.

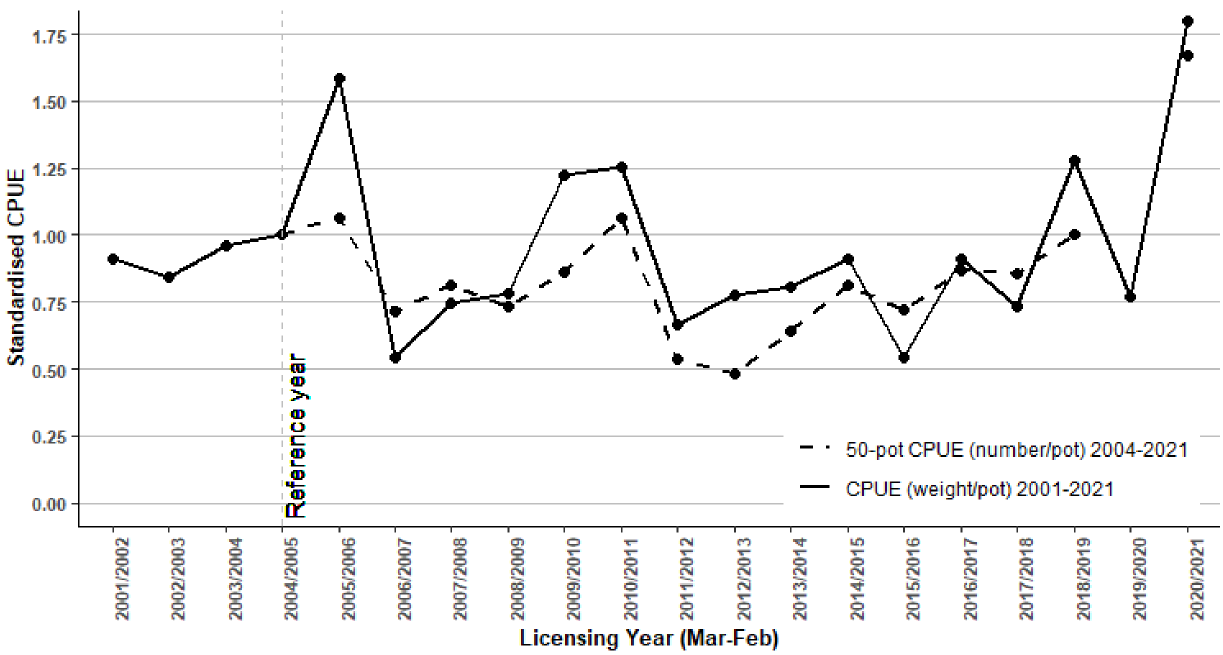

Figure 3.7 Pale Octopus standardised catch per unit effort (CPUE) for the Stanley region relative to 2004/05 levels in weight per pot (total commercial) and in number per pot (50-pot sampling). Note that 50-pot sampling data were not collected in 2019/20. Insufficient data were available to conduct similar analyses for other regions within the TOF.

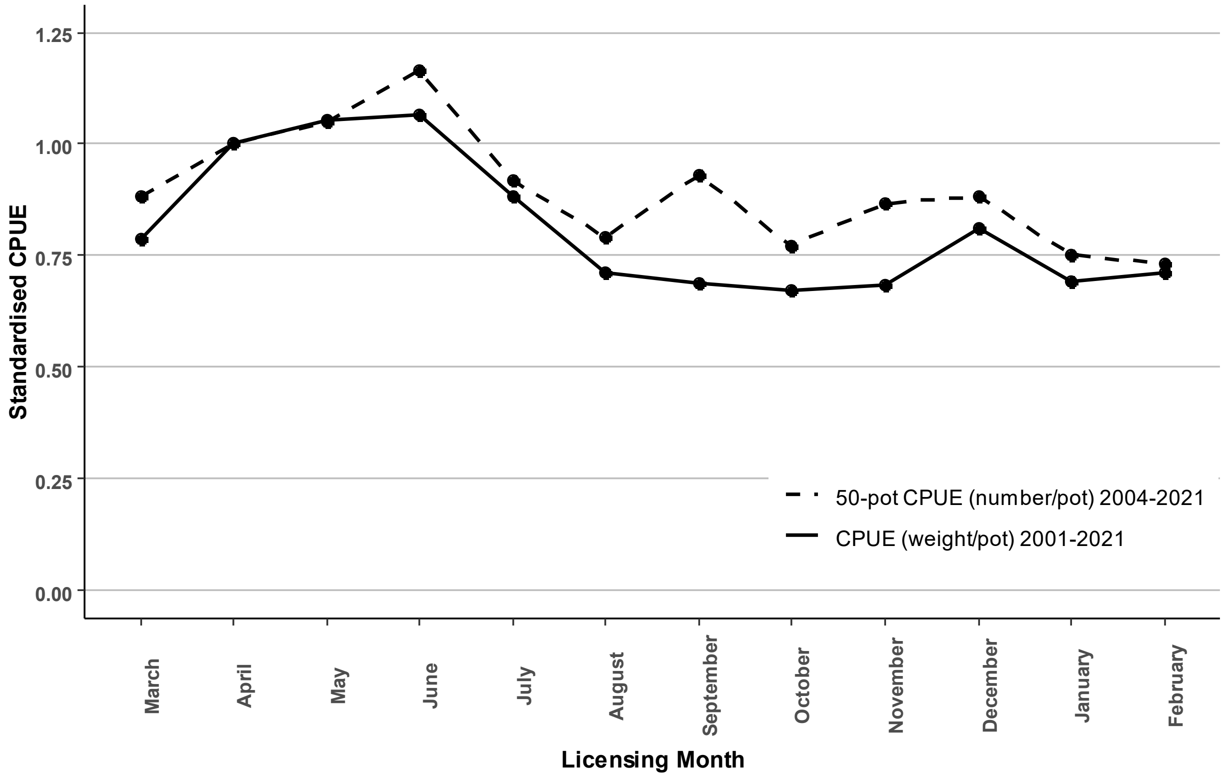

Figure 3.8 Pale Octopus standardised catch per unit effort (CPUE) relative to March levels in weight per pot (total commercial) and in number per pot (50-pot sampling).

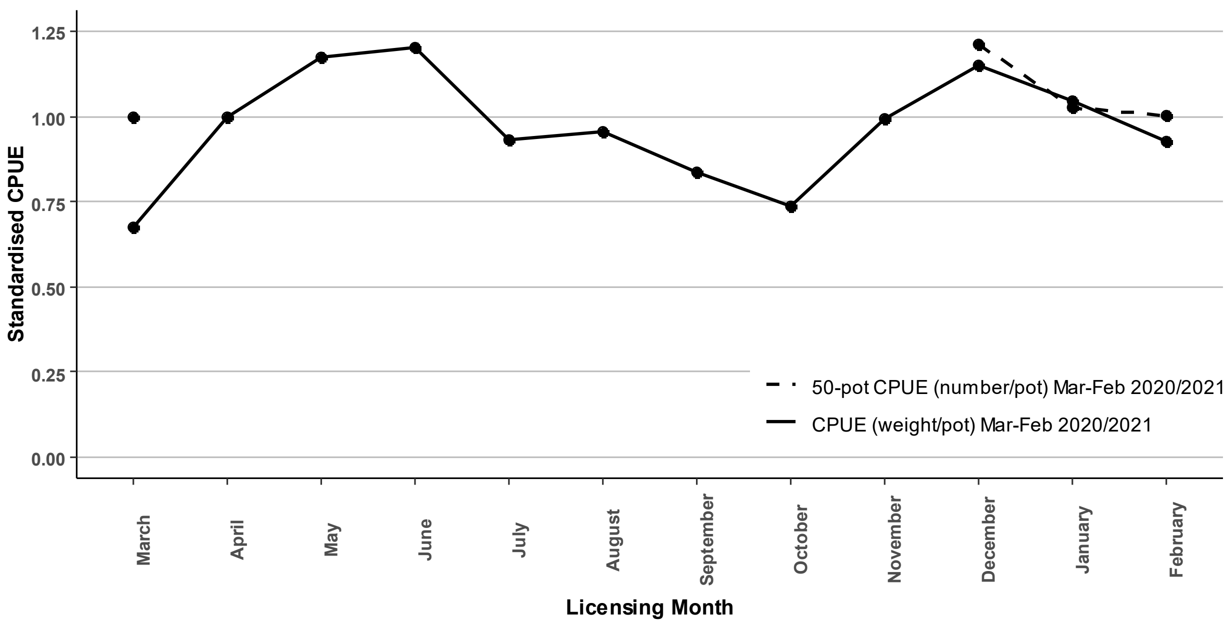

Figure 3.9 Pale Octopus standardised catch per unit effort (CPUE) relative to March levels in weight per pot (total commercial) and in number per pot (50-pot sampling) for the licencing year 2020/2021.

Commercial Pale Octopus catch from developmental fishing permits

The fishing permits, allowing access along the east coast below latitude 41° 0' 00'' South, resulted in a total catch of 4.1 t of Pale Octopus from a total of 24,100 pot-lifts.

Local patterns in Pale Octopus catch, effort, and CPUE

Notably, all results based on total catch and effort data presented above implicitly assumed that fishing activities are comparable over the period from the reference year in 2004/05 to the current assessment year in 2020/21. This assumption does not hold given that both fishing effort and catches have expanded to previously unexploited areas. The 2019/20 TOF assessment report (Krueck et al. 2021) highlighted shifts in effort and catch away from 'traditional' octopus fishing grounds towards newer areas – most notably away from historically productive fishing blocks in eastern Bass Strait and around Flinders Island to blocks east of King Island. These analyses suggested that fishing activities have changed considerably since the reference year in 2004/05 and that localised depletion of octopus biomass is a possible matter of concern in multiple traditionally fished areas.

In 2020/21, an exceptionally high concentration of fishing effort and catch was evident again in two offshore fishing blocks east of King Island (3D3 and 3D4; see Figure 1.1 for block numbers) and one inshore fishing block adjacent to Stanley (4E3) (Figure 3.10). The two blocks east of King Island together accounted for 52.8% of total catch and 48.8% of total effort within the fishery in 2020/21. The block adjacent to Stanley accounted for 20% of total catch and 18.3% of total effort in 2020/21. This concentration of effort and catch is spatially similar to that observed in 2019/20 – during that season the area east of King Island also accounted for the majority of catch and effort.

Such a high local concentration of effort and catch could be unsustainable and might indicate a lack of productivity elsewhere. In contrast to increases in these three blocks, declines were apparent in several traditionally fished blocks, notably in the eastern Bass Strait (Figure 3.10). However, with only two vessels in operation, fleet behaviour is also likely to be influenced by individual decisions that may be independent of catch rates.

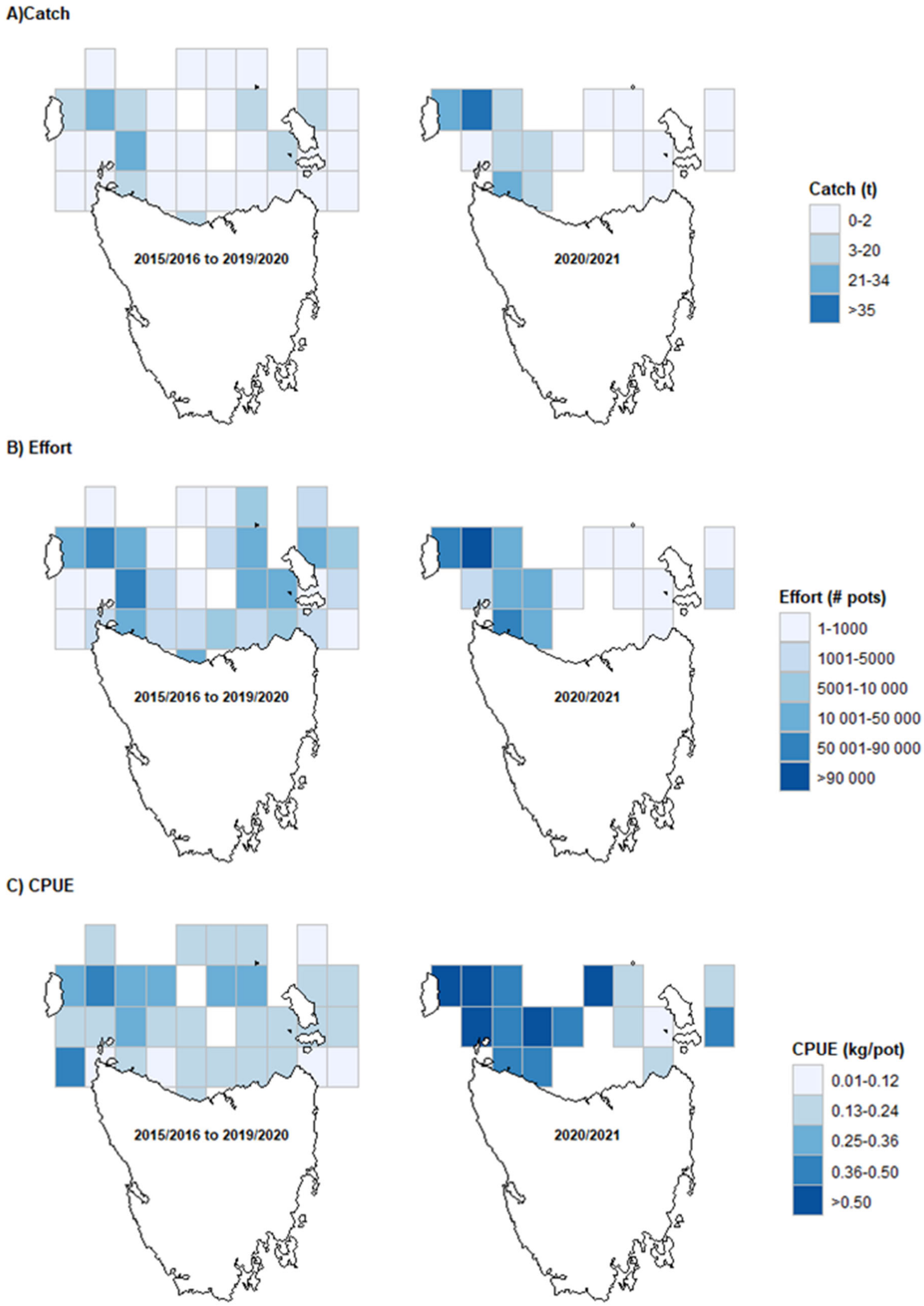

Figure 3.10 (A) Catch, (B) effort (pot lifts) and (C) nominal CPUE averaged over the last 5 years (left) and for the current licensing year 2020/21 (right).

Pale Octopus Catch-only results

CMSY results based on the assumption of "high" resilience showed clear regional variation within the TOF.

Stanley Region

CMSY results suggested that Pale Octopus biomass in the Stanley region remains high, presumably above 50% of unfished levels (green line, Figure 3.11), which is a commonly suggested target reference point.

CMSY simulations further indicated that the maximum sustainable yield (MSY) of Pale Octopus in the Stanley region is approximately 62 t, with a lower 95% confidence interval of approximately 41 t (Figure 3.12). The catch in this region in 2020/21 was close to the estimated MSY, but has notably exceeded this level in the past, specifically if considering lower confidence limits (Figure 3.12). Fishing mortality in 2020/21 was below the level of mortality that would sustain biomass at 50% of unfished levels (Figure 3.13).

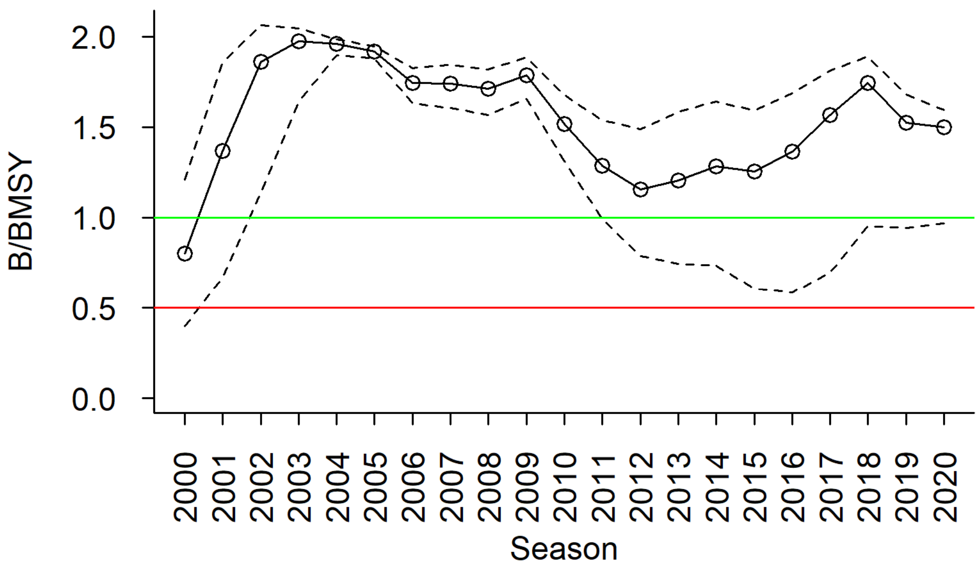

Figure 3.11 Trend in estimated depletion (biomass divided by biomass at maximum sustainable yield (MSY), including 95% confidence intervals) in the Stanley region. Results assume "high" resilience. The green line marks biomass delivering MSY (50% of unfished levels), and the red line marks a possible limit reference point of 50% of the biomass delivering MSY (25% of unfished levels).

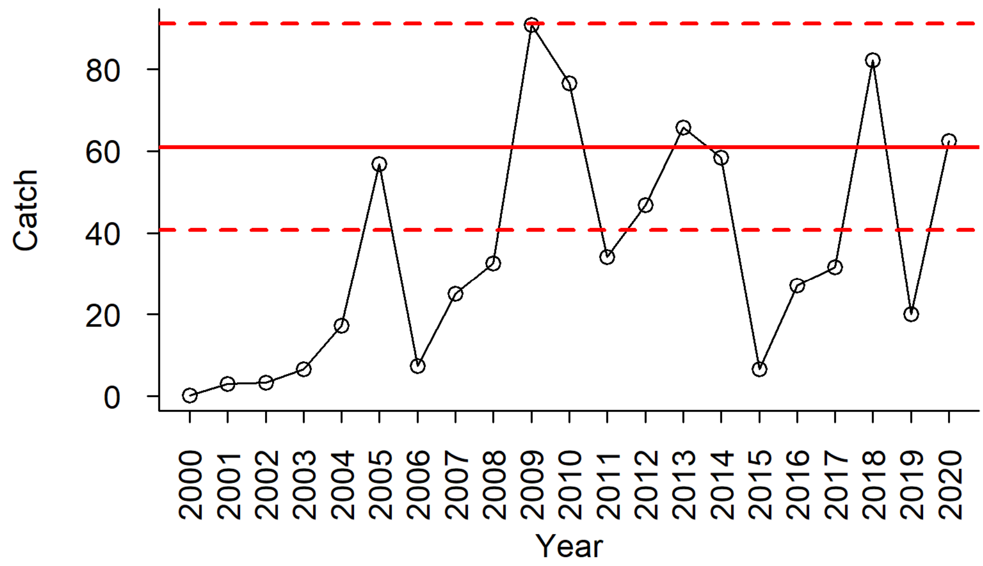

Figure 3.12 Trends in catch from the Stanley region relative to estimated maximum sustainable yield (MSY). Results assume “high” resilience. The solid red line represents MSY; dotted red lines represent 95% confidence intervals.

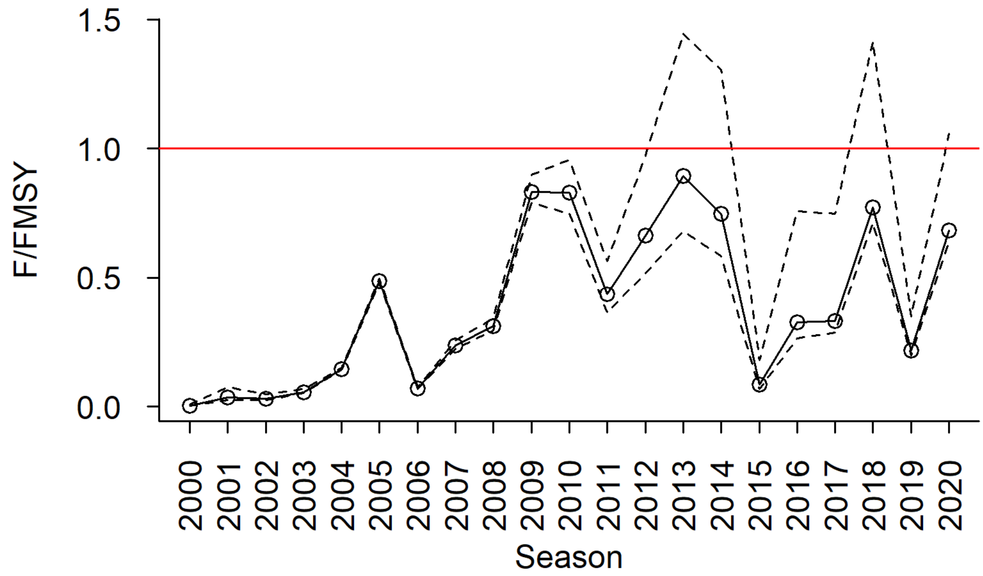

Figure 3.13 Trend in estimated fishing mortality (fishing mortality divided by fishing mortality at maximum sustainable yield (MSY), including 95% confidence intervals) in the Stanley region. Results assume “high” resilience. The red line marks fishing mortality at MSY.

Flinders Island West Region

CMSY results suggested that Pale Octopus biomass in the Flinders Island West region may have been depleting below commonly stated target levels (50% of unfished biomass; green line, Figure 3.14) from 2014/15 and below the commonly suggested limit reference point (25% of unfished biomass; red line, Figure 3.14) from 2018/19.

CMSY simulations further indicated that the maximum sustainable yield (MSY) of Pale Octopus in the Flinders Island West region is approximately 22 t, with a lower 95% confidence interval of approximately 20 t (Figure 3.15). The catch for this region in 2020/21 was well below the estimated MSY (Figure 3.15) but has substantially exceeded this level in the past. Fishing mortality in 2020/21 was below the level of mortality that would sustain biomass at 50% of unfished levels (Figure 3.16). However, narrow confidence intervals in and Figure 3.15 and Figure 3.16 suggest that CMSY simulations under the assumption of "high" resilience data did not produce many viable scenarios.

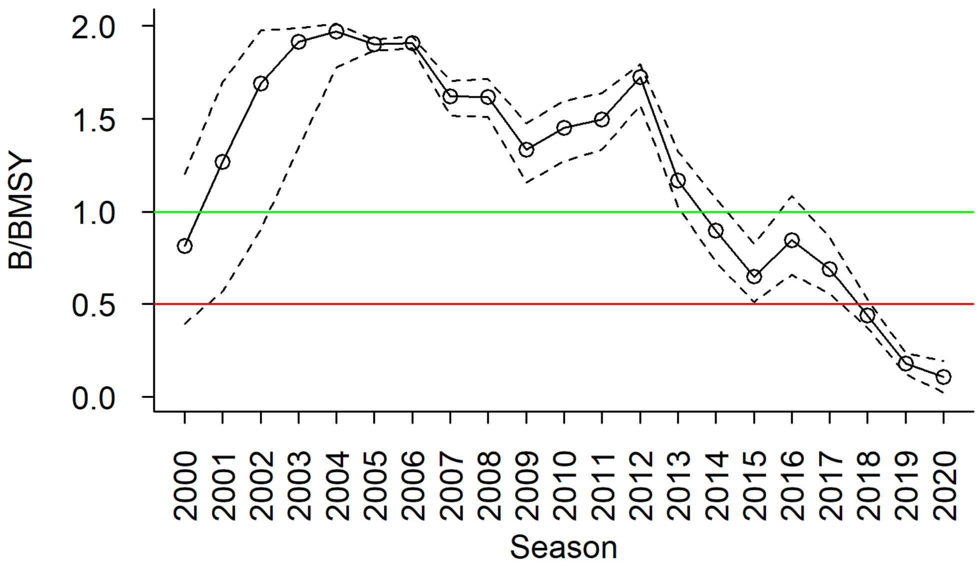

Figure 3.14 Trend in estimated depletion (biomass divided by biomass at maximum sustainable yield (MSY), including 95% confidence intervals) in the Flinders Island West region. Results assume "high" resilience. The green line marks biomass delivering MSY (50% of unfished levels), and the red line marks a limit reference point of 50% of biomass delivering MSY (25% of unfished levels).

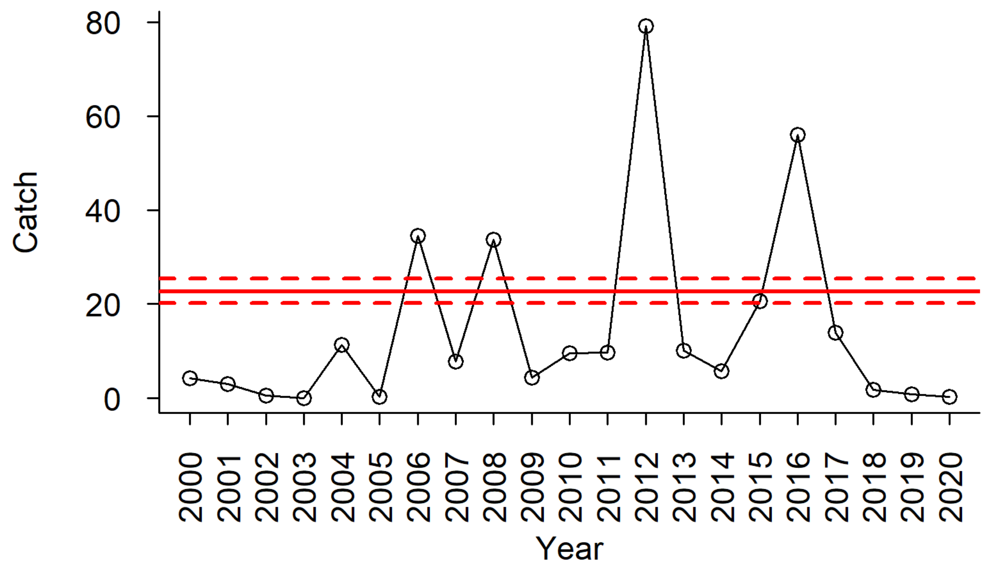

Figure 3.15 Trends in catch from the Flinders Island West region relative to estimated maximum sustainable yield (MSY). Results assume “high” resilience. The solid red line represents MSY; dotted red lines represent 95% confidence intervals.

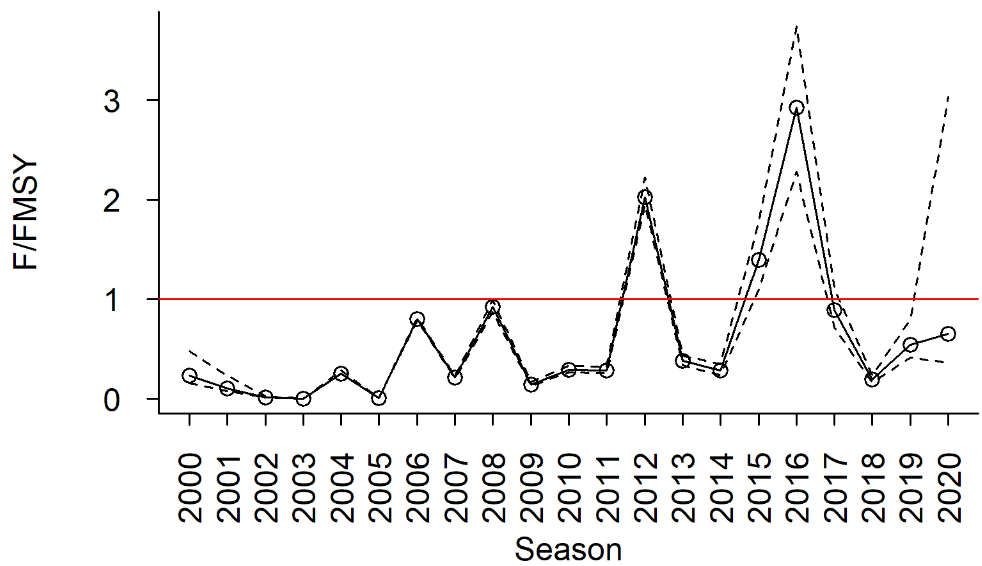

Figure 3.16 Trend in estimated fishing mortality (fishing mortality divided by fishing mortality at maximum sustainable yield (MSY), including 95% confidence intervals) in the Flinders Island West region. Results assume “high” resilience. The red line marks fishing mortality at MSY.

Flinders Island East Region

CMSY results suggest that Pale Octopus biomass in the Flinders Island East region may have been depleting below commonly stated target levels (50% of unfished biomass; green line, Figure 3.17) from 2009/10 and below the commonly suggested limit reference point (25% of unfished biomass; red line, Figure 3.17) from 2010/11.

CMSY simulations further indicated that the maximum sustainable yield (MSY) of Pale Octopus in the Flinders Island East region is approximately 17 t, with a lower 95% confidence interval of approximately 16 t (Figure 3.18). The catch for this region in 2020/21 was well below MSY (Figure 3.18), but fishing mortality was above the level of mortality that would sustain biomass at 50% of unfished levels for the first time since 2017/18 (Figure 3.19). However, the narrow confidence intervals in Figure 3.18 and Figure 3.19 suggest the CMSY simulations under the assumption of “high” resilience did not produce many viable scenarios.

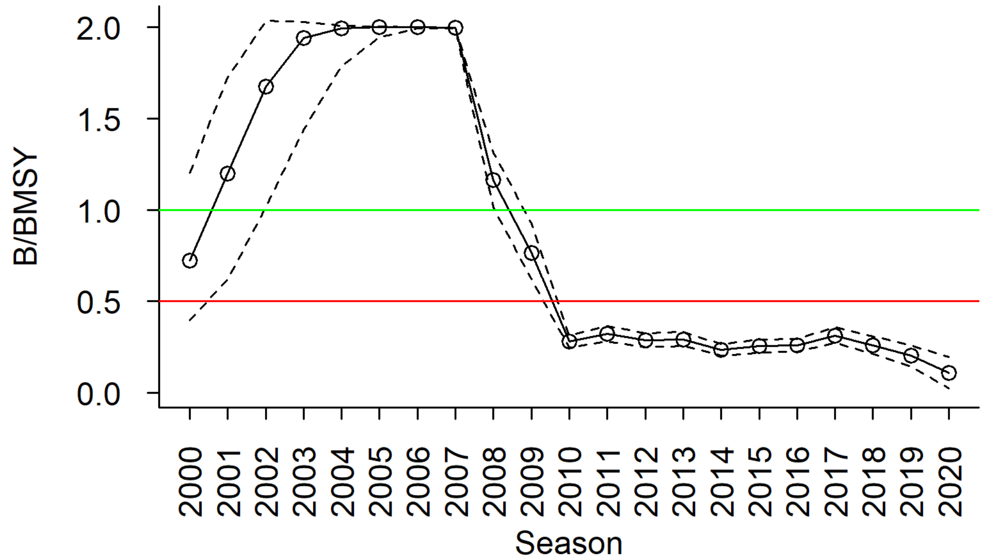

Figure 3.17 Trend in estimated depletion (biomass divided by biomass at maximum sustainable yield (MSY), including 95% confidence intervals) in the Flinders Island East region. Results assume “high” resilience. The green line marks biomass delivering MSY (50% of unfished levels), and the red line marks a limit reference point of 50% of biomass delivering MSY (25% of unfished levels).

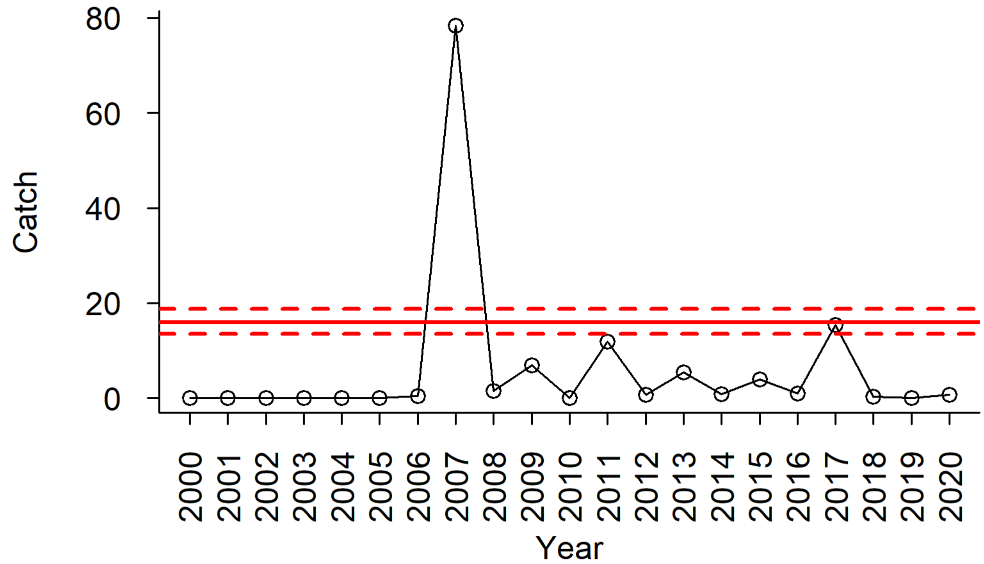

Figure 3.18 Trends in catch from the Flinders Island East region relative to estimated maximum sustainable yield (MSY). Results assume “high” resilience. The solid red line represents MSY; dotted red lines represent 95% confidence intervals.

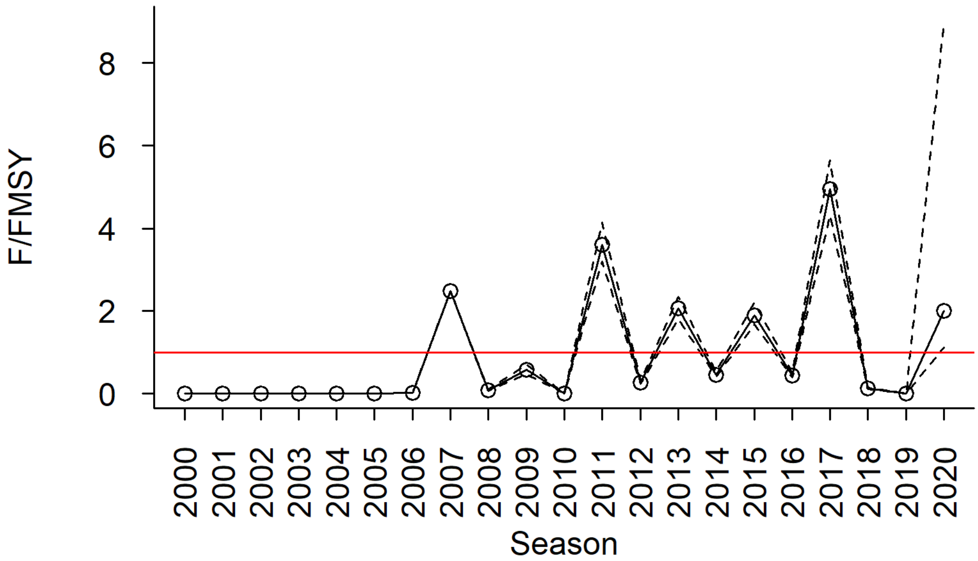

Figure 3.19 Trend in estimated fishing mortality (fishing mortality divided by fishing mortality at maximum sustainable yield (MSY), including 95% confidence intervals) in the Flinders Island East region. Results assume "high" resilience. The red line marks fishing mortality at MSY.

Pale Octopus Risk-Based Framework

The Pale Octopus Fishery within the TOF scored < 60 in the Marine Stewardship Council – Risk Based Framework (MSC-RBF) analysis, failing assessment with high risk of stock damage (Table 3.1). 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 the stock susceptible to 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, and the fact that fishing effort is concentrated in peak brooding season (autumn).

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 effectively caught 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 3.1 Risk-Based Framework scoring of the Pale Octopus fishery for the consequence analysis, productivity susceptibility analysis, and the combined total.

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	**< 60**	
Total RBF Score	**< 60**	

Māori and Gloomy Octopus catch

Total catches of Māori and Gloomy Octopus (mostly Māori Octopus) in Tasmania have fluctuated around 10 – 20 t since 2002/03 (Figure 3.20). Highest catches in the past can be attributed to the targeted Māori Octopus fishery in Eaglehawk Bay. One anomalously high catch in the Rock Lobster fishery matches the first year of required reporting within that fishery (2000/01, see Figure 3.20).

In recent years, catches have been dominated by the Rock Lobster fishery, with the exception of 2017/18, when the TOF appeared to target Gloomy Octopus near Flinders Island. Total commercial catch in 2020/21 across Tasmania of both Māori and Gloomy Octopus combined was 17.5 t, comprising 9.3 t from the Rock Lobster fishery, 1.0 t from the Scalefish fishery, 6.9 t from the TOF and east coast developmental permits for Pale Octopus, and 0.4 t from the Eaglehawk Bay Māori Octopus fishery.

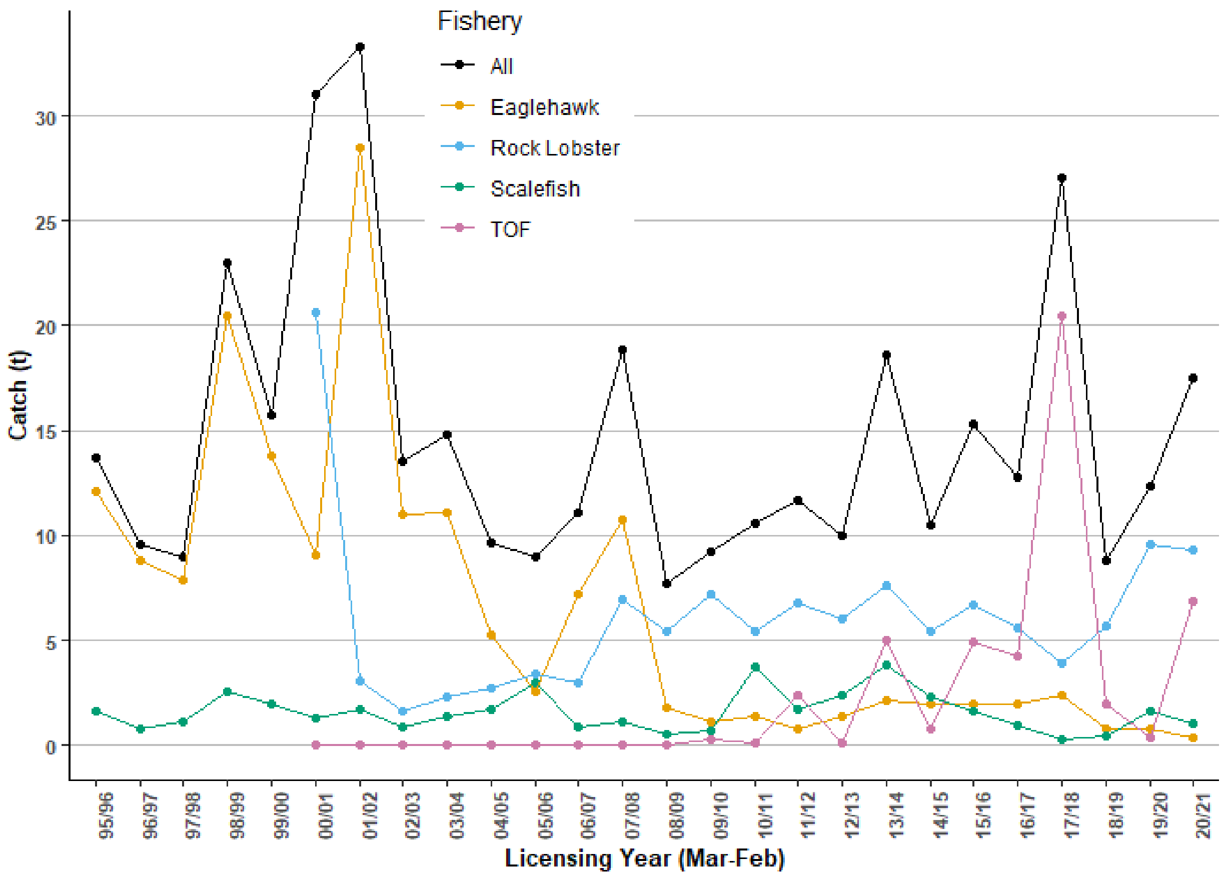

Figure 3.20 Total catches of octopus across all fisheries since octopus returns were first reported in each fishery. Excludes Pale Octopus caught in the TOF under fishing licence (octopus) and Pale Octopus caught under the east coast developmental permits for this species.

Māori and Gloomy Octopus catch from TOF and developmental permits

Total Māori Octopus catch from fisheries targeting Pale Octopus using unbaited traps – the TOF and the east coast developmental fishery – peaked at 6.6 t in 2020/21, comprising 6.3 t from the TOF and 0.3 t from the east coast (Figure 3.21). Previous annual catches fluctuated between 0-2 t.

Total Gloomy Octopus catch from these fisheries in 2020/21 was 0.3 t, comprising 13 kg from the east coast and the remainder from the TOF (Figure 3.21). The highest catch from these fisheries was 20.8 t in 2017/18, when the TOF appeared to target this species around Flinders Island. Following this peak, two years of zero catches of Gloomy Octopus were reported in both 2018/19 and 2019/20.

Both species were considered to be at negligible risk from unbaited trap fishing in an 2012/13 Ecological Risk Assessment (ERA) due to their low catches and biological traits including their reproductive biology (Bell et al. 2016). In particular, both species have a strategy of large number of eggs and planktonic larval dispersal which contrasts with the holobenthic strategy of Pale Octopus.

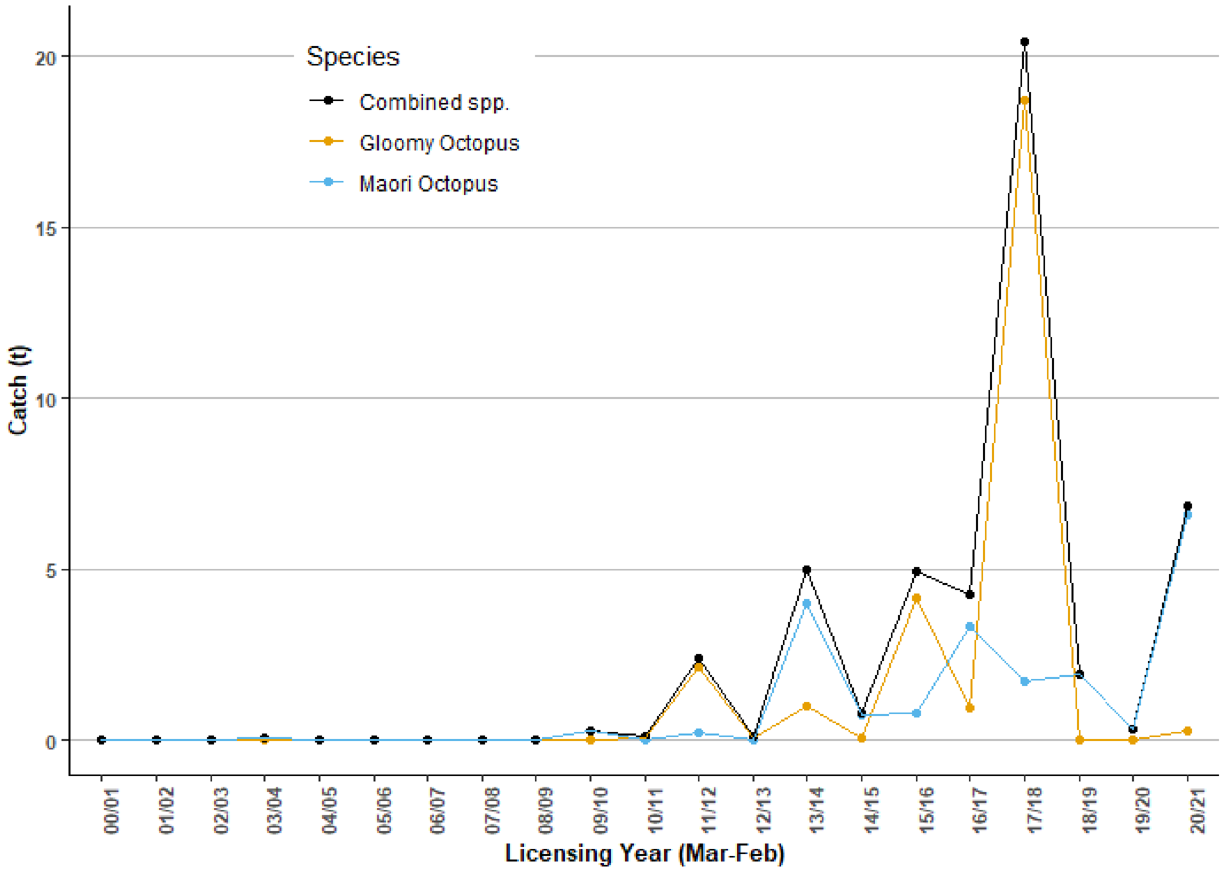

Figure 3.21 Total catches of Māori Octopus (*Macroctopus maorum*) and Gloomy Octopus (*Octopus tetricus)* from unbaited traps in the TOF and east coast developmental fishery for Pale Octopus since 2000/01.

Octopus catch from the Scalefish Fishery

Annual octopus catch within the Scalefish fishery has remained below 4 t since 1995/96 (Figure 3.22). Spear and hand collection are the main gear with which octopus are landed in this fishery, however a diversity of gear types and operations are responsible for octopus landings. In 2020/21, total octopus catch from this fishery was 1.0 t, comprising 0.9 t Māori Octopus, 0.02 t 'Octopus, unidentified' (presumable mostly Māori Octopus), 0.04 t Gloomy Octopus, and 0.04 Pale Octopus.

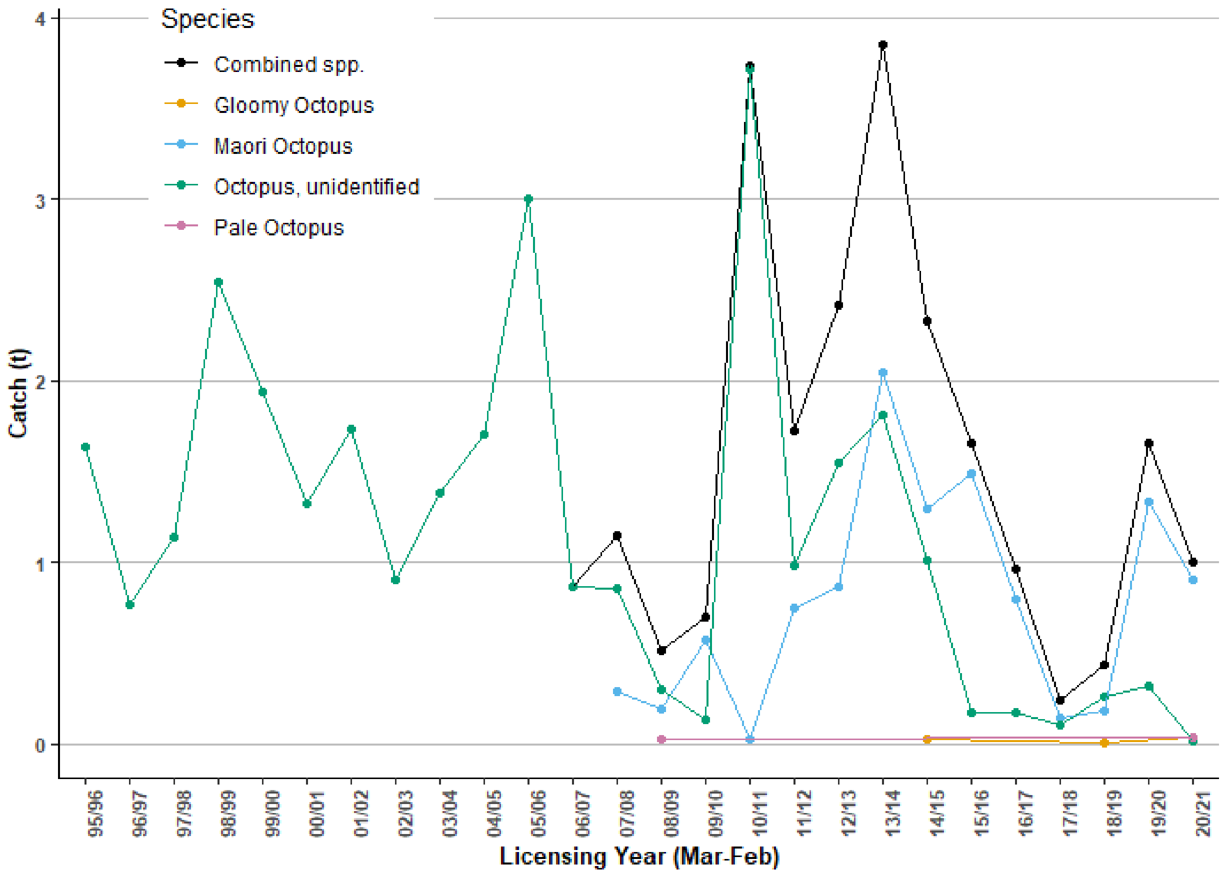

Figure 3.22 Total catches of octopus from diverse operations within the Scalefish fishery since 1995/96.

Octopus catch from the Rock Lobster Fishery

Octopus catch was not required to be reported by the Rock Lobster fishery before 2000/01. Since then, annual retained, landed octopus catch within this fishery has remained below 10 t (Figure 3.23). An outstanding exception is the first reporting year, 2000/01, when reported catch was 20.6 t. In 2020/21, octopus catch from the Rock Lobster fishery (presumably mostly Māori Octopus) was 9.3 t.

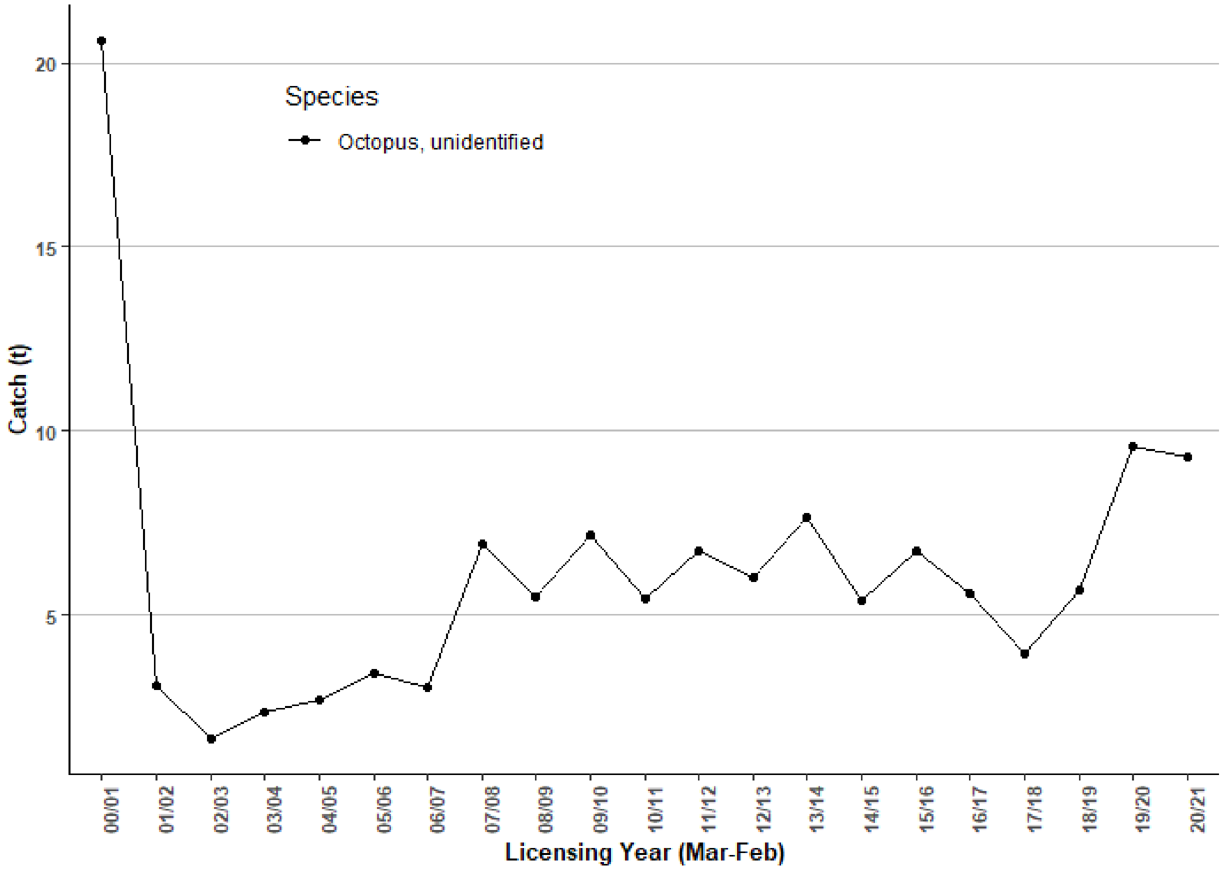

Figure 3.23 Total catches of octopus from the Rock Lobster fishery since 2000/01.

Octopus catch from the Eaglehawk Bay Māori Octopus Fishery

Annual octopus catch within the Eaglehawk Bay fishery fluctuated around 10 – 20 t until 2003/04 (Figure 3.24). There was a notable decline in 2008/09, preceding a ban on the use of barrier nets in this fishery in late 2009. Fishers also observed an increase in seal densities in the bay over time, and attributed catch declines to increased octopus predation by seals. Catch has remained below 3 t since 2008/09. In 2020/21, catch was 0.4 t (all Māori Octopus), following two seasons with catch < 2 t.

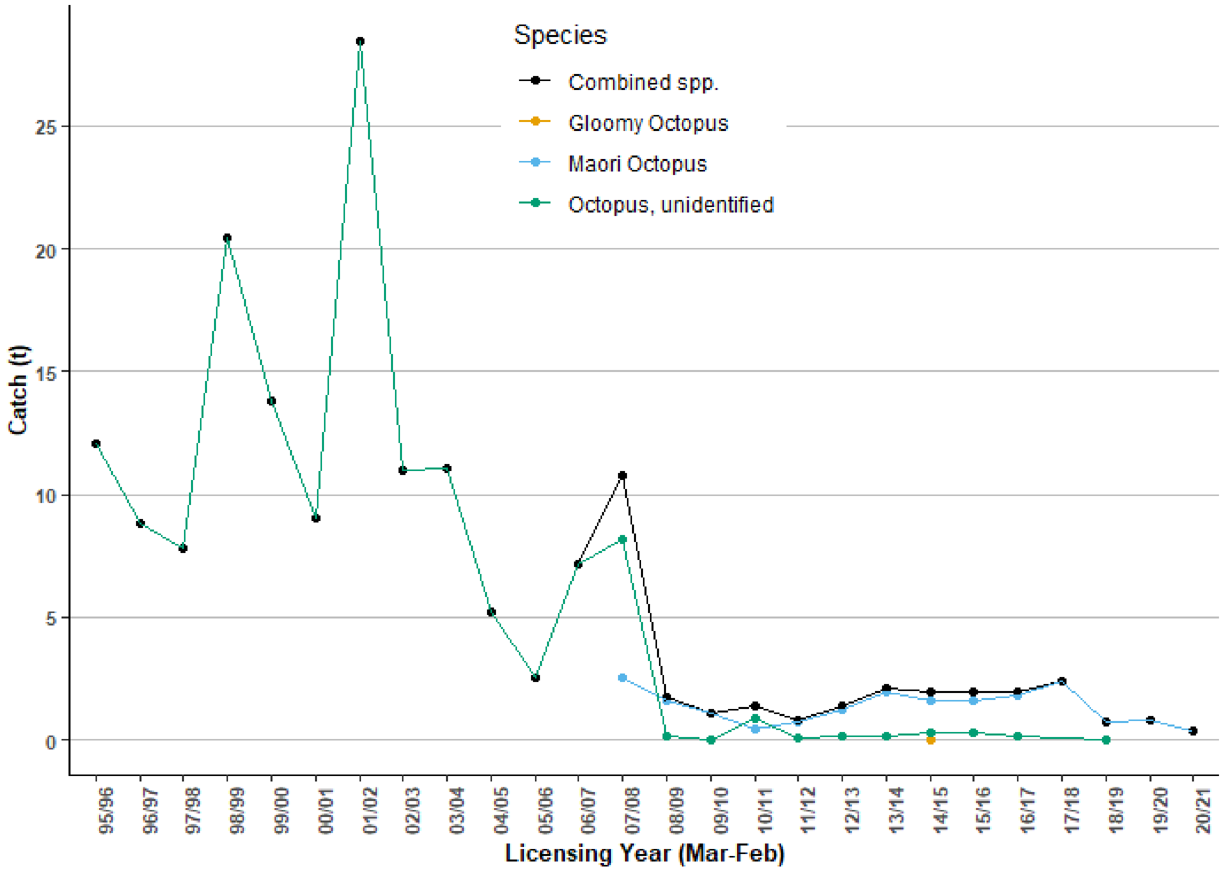

Figure 3.24 Total catches of octopus from the Eaglehawk Bay targeted Māori Octopus fishery since 1995/96.

Distribution of all octopus catch in Tasmanian waters

The geographic distribution of annual octopus catch per species was illustrated by averaging catch within fishing blocks over the last five years (2016/17 to 2020/21), including data from all fisheries – the TOF, east coast developmental fishery for Pale Octopus, the Rock Lobster fishery, the Scalefish fishery, and the Eaglehawk Bay Māori Octopus fishery (Figure 3.25). Pale Octopus catch was almost exclusively taken from the Bass Strait. Gloomy Octopus was mostly taken from the eastern Bass Strait around Flinders Island. Landings identified as Māori Octopus were mostly from the western Bass Strait and southeast coast, and 'Octopus, unidentified' (presumably mostly Māori Octopus) were taken from most parts of the Tasmania's coast, with notably less catch in the central Bass Strait/north coast area.

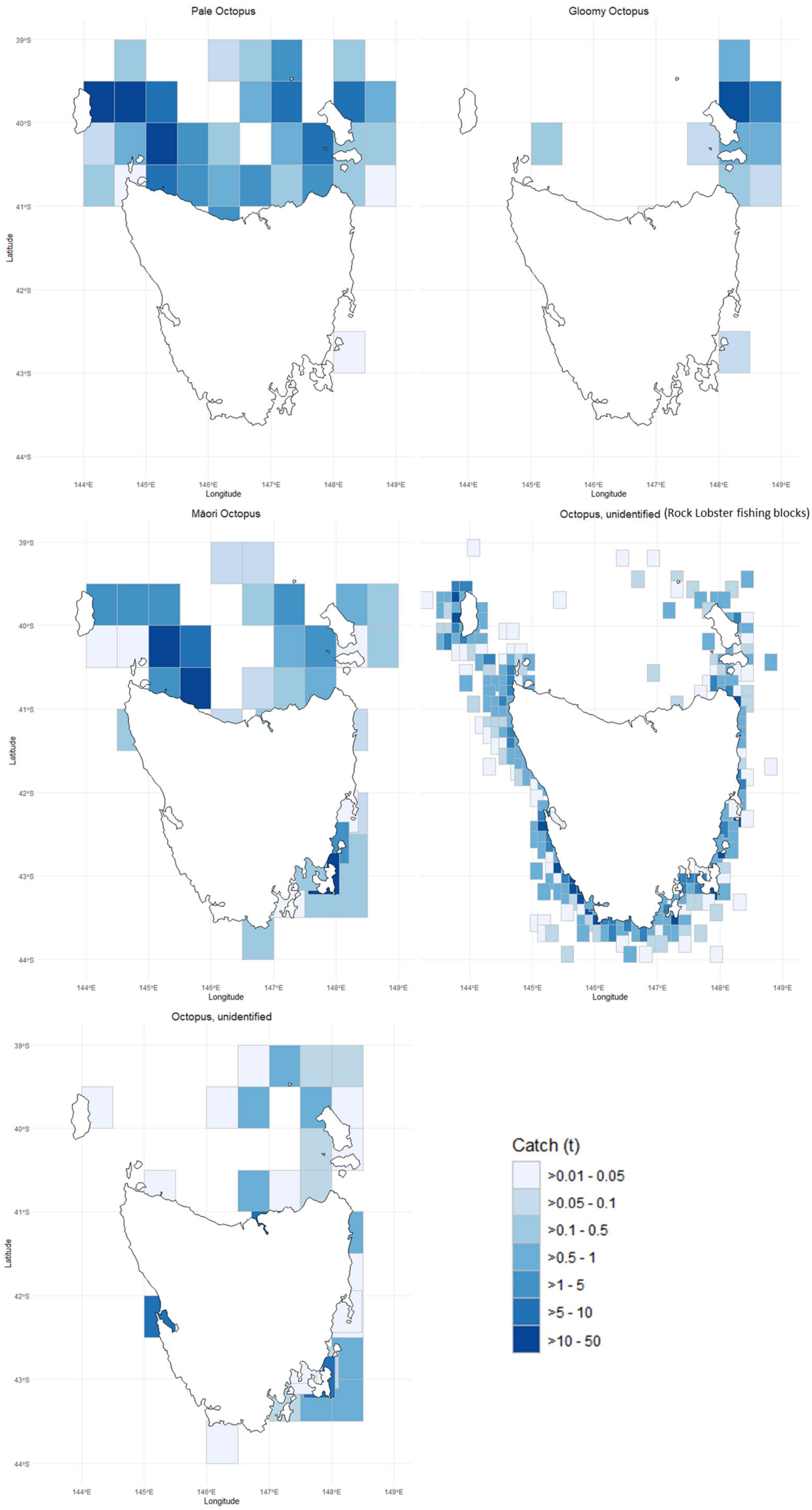

Figure 3.25 Distribution of annual catch per octopus species by fishing block, averaged over last five years (2016/17 to 2020/21). Note: Rock Lobster fishing blocks are smaller than the other fisheries, so data are presented separately.

Māori and Gloomy Octopus Risk-Based Framework

The Māori and Gloomy Octopus fisheries in Tasmania both scored 60 – 80 in the Marine Stewardship Council – Risk Based Framework (MSC-RBF) analysis, passing assessment with medium risk to stock damage (Table 3.2, Table 3.3). The Productivity Susceptibility Analysis scores for both species were based on the assumption that these species are moderately productive secondary consumers with short generation times (Māori Octopus < 3 years; Gloomy Octopus <1 year) and relatively energy intense reproductive strategies whereby females actively brood large clutches of eggs. Both species are highly susceptible to capture as catches overlap with >30% of stock distribution in Tasmanian waters, and there is a high risk of juveniles being retained by fishing gear. The Consequence Analysis for both species showed no evidence of impact to any subcomponent, meaning recruitment impairment is unlikely.

Table 3.2 Risk-Based Framework scoring of the **Māori Octopus** fishery for the consequence analysis, productivity susceptibility analysis, and the combined total.

Consequence Analysis		
Most vulnerable subcomponent	**Score**	**Score interpretation**
All	100	Change to any subcomponent unlikely to be detectable against natural variability for this population.
Productivity Susceptibility Analysis		
Productivity attribute	**Score**	**Score interpretation**
Average age at maturity	1	< 5 years
Average maximum age	1	< 10 years
Fecundity	1	100 – 20 000 eggs per year
Reproductive strategy	2	Demersal egg layer
Trophic level	2	> 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	Medium overlap with fishing gear
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.
Total Productivity Susceptibility Score	**60 – 80**	
Total RBF Score	**60 – 80**	

Table 3.3 Risk-Based Framework scoring of the **Gloomy Octopus** fishery for the consequence analysis, productivity susceptibility analysis, and the combined total.

Consequence Analysis		
Most vulnerable subcomponent	**Score**	**Score interpretation**
All	100	Change to any subcomponent unlikely to be detectable against natural variability for this population.
Productivity Susceptibility Analysis		
Productivity attribute	**Score**	**Score interpretation**
Average age at maturity	1	< 5 years
Average maximum age	1	< 10 years
Fecundity	1	> 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	Medium overlap with fishing gear
Selectivity (potential of gear to retain immature individuals)	3	c) Individuals < size at maturity a frequently caught. d) 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.
Total Productivity Susceptibility Score	**60 – 80**	
Total RBF Score	**60 – 80**	

4. Stock status

Pale Octopus (*Octopus pallidus*)

STOCK STATUS	DEPLETING

In 2020/21, the total catch of Pale Octopus in the Tasmanian Octopus Fishery (TOF) remained high (154 t). This is the highest catch in the history of the TOF and the first instance in which catches were above 100 tonnes over three consecutive years. Effort was recorded at 311,500 pot-lifts in 2020/21, representing a slight decrease from last year.

Until 2020/21, broad-scale trends in catch per unit effort (CPUE) showed a decrease from 2005/06 in both logbook-derived CPUE estimates and the 50-pot sampling data, albeit with annual fluctuations. However, both metrics of CPUE across the fishery were the highest on record in 2020/21.

Regional analyses indicate a shift in effort and catch away from previously productive areas in the eastern Bass Strait, with both effort and catch concentrated east of King Island in 2020/21. Despite high catch and CPUE in this new area, results revealed evidence of potential localised depletion in the traditionally fished areas in the eastern Bass Strait. Catch-only stock assessment methods further indicated that biomass in traditionally fished blocks around Flinders Island may be depleted beyond desirable levels and that peak catches from this area are unlikely to be sustainable. While the original Pale Octopus fishing ground off Stanley remains productive and there is no evidence that the biomass of Pale Octopus across the entire fishery is depleted to critical levels, the likely vulnerability of the species combined with a high probability of hyper-stable catch and CPUE means there is a considerable risk that recruitment may be impaired and sudden declines in biomass might occur with no warning.

On the basis of this information, Pale Octopus is classified as Depleting in the Bass Strait.

Gloomy Octopus (*Octopus tetricus*)

STOCK STATUS	SUSTAINABLE

Catch of Gloomy Octopus from the TOF and east coast developmental Pale Octopus fishery was only 0.3 t in the most recent year and has remained close to zero following an outlier peak of 20.8 t in 2017/18. Catch of Gloomy Octopus from other fisheries was negligible. Gloomy Octopus catches appear to be driven by the distribution of effort within the TOF. Gloomy Octopus are caught in eastern Bass Strait near Flinders Island, which is likely to represent the southern end of this species distribution. It is unknown whether the biomass of Gloomy Octopus in Tasmanian waters is sufficient for a more substantial fishery. However, fishing effort the TOF has been concentrated almost exclusively in western Bass Strait over recent recent years and catch has been negligible. Thus, Gloomy Octopus is classified as Sustainable.

Māori Octopus (*Macroctopus maorum*)

STOCK STATUS	SUSTAINABLE

A total of 7.9 t of Māori Octopus and 9.3 t of 'Octopus, unidentified' (presumably mostly Māori Octopus) were landed by Tasmanian commercial fishers in 2020/21 – totalling 17.2 t. Assuming all 'Octopus, unidentified' was indeed Māori Octopus, these catches comprise 6.6 t landed by-product from the TOF and east coast developmental Pale Octopus fisheries, 9.3 t landed by-product from the Rock Lobster fishery, 0.9 t landed by-product from the Scalefish fishery, and 0.4 t from the targeted Eaglehawk Bay octopus fishery.

Although, like Pale Octopus, Māori Octopus actively brood benthic egg clutches, Māori Octopus populations are likely to be more resilient than Pale Octopus because egg numbers are generally higher and large numbers of small planktonic larvae are produced, compared with small numbers or large benthic juveniles. Thus, the Māori Octopus fishery could potentially support similar or higher catches than the Pale Octopus fishery. However, quantities of Māori Octopus killed and discarded by the Rock Lobster fishery are unknown, challenging a reliable assessment of both catch and potential biomass depletion. When catch data and trip limits for octopus are compared with the total number of Rock Lobster trips per year, it appears that overall catch and, hence, discard mortality of Māori Octopus in this fishery may be low. Video observations suggest that the gear selectivity for Maori Octopus within the Rock Lobster fishery may also be low. Thus, the Tasmanian Māori Octopus stock is classified as Sustainable.

5. Environmental interactions within the TOF

By-product and by-catch

Aside from Māori and Gloomy Octopus, no by-product or bycatch species are taken with the TOF or the east coast developmental fishery for Pale Octopus, other than small invertebrates and fouling organisms that attach to the gear and are released back to the sea as the gear is redeployed.

Protected and threatened species interactions

The nature of the fishery and the gear used make interactions with protected and threatened species unlikely. Boats do not operate at night hence seabirds are not attracted to working lights. There are also no bait-discarding issues since the pots are unbaited. Furthermore, surface gear is minimal (two buoys and two ropes for each demersal line). Thus, the 2012/13 ERA considered that risks from octopus potting to protected and threatened 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 pot-lifts set annually, or in the Western Australia Rock Lobster Fishery where there are approximately 2 million pot-lifts 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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Appendix

Table A1 Coefficients of the Generalized Linear Model (GLM) comparing the influence of licencing year, month, and spatial fishing block on standardised CPUE within the TOF. The Estimate refers to the difference in CPUE between a year/month/block and the intercept (the first year/month/block in the series). Significance codes: *** < 0.001 < ** < 0.01 < * < 0.05 < **.** < 0.01

	Estimate	Standard Error	t value	Pr(>|t|)	Significance
(Intercept)	-2.54841953	0.36774903	-6.9297791	4.474198e-12	***
2001/2002	0.18085697	0.16675705	1.0845537	2.781455e-01	
2002/2003	0.67939276	0.20059217	3.3869355	7.094963e-04	***
2003/2004	0.65697131	0.18207912	3.6081640	3.098726e-04	***
2004/2005	0.85515418	0.13340964	6.4099877	1.520779e-10	***
2005/2006	1.06309812	0.12457604	8.5337288	1.622167e-17	***
2006/2007	0.46197407	0.12314822	3.7513662	1.768645e-04	***
2007/2008	0.74999354	0.12245075	6.1248587	9.417089e-10	***
2008/2009	0.49179405	0.12250689	4.0144195	6.002619e-05	***
2009/2010	0.77692818	0.12228042	6.3536597	2.193824e-10	***
2010/2011	0.77303272	0.12278984	6.2955758	3.190833e-10	***
2011/2012	0.20884288	0.12241532	1.7060191	8.803550e-02	.
2012/2013	0.50959551	0.12172786	4.1863507	2.858965e-05	***
2013/2014	0.36456444	0.12204565	2.9871153	2.823048e-03	**
2014/2015	0.52941303	0.12219919	4.3323777	1.489440e-05	***
2015/2016	0.40176709	0.12241434	3.2820264	1.034164e-03	**
2016/2017	0.49411516	0.12216983	4.0444940	5.282903e-05	***
2017/2018	0.21755983	0.12198230	1.7835360	7.452933e-02	.
2018/2019	0.77993544	0.12224671	6.3800115	1.848926e-10	***
2019/2020	0.53037702	0.12276188	4.3203723	1.572669e-05	***
2020/2021	1.13193660	0.12235043	9.2515947	2.663398e-20	***
April	0.23912835	0.02308500	10.3586042	5.113552e-25	***
May	0.29026033	0.02244663	12.9311295	6.035015e-38	***
June	0.30400916	0.02342054	12.9804504	3.207233e-38	***
July	0.11596456	0.02367360	4.8984755	9.809266e-07	***
August	-0.10280703	0.02456763	-4.1846540	2.880365e-05	***
September	-0.13714748	0.02502501	-5.4804164	4.345994e-08	***
October	-0.15731041	0.02396695	-6.5636390	5.510685e-11	***

November	-0.13810228	0.02401175	-5.7514466	9.107286e-09	***
December	0.02994576	0.02494769	1.2003419	2.300349e-01	
January	-0.12728867	0.02353178	-5.4092235	6.475460e-08	***
February	-0.10222102	0.02441304	-4.1871492	2.848947e-05	***
Block 3D3	0.50916003	0.34846405	1.4611551	1.440042e-01	
Block 3D4	0.69190989	0.34701238	1.9939055	4.618942e-02	*
Block 3E3	0.62692394	0.34765236	1.8033070	7.137002e-02	.
Block 3E4	0.75981338	0.60020338	1.2659265	2.055688e-01	
Block 3F1	0.62556690	0.60022014	1.0422291	2.973306e-01	
Block 3F2	0.55972535	0.49031706	1.1415580	2.536651e-01	
Block 3F4	0.45841042	0.38069256	1.2041486	2.285606e-01	
Block 3G1	0.24378542	0.37318524	0.6532558	5.136064e-01	
Block 3G2	-0.38441762	0.42572632	-0.9029689	3.665641e-01	
Block 3G3	0.64500481	0.34836181	1.8515371	6.412171e-02	.
Block 3G4	-1.02993557	0.41083089	-2.5069575	1.219323e-02	*
Block 3H1	0.33637717	0.36246935	0.9280155	3.534219e-01	
Block 3H3	0.33521239	0.34764782	0.9642298	3.349540e-01	
Block 3H4	0.26623062	0.35118528	0.7580916	4.484139e-01	
Block 4D1	-0.07292702	0.44918682	-0.1623534	8.710308e-01	
Block 4D2	0.60906202	0.38276130	1.5912320	1.115889e-01	
Block 4D3	1.16317051	0.42477280	2.7383357	6.186001e-03	**
Block 4D4	0.11536537	0.36577842	0.3153969	7.524669e-01	
Block 4E1	0.49340418	0.34715056	1.4212974	1.552614e-01	
Block 4E2	0.33597760	0.35072682	0.9579467	3.381127e-01	
Block 4E3	0.16739854	0.34727598	0.4820332	6.297929e-01	
Block 4E4	-0.08374278	0.34833651	-0.2404077	8.100191e-01	
Block 4F1	0.33830415	0.44762448	0.7557767	4.498008e-01	
Block 4F3	0.22238940	0.37085886	0.5996605	5.487461e-01	
Block 4F4	0.06018043	0.35070916	0.1715964	8.637583e-01	
Block 4G1	0.23218572	0.34882191	0.6656283	5.056641e-01	
Block 4G2	0.70907682	0.34756350	2.0401361	4.136292e-02	*
Block 4G3	0.14378342	0.34815022	0.4129925	6.796210e-01	
Block 4G4	0.52702310	0.34828352	1.5132014	1.302600e-01	
Block 4H1	0.17108190	0.37734967	0.4533776	6.502866e-01	

Block 4H2	-0.25430621	0.36124884	-0.7039641	4.814715e-01	
Block 4H3	-0.47541741	0.38029985	-1.2501120	2.112878e-01	
Block 4H4	-1.34868003	0.39367021	-3.4259134	6.151930e-04	***
Block 5F1	0.18532826	0.34990035	0.5296601	5.963593e-01	