



Department of  
Primary Industries

## Stock assessment

Informing the 2020-21 TAC setting process for the NSW Ocean Trawl Fishery (Inshore Prawn, Offshore Prawn and Northern Fish Trawl)

### **Tiger Flathead (*Platycephalus richardsoni*)**

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## INTRODUCTION AND SCOPE OF THIS ASSESSMENT

Assessment of the status of the stock of Tiger Flathead (*Platycephalus richardsoni*, Syn. *Neoplatycephalus richardsoni*) that is fished by commercial and recreational fishers in New South Wales (NSW) is principally based on the modelling and assessment done for this species by the Commonwealth of Australia. The Commonwealth managed Southern and Eastern Scalefish and Shark Fishery (SESSF) takes approximately 96% of total Australian catch of Tiger Flathead. The primary mechanism for controlling the harvest of Tiger Flathead in the SESSF is through the allocation of an Annual Total Allowable Catch (TAC). Determination of annual TACs for the Commonwealth SESSF is based on the SESSF Harvest Strategy Framework (HSF) (AFMA, 2017) that derives from the Commonwealth Fisheries Harvest Strategy Policy (HSP) (DAFF, 2007). For SESSF management purposes, Tiger Flathead are managed under the multi-species "Flathead" category such that the Commonwealth TAC set for "Flathead" covers catches of Tiger Flathead, Sand Flathead (*Platycephalus bassensis*), Bluespotted Flathead (*P. caeruleopunctatus*) and Gold-spot or Toothy Flathead (*N. aurimaculatus*) (AFMA, 2019b). Tiger flathead is, however, the only one of these flathead species currently assessed by the Commonwealth.

The Commonwealth assessment of the Tiger Flathead stock evaluates stock status relative to limit and target reference points prescribed in the HSF/HSP. The Tier-1 assessment uses a statistical catch-at-length, catch-at-age model. The model provides retrospective and prospective estimates of biomass (the latter for alternative TACs) and thereby generates, through harvest control rules, a Recommended Biological Catch (RBC). The intention of this process is to move the stock biomass toward and maintain it around the target reference point.

This assessment of the status of Tiger flathead, in waters under NSW jurisdiction, comprises:

- (1) a summary of the most recent Commonwealth stock assessment for Tiger Flathead (Day, 2019) and current determinations of status based on criteria specified by the Commonwealth and also those used for the Status of Australian Fish Stocks (SAFS);
- (2) the rationale by which the Commonwealth assessment for Tiger Flathead is considered to be relevant and valid for determining the status of the Tiger Flathead stock fished within NSW jurisdiction;
- (3) information that may inform the determination of the 2020-21 NSW TAC for Tiger flathead in the Ocean Trawl Fishery. This is done in the absence of: (i) a formal NSW harvest strategy for this species/fishery; and (ii) a formal resource sharing agreement between NSW and the Commonwealth.

More detailed information concerning the methodology of the Commonwealth Tier-1 assessment model is provided in Appendix 1. For a full description, refer to Day (2019).

## ASSESSMENT SUMMARY

### Stock Structure and distribution

Tiger Flathead is a demersal finfish species, endemic to Australia, which inhabits depths of 10 – 400 m but most commonly occurs in depths 50 – 200 m on the continental shelf from northern NSW, westward through Victorian (Vic.) waters to south-east South Australia (SA), across Bass Strait and around Tasmania (Tas.).

Stock structure is poorly understood. There is some evidence of morphological variation across the distribution range, with observed regional differences in growth, appearance and timing of reproduction, especially off eastern Tasmania. No stock identification studies using genetic techniques have been undertaken. For assessment and management purposes, a single stock has been assumed for the assessment done for the Commonwealth (Day, 2019; Patterson et al., 2019; Emery et al., 2018).

Thus, assessment of the stock status of Tiger Flathead is done at the biological stock level, spanning Commonwealth, NSW, Vic. and Tas. Jurisdictions.

### Biology

Maximum age is approx. 20 years with males reaching a maximum size of approx. 50 cm total length (TL) and females 60 cm TL. Females mature (50% maturity) at approx. 300 mm TL at 3 to 5 years of age. In addition to reaching a greater maximum size, females grow substantially faster than males (AFMA, 2019a; Day, 2019; Patterson et al., 2019; Emery et al., 2018). Sex-specific growth curves are estimated within the assessment model with a single parameter (maximum length,  $l_{max}$ ) fixed and parameters  $l_{min}$ ,  $K$  and  $CV_{growth}$  estimated (Day, 2019).

Spawning occurs over an extended period between spring and autumn with some variation in timing depending on location. Females produce 1.5 – 2.5 million eggs per spawning season (AFMA, 2019a).

Estimates of the rate of natural mortality,  $M$ , reported in the literature vary considerably, from 0.21 to 0.46  $yr^{-1}$ . The assessment uses a value of 0.27  $yr^{-1}$  and examines sensitivity of the model to scenarios based on alternative values of  $M$  (0.22, 0.32  $yr^{-1}$ ) (Day, 2019).

### Stock Status and rationale

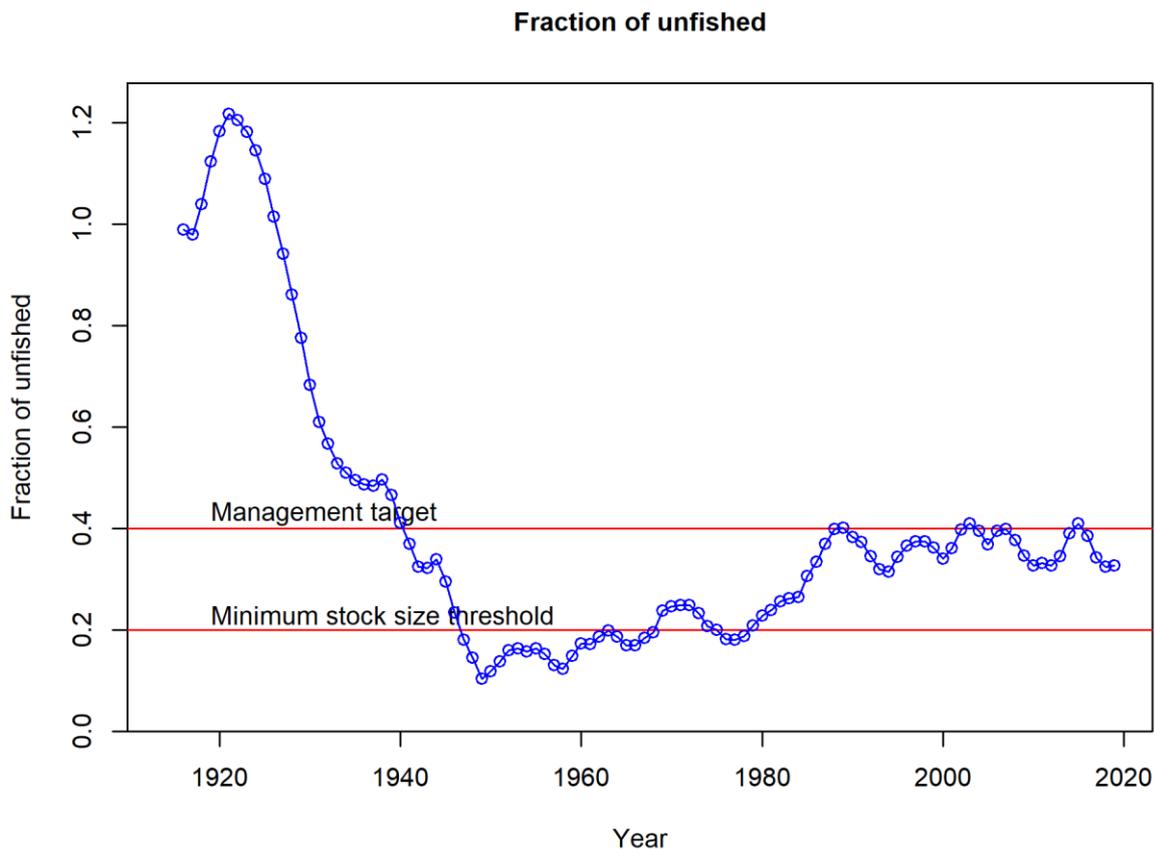
The most recent stock assessment for Tiger Flathead was done in 2019, based on data up to 2018 (Day, 2019). Spawning biomass at the commencement of 2019 was estimated to be 34% of the pre-exploitation level (Figure 1). This is substantially greater than the limit reference point of 20% depletion but below the management inflexion point of 35% and the target reference point of 40% depletion.

The estimated depletion spawning stock biomass of 34% is, however, substantially reduced from the 42% depletion estimated from the 2016 assessment (Day, 2019). This is mainly due to below average estimated recruitment during the 3 years 2012-14.

Based on the agreed harvest control rule, average recruitment (based on the stock-recruitment relationship) since 2016 and model projections, RBCs calculated for the next 3 years are 2,334 t for 2020, 2,648 t for 2021 and 2,706 t for 2022. Average RBC for this 3-year period (2020-22) is 2,563 t (Day, 2019).

The 2020 RBC of 2,334 t represents a 17.4 % decrease from the 2019-20 RBC of 2,826 t. The 3-year 2020-22 RBC of 2,563 t represents a 9.3% decrease from the 2019-20 RBC.

**Figure 1** Time-trajectory of spawning biomass depletion corresponding to the MPD estimates for the base-case analysis for tiger flathead. This figure reprinted from Fig. 14 in Day (2019).



The most recent classification of stock status by the Commonwealth of **not overfished** and **not subject to overfishing** (Patterson et al., 2019) was based on the previous tier-1 assessment of status (Day, 2016, 2017). The most recent classification of stock status under SAFS criteria was **sustainable** (Emery et al., 2018), also based on the 2016 tier-1 assessment. The Commonwealth TAC is informed by: (i) the model-estimated "Recommended Biological Catch" (RBC) based on the harvest strategy control rules; and then (ii) subtracts allowances for State catches (including NSW) and discards (AFMA, 2019c). Based on the recent tier-1 assessment (Day, 2019), the Commonwealth classification of **not overfished** and SAFS classification of **sustainable** continue to be applicable based on applicable criteria. Moreover,

although the Commonwealth TAC for 2020-21 has not yet been determined, it is reasonable to conclude that it will be based on existing policies and harvest control rules with the objective of maintaining biomass around the target reference point. Thus, the Commonwealth classification of **not subject to overfishing** will continue to be applicable.

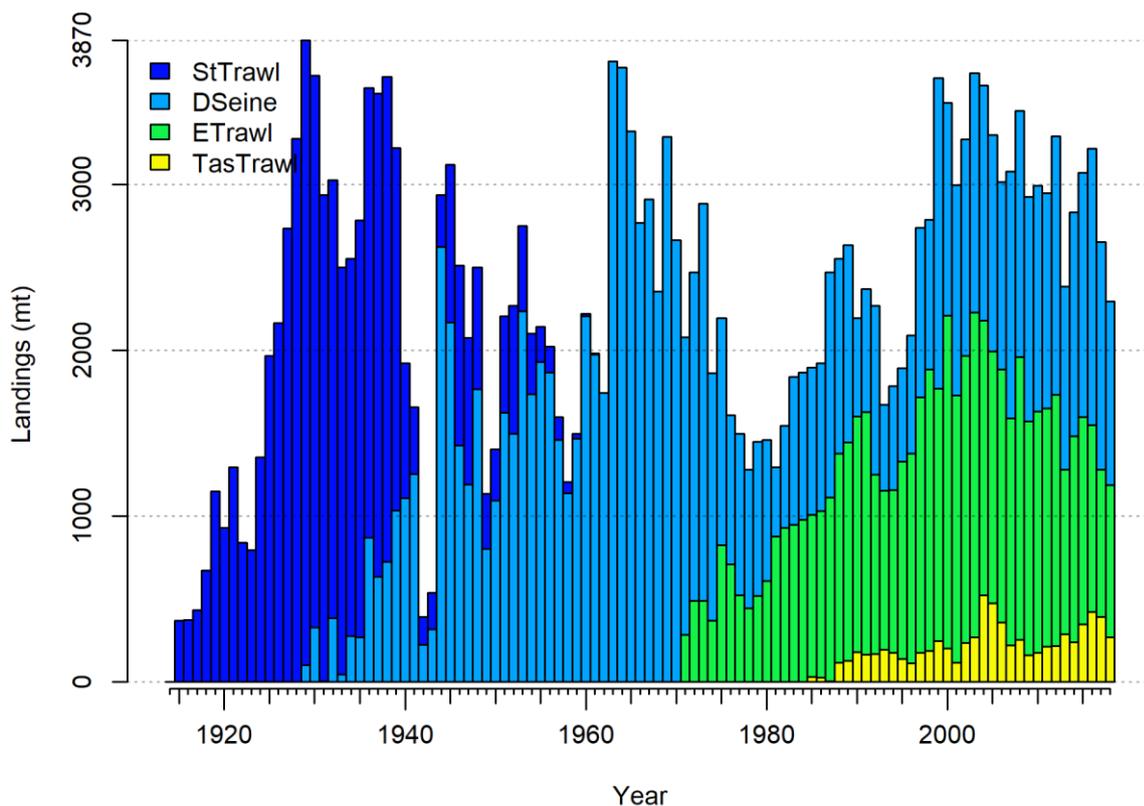
## Fisheries Statistics

### Catch information

#### Commercial

Commercial landed catches of Tiger Flathead that were included in the 2019 assessment (Day, 2019) between 1915 and 2018 are shown in Figure 2. These data represent catches from the four fleets that were represented in the assessment model (Steam trawl, Danish seine, Eastern trawl and Tasmanian trawl). Commercial catches from NSW state waters are included within the Eastern trawl fleet category.

**Figure 2** Total landed catch of tiger flathead by fleet (stacked) from 1915-2018. This figure reprinted from Fig. 1 in Day (2019).



### Recreational / Aboriginal

The Commonwealth assessment does not, at present, include estimates of Tiger Flathead catches by the recreational or Aboriginal sectors.

### Charter Boat

The Commonwealth assessment does not, at present, include estimates of Tiger Flathead catches by the Charter boat sector.

### Discards

Information about rates of discarding was available from observer surveys done by NSW Fisheries (Liggins, 1996) and the Integrated Scientific Monitoring Program between 1992 and 2006 (Day, 2019). Typically, the discarding rate for Tiger Flathead was around 8% for Danish seine, 10% for eastern Trawl and 1% for Tasmanian Trawl components of the fishery. Annual estimates for each fleet during the period 1992-2006 were used during model calibration. Based on information that the total discards for all species taken by steam trawlers in the 1920s was of the order of 20% of the retained catch), a constant discard fraction of 17% was assumed for the Steam trawl fleet during the period 1915-1961 and for the Danish seine fleet during 1929-1960 (Day, 2019).

### Illegal, Unregulated and Unreported (IUU)

The Commonwealth assessment does not, at present, include any allowance for an IUU component of fishing mortality.

### Other jurisdictions

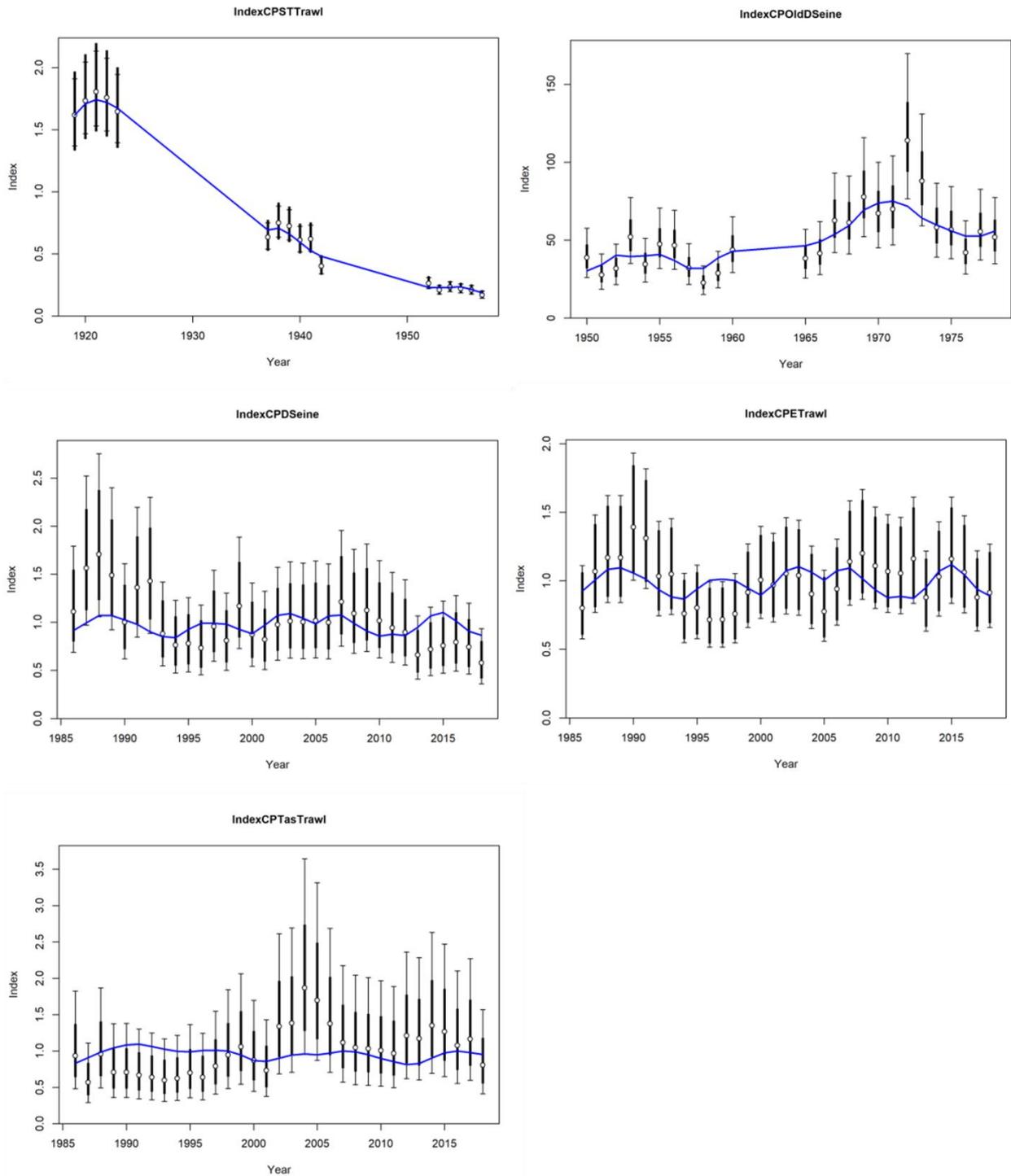
The Commonwealth assessment includes landed commercial catch data from State jurisdictions (NSW, Vic., Tas.). Discard fractions estimated for the Commonwealth fishery are applied to the relatively small component of the total landed catch that occurs in the State jurisdictions.

### **Catch rate information**

Indices of catch rates used in the Commonwealth assessment derive from multiple sources: (i) a standardised catch rate index for the historical steam trawl fleet for the years 1919-23, 1937-42 and 1952-57 (Klaer, 2006); (ii) an unstandardized catch rate index for the Danish seine in early years (Cui et al., 2004); (iii) standardised catch rate indices from the SEF1 logbook for the years 1986-2018 for each of 3 fleets (Danish seine, Eastern Trawl Fleet, Tasmanian Trawl Fleet) (Sporcic, 2019) and (iv) abundance indices from the Fishery Independent Survey during 2008-16 (Sporcic et al., 2019). The greatest decline in abundance is apparent during the first 40 years of the fishery between 1920 and 1960 (Fig. 3). Patterns of observed indices of abundance since 1985 exhibit fluctuations but no apparent long-term trend over the 3 decades 1985 – 2018 (Figure 3).

**Figure 3** Observed (circles) and model-estimated (lines) catch rates vs year, with approximate 95% asymptotic intervals. This figure reprinted from Fig. 10 in Day (2019).

“CPSTTrawl” refers to the Steam Trawl Fleet, “CPOldDseine” and “CPDseine” refer to the Danish seine fleet, “CPETrawl” refers to the Eastern trawl fleet, “CPTasTrawl” refers to the Tasmanian trawl fleet and “CPFIS” refers to the Fishery Independent Survey.



## THE COMMONWEALTH ASSESSMENT AS A BASIS FOR STOCK STATUS IN NSW

As a "Tier 1" Commonwealth assessment, this assessment is classed as being of high quality. It is based on a statistical catch-at-age / catch-at-length model incorporating multiple fleets and is calibrated with multiple time-series of data including indices of abundance, estimates of discarding, and size- and age-distributions. The model is conditioned on landed catch data for commercial fisheries sourced from each of the relevant jurisdictions (Commonwealth, NSW, Victoria and Tasmania).

### Accounting of NSW catches in the Commonwealth Tier-1 assessment model

Landings of Tiger Flathead from NSW commercial fisheries are accounted for in the Commonwealth Tier-1 model, representing an average of 5.6% of the total landings since 2001 and 4.2% of total landings during the last 3 years (Table 1). Because (i) fishing mortality in waters under NSW jurisdiction are included in the model; (ii) the vast majority of fishing mortality occurs in the Commonwealth SESSF; and (iii) the stock of Tiger Flathead fished in Commonwealth and State jurisdictions is considered a single biological stock, it is reasonable that NSW use the Commonwealth assessment as the basis for determining stock status in NSW.

**Table 1** Annual landed catches used in the Commonwealth assessment model (Total, Eastern trawl fleet, and NSW jurisdiction) compared to landed catch statistics held by NSW DPI.

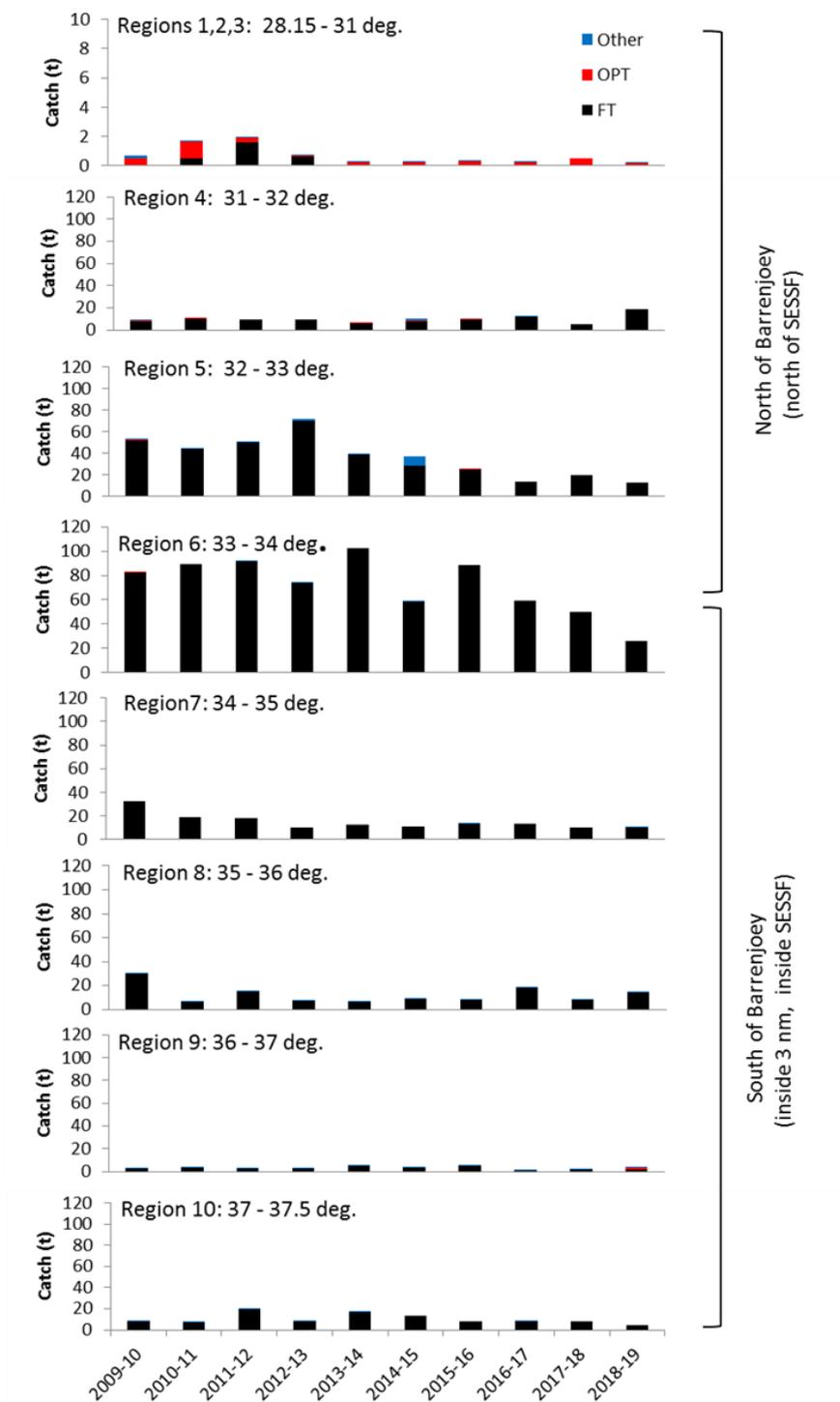
Note: Catches for 2019 (shown in red) were assumed to be the same as the preceding year.

Year	Landed catch used in model (t)				Actual NSW landed catch (t)	
	Total (t)	Eastern trawl fleet	NSW jurisdiction	NSW catch as % of total	Landed catch	NSW landings as % of total
2001	2,979	1,612	124	4.2	129.0	4.3
2002	3,260	1,731	108	3.3	107.9	3.3
2003	3,673	1,957	169	4.6	171.5	4.7
2004	3,592	1,658	199	5.5	209.2	5.8
2005	3,297	1,516	241	7.3	241.2	7.3
2006	3,019	1,526	273	9.1	281.8	9.3
2007	3,055	1,368	153	5.0	152.9	5.0
2008	3,447	1,705	192	5.6	191.7	5.6
2009	2,926	1,408	193	6.6	207.7	7.1
2010	2,991	1,458	202	6.8	202.1	6.8
2011	2,949	1,435	194	6.6	194.1	6.6
2012	3,293	1,516	196	6.0	196.3	6.0
2013	2,385	995	182	7.6	181.9	7.6
2014	2,838	1,244	164	5.8	164.4	5.8
2015	3,079	1,248	151	4.9	151.1	4.9
2016	3,220	1,126	145	4.5	142.3	4.4
2017	2,658	887	108	4.0	106.7	4.0
2018	2,297	921	96	4.2	96.3	4.2
2019	2,297	921	96	4.2		

### Location of NSW catches relative to the SESSF

Catches of Tiger flathead in waters under NSW jurisdiction are concentrated within latitudes (i) 32 – 33.58°S, immediately to the north of the SESSF boundary at Barrenjoey Headland; and (ii) 33.58 – 37.5°S, between the NSW coastline and the boundary with the SESSF at 3nm offshore (Fig. 4). Consequently, the assumption of a common stock across these jurisdictional boundaries is reasonable.

**Figure 4** Spatial distribution of Tiger flathead catch in waters under NSW jurisdiction, 2009-10 to 2018-19, by fishing method (FT – Fish trawl, OPT – Ocean prawn trawl, Other).

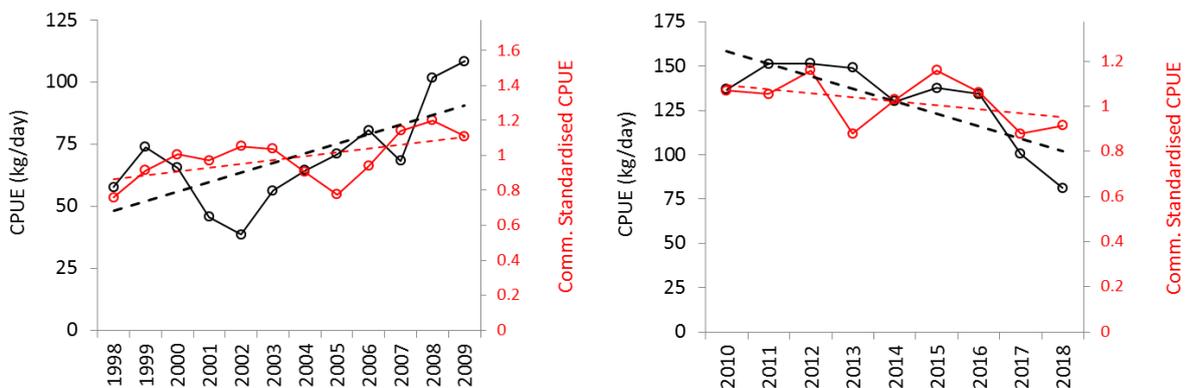


## NSW and SESSF Eastern Trawl Fleet catch rates

Trends in catch rates (CPUE) for Tiger Flathead taken by fish trawlers operating within NSW jurisdiction are generally consistent with indices of abundance based on catch rates from fish trawlers operating in the Eastern Trawl Fleet of the SESSF (Fig. 5). Both sources of data, show increasing trends in abundance during 1998-2009 and decreasing trends 2010-2018. This suggests that the component of the stock in NSW waters (inside 3 nm on the south coast of NSW and to the north of the SESSF boundary at Sydney) is exhibiting similar dynamics (with respect to abundance) to the component of stock under Commonwealth jurisdiction and this is consistent with the assumption of a single biological stock.

**Figure 5** Annual CPUE (total catch / total effort) based on reported catches of “Tiger Flathead” taken by fish trawlers operating within NSW jurisdiction (black) and standardised catch rates for the Eastern trawl fleet of the SESSF (red), 1998 – 2009 (left panel) and 2010-2018 (right panel). Dashed lines show linear trends. Data sources: NSW RAS database & Day (2019)

Linear trends in CPUE are shown by dashed lines on each graph. Data sources: NSW data from NSW RAS database; Commonwealth data from Day (2019).



## Minor inconsistencies re the representation of NSW data and regulations within the Commonwealth Tier-1 assessment model

There are several minor issues with respect to the reliability of NSW landings data and the representation of NSW catch data and fishing regulations within the Commonwealth model:

- There is uncertainty associated with the accuracy of reported landings of “Tiger Flathead” in NSW (and probably other jurisdictions also). In NSW, there may be a component of landings of Tiger Flathead that is unreported by fishers. Tiger Flathead may be misreported as “Flathead (Other)” in NSW. Between 12 and 40 t of landings of “Flathead (Other)” were reported annually during 2009/10 -2018/19, by fish trawlers and prawn trawlers. It is likely that these catches principally comprise Tiger Flathead

and Bluespotted Flathead (*Platycephalus caeruleopunctatus*). The magnitude of these catches does, however, represent such a small proportion (1% order of magnitude) of the total Australian catch of Tiger Flathead that such misreporting would have little effect on model estimates and assessment outcomes.

- There are minor discrepancies between the NSW landings used in the model and the historical catches recorded in the NSW database (Table 1). The mean annual discrepancy between 2001 and 2018 is 1.0%. Note, however, that a 1% discrepancy for NSW landings results in a discrepancy of approximately 0.05% in total landings across all jurisdictions. Such small discrepancies have insignificant impact on modelling outcomes.
- The Commonwealth assessment does not consider recreational or Aboriginal catch. The model is conditioned on commercial catches alone. Neither does the process by which the Commonwealth TAC is calculated from the RBC account for recreational/Aboriginal catch. A survey of the catches in NSW by NSW-resident recreational fishers during 2013/14 estimated a retained catch of 39,417 (se 14,738) Tiger Flathead and a discarded catch of 42,913 (se 19,117) fish (West et al., 2015). If the mean weight of landed Tiger Flathead was 0.521 kg (estimate in NSW DPI Resource Assessment System database), approximately 20 t of Tiger Flathead were landed by NSW-resident recreational anglers. This magnitude of catch represents less than 1% of the annual commercial landings of Tiger Flathead. Assuming that the total landings by recreational and Aboriginal fishers from all State jurisdictions are of a similar order of magnitude, it can be concluded that the omission of recreational and Aboriginal catches from the model and Commonwealth assessment has little effect on model estimates and assessment outcomes.
- The Commonwealth assessment model does not specifically recognise the minimum legal length (MLL) of 33 cm for Tiger Flathead taken under NSW jurisdiction, which is 5 cm greater than the MLL of 28 cm applicable in the SESSF (AFMA, 2019b). The model combines NSW and SESSF catches within the "Eastern trawl fleet" and uses a single selectivity ogive. Given the relativity of the NSW and Commonwealth components of catch, this simplification would have minimal effect on model estimates and assessment outcomes.

## INFORMING A TAC FOR NSW

Determination of a TAC for the NSW Ocean Trawl fishery for the 2020-21 fishing period may potentially be informed by the following facts and observations:

1. There is currently no harvest strategy for Tiger flathead and trawl fisheries under NSW jurisdiction. Consequently, limit and target reference points specifically relating to the NSW fisheries for Tiger flathead are undefined. For the purpose of classifying exploitation status under SAFS criteria, NSW adopts a default 20% depletion of spawning biomass as a limit reference point. In one sense, this aligns with the Commonwealth's limit reference point of 20% depletion for Tiger flathead. Note, however, that the SAFS default criterion for a 20% limit reference point is based on balance of probability in the current year, whereas the Commonwealth policy relating to the SESSF requires that a stock will remain above the 20% depletion level in at least 9 out of 10 years. The Commonwealth's target reference point for Tiger flathead is 40% depletion of spawning biomass.
2. There is currently no resource sharing policy between NSW and the Commonwealth relating to the shared stock of Tiger flathead.
3. As a consequence of there being no harvest strategy ("1" above) and no resource sharing policy ("2" above), assessing the consequences of alternative TACs for Tiger flathead in NSW waters is problematic for 2020-21 and into the future.
4. Technically, the magnitude of the TAC set for Tiger flathead for the relevant commercial fisheries under NSW jurisdiction is likely to have no impact on the sustainability of the Tiger Flathead population. This is because the Harvest Strategy Policy used by the Commonwealth for the SESSF requires that the Commonwealth TAC be determined using the calculation:  $TAC = RBC - State\ catch\ allowance - Discards\ allowance$ . Based on this policy, the Commonwealth TAC would be set so that the RBC is not breached and stock continues to track to the target reference point.
5. Setting a NSW TAC that is "out of step" with (i) the Commonwealth's harvest strategy and RBC; (ii) Commonwealth versus NSW catch histories (see Table 1); and (iii) the current Commonwealth stock assessment (Day, 2019); would seem to be counter-productive to the effective ongoing management of this shared resource.
6. The determination of the 2020-21 Commonwealth TAC for Tiger Flathead is likely to be based on:
  - a. the 2,334 t RBC for 2020 (1-year) or the 2,563 t 2020-2022 (3-year) average RBC from the current assessment model (Day, 2019);
  - b. an allowance for State catches of approx. 176 t (based on the average for 2016-2018: 209.8 t, 286.5 t, 132.3 t);
  - c. an allowance for discards of 164 t (estimated from model projections, Day 2019);

and would likely result in a Commonwealth TAC of approximately:

- d. 1,994 t for 2020 (1-year TAC)  
representing a decrease of 19.2 % from the 2019-20 TAC of 2,468 t;
  - e. or 2,223 t TAC (3-year multi-year TAC)  
representing a decrease of 9.9 % from the 2019-20 TAC of 2,468 t.
7. The 2019-20 TAC for the NSW Ocean Trawl Fishery of 166.9 t was set equal to the maximum annual landings from the period 2009-10 to 2016-17 for the sectors of the fishery that became quota-managed (Inshore Prawn Trawl, Offshore Prawn trawl and Northern Fish Trawl) (Tables 2 and 3, Fig. 6). A catch of this magnitude was not taken during any of the 9 years 2010-11 to 2018-19. During the last 5 years (2014-15 to 2018-19) the mean annual catch was 85.9 t, representing 51% of the 2019-20 TAC. During the last 3 years (2016-17 to 2018-19) the mean annual catch was 72.0 t, representing only 43% of the 2019-20 TAC.

**Table 2** Summary statistics based on recent annual commercial catches (2009/10 – 2018/19) for Flathead reported as “Tiger Flathead” in NSW waters.

Grey column indicates the aggregated catches of the fisheries / share-classes for which a NSW TAC currently applies (Fish Trawl North, Prawn Trawl Offshore, Prawn Trawl Inshore). Annual catches for Fish Trawl South, Other NSW fisheries and the total are also tabled.

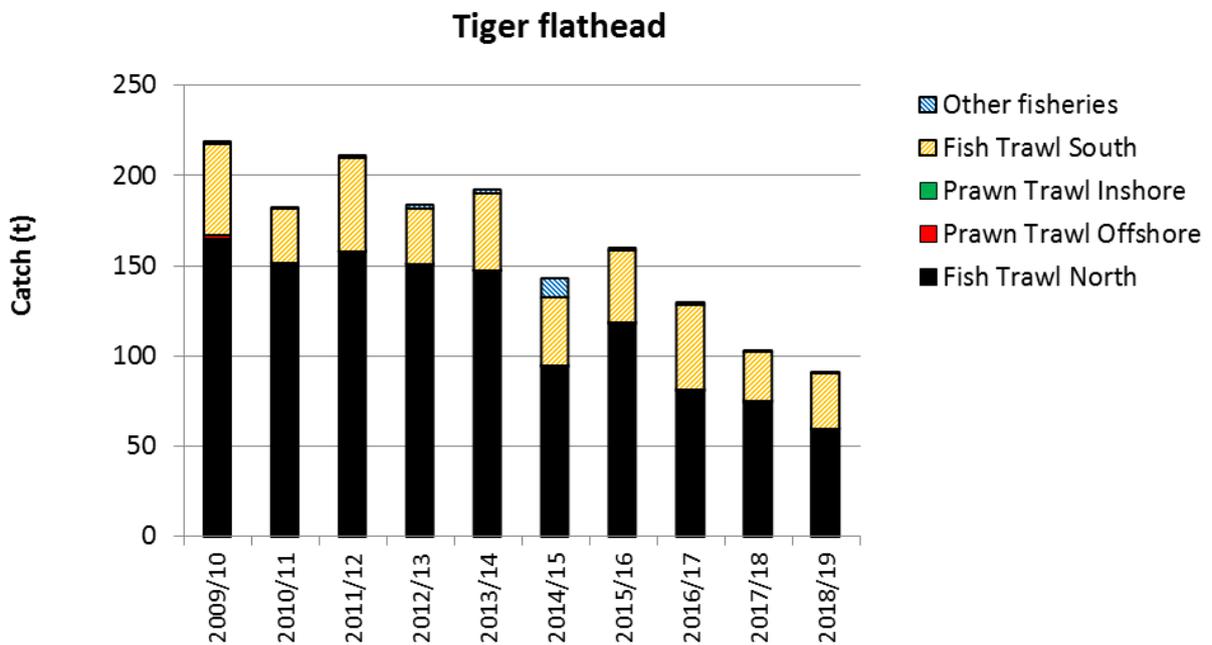
Year	NSW TAC share-class fisheries (Catch, t)	Fish Trawl south (Catch, t)	Other fisheries (Catch, t)	Total (Catch, t)
<b>2009/10</b>	166.930	50.786	1.485	219.201
<b>2010/11</b>	151.504	30.577	0.726	182.806
<b>2011/12</b>	158.329	51.311	1.822	211.462
<b>2012/13</b>	151.232	30.582	1.818	183.632
<b>2013/14</b>	147.752	42.265	2.224	192.241
<b>2014/15</b>	94.781	37.589	11.169	143.539
<b>2015/16</b>	118.622	40.327	0.833	159.782
<b>2016/17</b>	81.322	47.455	0.799	129.575
<b>2017/18</b>	75.180	27.508	0.263	102.950
<b>2018/19</b>	59.547	31.206	0.335	91.088
<b>Min:</b>	59.547	27.508	0.263	91.088
<b>Max:</b>	166.930	51.311	11.169	219.201
<b>Median:</b>	133.187	38.958	1.159	171.294
<b>Mean:</b>	120.520	38.961	2.147	161.628

**Table 3 Annual catches of “Tiger Flathead” by NSW commercial fisheries, by fishery/share-class, 2009/10 – 2018/19.**

Grey columns indicate share-classes for which a NSW TAC will apply.

Year	Fishery / Share-class					Total (t)
	Fish Trawl North (t)	Fish Trawl South (t)	Prawn Trawl Inshore (t)	Prawn Trawl Offshore (t)	Other (t)	
2009/10	164.932	50.786	0.014	1.984	1.485	219.201
2010/11	150.363	30.577	0.079	1.062	0.726	182.806
2011/12	158.006	51.311	0.028	0.296	1.822	211.462
2012/13	151.172	30.582	0.006	0.054	1.818	183.632
2013/14	147.172	42.265	0.005	0.575	2.224	192.241
2014/15	94.248	37.589	0.004	0.529	11.169	143.539
2015/16	117.775	40.327	0.043	0.804	0.833	159.782
2016/17	80.690	47.455	0.057	0.575	0.799	129.575
2017/18	74.668	27.508	0.061	0.451	0.263	102.950
2018/19	59.410	31.206	0.002	0.135	0.335	91.088

**Figure 6 Reported landings of Tiger flathead in NSW commercial fisheries / share-classes, 2009/10 – 2018/19.**



8. During the last 5 years (2014-15 to 2018-19), the mean annual catch of Tiger flathead from the components of NSW fisheries now consolidated in the Ocean Trawl Fishery represented 68.5 % of the mean annual catch of Tiger flathead from all NSW fisheries (Tables 2 and 3, Fig. 6). The vast majority of the remaining 31.5 % of NSW catch came from the Southern Fish Trawl fishery. This fishery is likely to remain outside TAC management during 2020-21.

## APPENDIX 1 – Summary of Commonwealth assessment model (Day, 2019)

### Stock assessment methodology

Year of most recent assessment	2019 (using data to 2018)
Assessment method	<p>Commonwealth Tier 1 assessment using a 2-sex, multiple fleet, statistical age- and length-structured model implemented in the software package <i>Stock Synthesis version SS-V3.30.14</i> (see Day, 2019)</p> <p>Estimation of a recommended Biological Catch (RBC) based on (i) the Commonwealth SESSF Harvest Strategy Framework (HSF) and (ii) SERAG adoption of RBC calculation according to a “20:35:40” (<math>B_{lim}</math> : Inflection point : <math>F_{targ}</math>) strategy</p>
Main data inputs	<p>COMMERCIAL LANDINGS for each of 4 “fleets”: Steam trawl: steam trawlers (1915 – 1961); Danish seine: Danish seiners from NSW, eastern Victoria and Bass Strait (1929 – 2018); Eastern trawl: diesel otter trawlers from NSW, eastern Victoria and Bass Strait (1971 – 2018, <u>this includes NSW and Victorian state catches</u>); Tasmanian trawl: diesel otter trawlers from eastern Tasmania (1985 – 2018); <u>this includes Tasmanian state catches</u>. Calendar year landings for 2019 assumed to be same as 2018 catches</p> <p>DISCARDED COMMERCIAL CATCH estimates: from Integrated Scientific Monitoring Program for Danish seine, Eastern trawl and Tasmanian trawl fleets (1992-present); assumed discard fraction of 17% in base-case for Steam trawl (1915-1961) and early Danish seine (1929-1960) fleets; assumed discard fractions for Danish seine fleet (1961-present) based on observed ratios since 1994</p> <p>COMMERCIAL CATCH RATES (CPUE): standardised CPUE indices for steam trawl fleet (1919-23, 1937-42, 1952-57); unstandardized catch rate indices for Danish seine (1950-78); standardised CPUE indices for Danish seine, Eastern trawl and Tasmanian trawl fleets (1986-2018)</p> <p>ABUNDANCE INDICES FROM FISHERY INDEPENDENT SURVEY in zones that correspond to the Eastern trawl and Tasmanian trawl fleets (2008-16)</p> <p>AGE-AT-LENGTH MEASUREMENTS (sex-specific) based on sectioned otoliths for: Danish seine fleet (1998, 2000-18); Eastern trawl fleet (1998-2002, 2004-18); Tasmanian trawl fleet (1999-00, 2002, 2005-08, 2010, 2012-18)</p> <p>Estimated standard deviation of age reading error (by age)</p> <p>LENGTH COMPOSITION DATA for: onboard retained catch for Danish seine fleet (1993-94, 1998-2007, 2009-18); onboard retained</p>

## Stock assessment methodology

catch for Eastern trawl fleet (1977, 1993, 1996-18); onboard retained catch for Tasmanian trawl fleet (1998-2006, 2008, 2010-18); port data (landed catch) for Steam trawl fleet (1945-58); port data (landed catch) for Danish seine fleet (1945-67, 1992, 1994-18); port data (landed catch) for Eastern trawl fleet (1965-67, 1969-18); port data (landed catch) for Tasmanian trawl fleet (1999-00, 2002-06, 2011-13, 2015-2016); onboard discarded catch for Danish seine fleet (1998-2000, 2002-03, 2006-07, 2011-16, 2018); onboard discarded catch for Eastern trawl fleet (1992-93, 1997-2006, 2008-18)

### Key model structure and assumptions

2-sex, multiple fleet, statistical age- and length-structured model implemented in the package *Stock Synthesis ver. 55-V3.30.14*

5 fleets modelled (4 commercial fishing fleets + FIS "fleet")

Single biological stock of Tiger Flathead assumed

Stock assumed to be unexploited at start of 1915 (i.e. catches prior to this minimal)

As model is conditioned on landed catch, it is assumed that:

- (i) Commercial catches reported for each fleet and from each jurisdiction are accurate
- (ii) Catches from other sectors (recreational and Aboriginal) are insignificant (relative to commercial catches)

Iterative reweighting used to adjust standard errors of catch rate indices so that their average equals those estimated by the model

Selectivity varies among fleets and is time-invariant except for a change in 1978 for the Danish seine fleet and in 1985 for the Eastern trawl fleet

Selectivity ogives modelled as logistic functions of length with 2 parameters estimated within the assessment model

Retention (versus discard) modelled as a logistic function of length with inflection and slope parameters estimated for Danish seine, Eastern trawl and Tasmanian trawl fleets

Natural mortality,  $M$ , assumed age- and time-invariant and equal to  $0.27 \text{ yr}^{-1}$  for base-case of model

Beverton-Holt stock-recruitment relationship parameterised by (i) pre-exploitation recruitment ( $R_0$ ) and steepness ( $h$ )

Recruitment deviations estimated for period 1915 – 2015

Magnitude of process error in annual recruitment was set to 0.7

An age plus-group modelled at age 20; growth assumed to be time-invariant; mean size-at-age time invariant

## Stock assessment methodology

Distribution of size-at-age determined from fitting the growth curve within the assessment using age-at-length data (this done for 2 genders)

Max total length 55.9 cm TL

Length-weight parameters:  $a = 5.88 \times 10^{-6}$ ,  $b = 3.31$

50% maturity at 30 cm TL

Relative weightings of input data series were based on the use of trip and shot numbers (when available) and the "Francis weighting method" rather than length/age frequency sample sizes, arbitrary caps on sample sizes or arbitrary down-weightings of likelihood components. For early length-frequency data down-weighting factors and caps were applied.

Tuning of the model involved a multi-step procedure (see Day, 2019)

### Sources of uncertainty evaluated

Evaluation of base-case model fits (estimated) to observed for:

- indices of abundance time-series (by fleet and FIS)
- discard fraction time-series (by fleet)
- length compositions (retained catch) (i) aggregated across time (by fleet) and (ii) by year (by fleet and FIS)
- length compositions (discarded catch) (i) aggregated across time (by fleet) and (ii) by year (by fleet and FIS)
- age compositions (retained catch) (i) aggregated across time (by fleet) and (ii) by year (by fleet)
- age compositions (discarded catch) (i) aggregated across time (by fleet) and (ii) by year (by fleet)

Sensitivity scenarios based on alternative assumptions to those used in the base-case included:

- low ( $M = 0.22 \text{ yr}^{-1}$ ) and high ( $M = 0.32 \text{ yr}^{-1}$ ) values of natural mortality
- low (27 cm) and high (33 cm) values of size at 50% maturity
- low (0.4), intermediate (0.4) and high (0.8) values of recruitment process error
- first year of recruitment 1915 v 1918
- stock-recruitment steepness 0.65, 0.75, 0.85 with  $M$  fixed at 0.27
- estimate natural mortality  $M$  with stock-recruitment steepness fixed at 0.75
- alternative weightings on length composition data (x 2, x 0.5)

**Stock assessment methodology**

- alternative weightings on age-at-length data (x 2, x 0.5)
- alternative weightings on survey (CPUE) data (x 2, x 0.5)

**Status Indicators, Limit , Inflection and Target Reference Levels**

Biomass indicator or proxy	Depletion of spawning biomass (model estimated)
Biomass LIMIT reference level	B <sub>20</sub> (20% of pre-exploitation spawning biomass)
Biomass Harvest Control Rule (HCR) INFLECTION ref. level ("BREAKPOINT")	B <sub>35</sub> (35% of pre-exploitation spawning biomass)
Biomass TARGET reference level	B <sub>40</sub> (40% of pre-exploitation spawning biomass)
Fishing mortality indicator or proxy	Fishing mortality (model estimated)
Fishing mortality LIMIT reference level	NA
Fishing mortality TARGET reference level	F <sub>40</sub> (Fishing mortality rate that achieves B <sub>40</sub> )

**Stock Assessment Result Summary**

Biomass status in relation to LIMIT	Projected for start of 2020: B = 34 % >> <b>B<sub>20</sub></b>
Biomass status in relation to INFLECTION (BREAKPOINT)	Projected for start of 2020: B = 34% < <b>B<sub>35</sub></b>
Biomass status in relation to TARGET	Projected for start of 2020: B = 34% < <b>B<sub>40</sub></b>
Commonwealth 2019 stock status	<b>Not overfished *</b> <b>Not subject to overfishing *</b>

## Stock Assessment Result Summary

SAFS 2019 stock status                      **Sustainable \***

\* Commonwealth stock status classification of "Not overfished / Not subject to overfishing" (Patterson et al., 2019) and SAFS 2018 stock status classification of "Sustainable" (Emery et al., 2018) were based on previous version of Tiger flathead model (Day, 2016). Based on criteria for these classifications and results from the current model (Day, 2019), these classifications still apply.

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