Department of Primary Industries

Stock assessment report 2019 – Ocean Trawl Fishery (Inshore Prawn, Offshore Prawn, Deepwater Prawn and Northern Fish Trawl)

Bluespotted Flathead (*Platycephalus caeruleopunctatus*)

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EXECUTIVE SUMMARY

Stock status and rationale

This stock assessment for Bluespotted Flathead (*Platycephalus caeruleopunctatus*, CAAB 37 296007) was completed according to the Status of Australian Fish Stocks (SAFS) framework, using data up to and including 2018/19. The assessment is presented at the biological stock level – Eastern Australia.

A total allowable commercial catch (TACC) was first introduced for Bluespotted Flathead for the NSW Ocean Trawl Fishery in state waters north of Barrenjoey Point for the 2019/20 fishing season (1 May 2019 to 30 April 2020) and was set at 108.1 t. No catch quota was implemented for the Southern Fish Trawl Restricted Fishery in state waters south of Barrenjoey Point; however, those catches have been restricted by a combined flathead trip limit of 200 kg since 1996.

The recreational catch of Bluespotted Flathead in NSW waters accounts for approximately 74% of the total state harvest, when catches by interstate fishers are included, or 65% when only catches by NSW anglers are included. Recreational catches are limited by a daily bag limit of 10 (in total with Tiger Flathead, *Platycephalus richardsoni*) or 20 in possession, and all fisheries are restricted by a size limit of 33 cm total length (TL).

While the species distribution extends from southern Queensland to eastern Victoria, the Bluespotted Flathead stock is primarily fished in NSW state waters and no landings data are available for other jurisdictions, which include the Commonwealth, Queensland and Victoria. There are currently no cross-jurisdictional stock assessments, harvest strategies or resource allocation policies in place for the species.

Bluespotted Flathead is listed among the combined species taken under the basket Tiger Flathead total allowable catch (TAC) of the Commonwealth Southern and Eastern Scalefish and Shark Fishery (SESSF) in offshore waters south of Barrenjoey Point; however, the limited observer data available suggest that the species comprises a negligible proportion of the total catch.

On the basis of the first comprehensive NSW stock assessment in 2018, Bluespotted Flathead was assessed as a **sustainable stock** according to the SAFS criteria (Hall 2018a,b). The species was first included in the national reporting in 2018; however, only NSW data contributed towards the assessment.

The 2018 NSW assessment used a modified Catch-MSY approach, and recommended that the TACC for Bluespotted Flathead should not exceed the lower bound of the 95% confidence limit of the estimated MSY, which equated to approximately 164 t (including 'Flathead (other)' catches for the prawn trawl sector) to ensure no further depletion of the stock. Fixed catch projections suggested that a TACC of less than 109 t would be required to recover the estimated biomass of the stock from 32.7–34% towards 40% depletion within 5 years. The many limitations of the modified Catch-MSY approach were acknowledged.

On the basis of this 2019 NSW assessment, the current status of Bluespotted Flathead has been assessed as a **sustainable stock** due to increasing or stable trends in standardised catch rates over the last 3 years, stable size and age structures and estimates of fishing mortality approximately equal to natural mortality for over 45 years.

Status indicators and limit reference levels	
Biomass indicator or proxy	None specified in a formal harvest strategy. In the interim, for the purposes of this stock assessment a weight-of-evidence approach was used, which included: the mean estimated biomass depletion (as a percentage of the estimated maximum biomass, *K*) from modified Catch-MSY analyses (e.g., Martell and Froese 2013); and annual standardised catch rates from the fish trawl (otter trawl) and ocean prawn (otter trawl) sectors of the Ocean Trawl Fishery.
Biomass limit reference level	None specified in a formal harvest strategy. In the interim, for the purposes of this stock assessment the following were selected: 20% of the estimated maximum biomass for the limit reference point (B_{lim}) and 48% of the estimated maximum biomass as the target reference point (B_{targ}), in line with the *Harvest Strategy Framework for the Commonwealth Southern and Eastern Scalefish and Shark Fishery* (AFMA 2017); and significant declines in standardised catch rates over more than 3 years as a trigger reference point.
Fishing mortality indicator or proxy	None specified in a formal harvest strategy. In the interim, for the purposes of this stock assessment a weight-of-evidence approach was used, which included: the estimated mean annual harvest rate from modified Catch-MSY analyses; and fishing mortality estimates from length-converted catch-curve analyses of length frequencies from commercial catches.
Fishing mortality limit reference level	None specified in a formal harvest strategy. In the interim, for the purposes of this stock assessment the following were selected: estimated harvest rate corresponding to 20% of estimated maximum biomass for the limit reference point (H_{lim}) and the estimated harvest rate corresponding to when the stock is a 48% of estimated maximum biomass for the target reference point (H_{targ}), in line with the *Harvest Strategy Framework for the Commonwealth Southern and Eastern Scalefish and Shark Fishery* (AFMA 2017); and significant increases in fishing mortality estimates over more than 3 years as a trigger reference point.

Stock assessment results (results of review of indicators)	
Biomass status in relation to limit	Results of the modified Catch-MSY modelling (completed in 2018) suggest that the biomass of Bluespotted Flathead in NSW waters is depleted to 32.6–34.2% of the estimated maximum biomass, irrespective of which historical catch series was used in the analyses.

Stock assessment results (results of review of indicators)	
	This is below the B_{targ} reference point of 48% of estimated maximum biomass, but above the B_{lim} reference point of 20%. Standardised catch rates have been above or near the long-term (21-year) averages for the last 10 years for monthly recorded data, but near or below shorter-term (9-year) averages for the last 6 years for daily recorded data. In all cases, increasing or stable trends are evident in catch rates over the last 3 years. The longer-term catch rates must be interpreted with caution due to the potential influence of catch reporting changes in July 2009. Annual length frequencies of fish sampled from the commercial catch over a period spanning 51 years suggest that the size structure of the population has remained stable. The weight of evidence indicates that the biomass of the stock is unlikely to be recruitment overfished and that current harvest rates are permitting some biomass recovery towards B_{targ}.
Fishing mortality in relation to limit	Results of the modified Catch-MSY modelling suggest that the current harvest rate of Bluespotted Flathead in NSW waters is below H_{lim} and either close to or below H_{targ}, depending on which historical catch series was analysed. The fishing mortality estimates from the length-converted catch-curve analyses supported this finding when the average estimate of natural mortality (M=0.49) was used. However, these latter results are very sensitive to the assumed value of M and should be treated with caution. The weight of evidence indicates that the current level of fishing pressure is unlikely to cause the stock to become recruitment overfished.
Previous stock status	Bluespotted Flathead was previously assessed as a **sustainable stock** under the SAFS framework in 2018.
Current stock status	Bluespotted Flathead is currently assessed as a **sustainable stock** on the basis of this NSW stock assessment.

Important considerations for TACC determination

The following are important points regarding this stock assessment to consider with respect to TACC determination:

- Overall, the data collated in this stock assessment suggest that the input controls used to manage effort in the commercial OTF have proved effective at reducing effort levels between 1997/98 and 2018/19 and consequently fishing pressure on Bluespotted Flathead.
- Assessment results suggest that the biomass of Bluespotted Flathead has been gradually depleted through a long history of removals and is currently estimated to be at 32–34% of the estimated maximum biomass.
- The modified Catch-MSY modelling approaches used to derive these estimates are very simplistic and generic, and results should be interpreted with caution.
- Recent increasing or stable trends in catch rates and slightly lower fishing mortality estimates suggest that current harvest rates are sustainable and may be permitting some recovery of biomass.
- The potential influence of catch reporting changes on commercial catch rates (especially during the transition from monthly to daily reporting around July 2009) limits their application as an index of relative abundance.
- Ongoing misreporting of multi-day trips as single fishing events further compromise the accuracy of current catch-rate data.
- Future harvest rates should be set to allow for the high uncertainty in this assessment and ensure further recovery of the biomass toward B_{targ}.
- The large recreational harvest of Bluespotted Flathead comprises at least 74% of the annual total harvest, based on three point estimates, and is likely to exceed that quantity given an unknown and unaccounted-for potential discard mortality among the large number of fish released.
- The uncertainty regarding the magnitude of, and temporal variation in, total removals by the recreational sector complicates interpretation of the modified Catch-MSY modelling results.
- Likewise, the uncertainty around the accuracy of historical commercial catch data (especially prior to July 1990) and unknown temporal variation in discards should be considered when interpreting the results of the modified Catch-MSY modelling.
- Updated discard estimates will be available from the recent prawn trawl observer survey (in 2017-2019); however, discarding practices and rates are likely to change following the introduction of catch quota in May 2009 and the observer surveys for the OTF have now ceased.
- Ongoing issues with flathead species misidentification and misreporting as 'Flathead (other)' also cause further uncertainty in catch data.
- There may also be unknown quantities of catch taken in other jurisdictions that overlap with the species' distribution.
- Data assessed in this report date only as far back as 1947/48. Trawl fishing in NSW waters is known to have occurred since at least 1920. Even if Bluespotted Flathead were not retained from trawling before 1947/48, they are still likely to have been caught by trawl gears as by-catch. Any potential historical discard or targeted mortality prior to 1947/48 has not been considered in this stock assessment.

1. Introduction

This stock assessment report for Bluespotted Flathead (*Platycephalus caeruleopunctatus*, CAAB 37 296007) reviews information to inform an assessment of the biological stock status against the criteria for the Status of Australian Fish Stocks (SAFS) and aid determination of a total allowable commercial catch (TACC) in New South Wales (NSW) waters for the 2020/21 fishing season. The aims of the report are to: (1) compile and analyse recent fisheries statistics to inform the assessment; (2) assess and determine the status of the biological stock; (3) outline information and data limitations and uncertainty in the assessment; and (4) provide comment on the strategic direction for future research and assessment.

A thorough assessment of all historical data available for Bluespotted Flathead was completed in 2018 (Hall 2018b). This current stock assessment report updates the fisheries statistics and some assessments to include recent data up to and including 2018/19. While some unavoidable repetition with the previous report was required for completeness, other components that were completed in 2018 are only briefly summarised in the current report, and for more comprehensive data and analyses on those refer to Hall (2018b).

1.1. Stock structure

The Bluespotted Flathead occurs in estuarine and coastal waters (to depths of 80 m) from southern Queensland to eastern Victoria. The stock structure of Bluespotted Flathead has not been formally investigated and remains unknown. However, a review of the species' taxonomy that examined specimens from along the NSW coast and Lakes Entrance, Victoria, identified no significant variation in morphological characters within the species (Imamura 2015). Limited tagging data also suggest that, while some individuals show high site fidelity in estuarine habitats, other individuals move large distances in coastal waters within a short period (Fetterplace et al. 2016). Therefore, some longshore mixing of populations is possible. On the basis of this evidence, assessment of the stock status of Bluespotted Flathead is presented at the biological stock level – Eastern Australia (Hall 2018a).

1.2. Biology

The abundance and life history of Bluespotted Flathead vary significantly with water depth and latitude (Liggins 1996; Barnes et al. 2011; Barnes 2012). Juveniles (<25 cm total length, TL) are more common in inshore waters that are shallower than 30 m depth; while mature adults occur in deeper waters to 80 m depth. Because the shape of the continental shelf varies from wide and shallow along the north coast to narrow and steep along the south coast, the distribution and size structure of Bluespotted Flathead also varies, which in turn influences catches and discard rates along the NSW coast (Liggins 1996; Barnes et al. 2011; Barnes 2012).

Bluespotted Flathead reaches a maximum size of about 68 cm TL and 3 kg in weight, with a pronounced sexual dimorphism. Females attain larger sizes than males at equivalent ages (Barnes et al. 2011). Males mature at about 1 year of age and 21 to 23 cm TL; while females mature later than males at 2 years of age and 28 cm TL in northern NSW and at 3 years of age and 35 cm TL in central NSW. The species is relatively fast growing and short-lived, reaching a maximum recorded age of just 9 years (Table 1).

Table 1 **Biological parameters for Bluespotted Flathead sourced from publications or estimated in this stock assessment.**

Parameter	Value	Data type	Source, reference
Maximum age (longevity), years	9	Sectioned otoliths (prawn trawl samples)	(Barnes et al. 2011)
Natural mortality (M)	0.65 0.33	Updated Hoenig equation Updated Pauly equation (data from prawn trawl samples)	(Then et al. 2014; Hall 2018b)
Asymptotic maximum length (Linf vB), cm	59.0	Sectioned otoliths (prawn trawl samples)	(Barnes et al. 2011; Hall 2018b)
Brody growth coefficient (K vB)	0.20	Sectioned otoliths (prawn trawl samples)	(Barnes et al. 2011; Hall 2018b)
Theoretical age at zero length (t0 vB)	-1.32	Sectioned otoliths (prawn trawl samples)	(Barnes et al. 2011; Hall 2018b)
Weight at age a parameter (Waa)	0.0046	Port monitoring (trawl catches)	(Hall 2018b)
Weight at age b parameter (Wab)	3.1014	Port monitoring (trawl catches)	(Hall 2018b)
Age at 50% maturity (M50a)	F: 1.8–3.0 M: 1.0–1.1	Prawn trawl samples	(Barnes 2012)

2. Fisheries statistics

2.1. Catch information

Commercial catches of Bluespotted Flathead in NSW waters are primarily taken by the ocean prawn trawl (OPT) and northern fish trawl (NFT) sectors of the Ocean Trawl Fishery (OTF), with smaller catches reported by the Southern Fish Trawl (SFT) Restricted Fishery, which operates south of Barrenjoey Point. Much smaller catches are also reported by commercial fishers in the NSW Estuary General Fishery (EGF, mostly using mesh nets) and Ocean Trap and Line Fishery (OTLF, mostly using handlines) (Figure 1). Bluespotted Flathead is also an important species for the NSW recreational and charter boat fisheries, with the former recently accounting for the largest estimated catches of the species in NSW state waters.

Although the SFT sector is considered a separate fishery from the OTF for management purposes and is currently under transfer to Commonwealth management, fishers use identical fishing gears to the NFT sector of the OTF and target the same Bluespotted Flathead stock. So, until the transfer is completed and for the purposes of this report, SFT data have been included in all OTF data summaries, either as an additional sector or combined with NFT data and collectively referred to as the 'fish trawl sector'. In addition, a few fishers within the fish trawl sector use Danish seine gears. In most instances these data have been combined with the fish trawl (otter trawl) data to overcome confidentiality issues; however, they are excluded from all catch-rate analyses because of the vastly different catching efficiencies of the two methods.

The ocean prawn trawl (OPT) sector also use otter trawls, but these differ in mesh size and codend configuration from the fish trawls, so these data are analysed separately where required. At times OPT data are further broken down into to the three endorsement types of inshore (out to 3 nm from the coastline), offshore (out to the 4,000 m depth contour) and deepwater (east of the 4,000 m depth contour) prawn trawl. Fishers are permitted to, and many do, hold multiple endorsements in the OTF and SFT fisheries.

Given the small amount of commercial catch taken in other fisheries, the finer-scale analyses of commercial catch-and-effort data are limited to the OTF data only; however, all sources of removals and discards are included in any analyses involving total catches.

2.1.1. Commercial

Total annual reported commercial catches of Bluespotted Flathead in NSW are available since 1947/48 to present (Figure 1 and Table 2). The prawn trawl component of the 'Flathead unspecified' data are also included in the historical catch series, because anecdotal evidence from fishers suggest that these likely comprise mostly Bluespotted Flathead (Hall 2018b). Early catches fluctuated considerably and then stabilised during the 1990s and 2000s at around 100–200 t per annum. Over recent years, catches have decreased from 210 t in 2010/11 to an historical low of 95 t in 2014/15 and then increased again to 146.2 t in 2017/18 and 123.5 t in 2018/19 (Figure 1 and Table 2). The data for the 2018/19 fiscal year are likely to be incomplete at this stage.

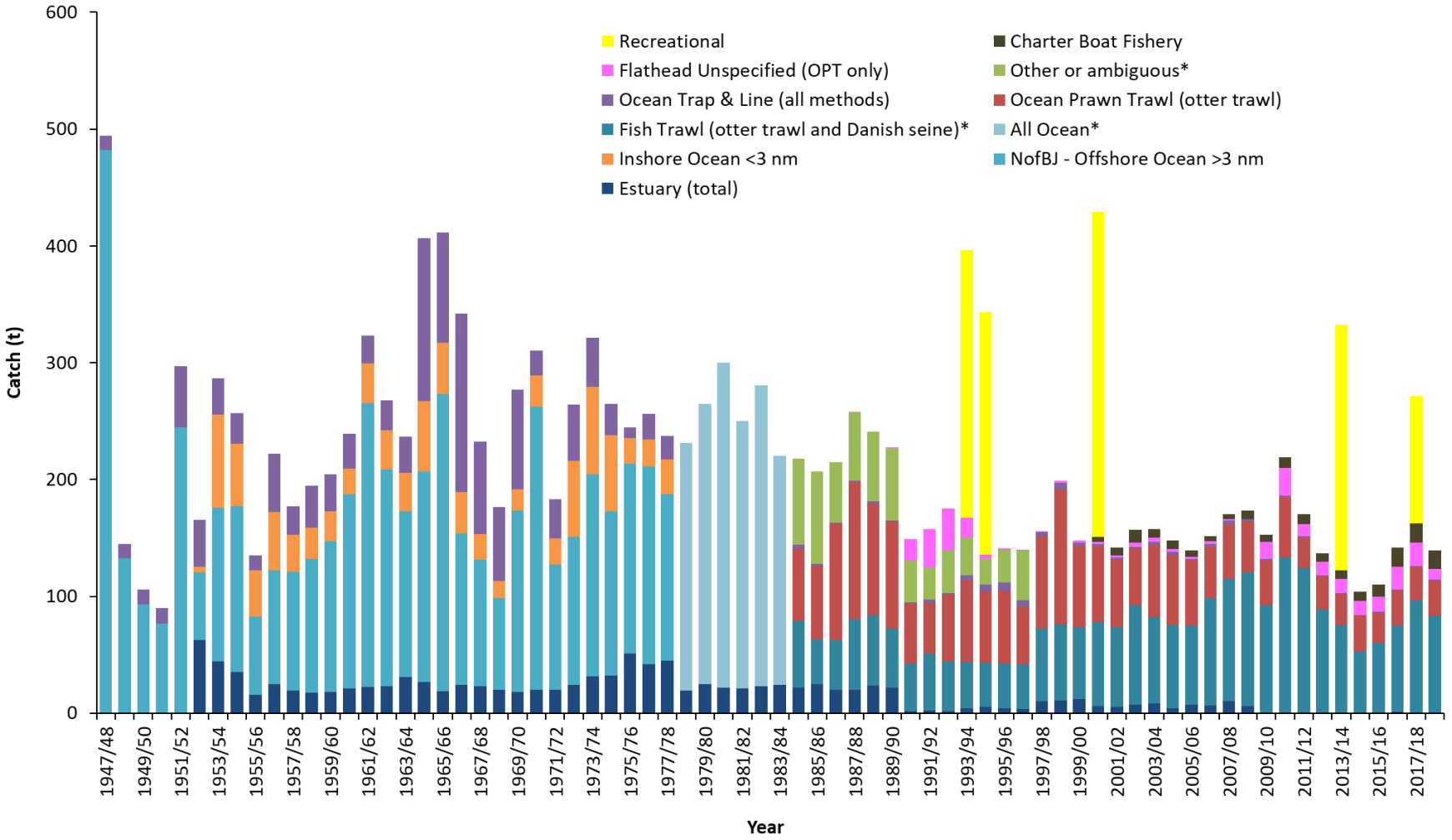


Figure 1 Annual total catch (tonnes) of Bluespotted Flathead for all sectors in NSW waters between 1947/48 and 2018/19. Data from 2018/19 are likely to be incomplete. Offshore catches are only included north of Barrenjoey Point (NofBJ) and data in some sectors (*) and years (1978/79–1989/90) have been adjusted south of BJ to remove Commonwealth catches. Recreational catch data are available from four periods, with the estimate from 2017/18 a partial sample of NSW anglers. Charter boat data are only available after 2000/01. OPT=Ocean Prawn Trawl.

Table 2 **Annual commercial catch (tonnes) of Bluespotted Flathead reported by NSW fisheries between 1947/48 to 2018/19. Data from 2018/19 are likely to be incomplete. Offshore catches are only included north of Barrenjoey Point (NofBJ) and data in some sectors (#) and years (1978/79–1989/90) have been adjusted south of BJ to remove Commonwealth catches. OPT=Ocean Prawn Trawl**

Fiscal Year	Offshore Ocean >3 nm (NofBJ only)	Inshore Ocean <3 nm	Ocean (all methods)#	Ocean Prawn Trawl (OPT) (otter trawl)	Fish Trawl (otter trawl and Danish seine)#	Other or ambiguous methods#	Ocean Trap and Line (all methods)	Estuary (all methods)	Flathead Unspecified (OPT)	Total NSW all sectors + Unspecified (OPT)
1947/48	482.2						12.0			494.1
1948/49	132.6						12.3			144.9
1949/50	93.0						13.1			106.1
1950/51	76.5						13.8			90.3
1951/52	244.6						52.5			297.1
1952/53	57.7	5.2					40.0	62.5		165.4
1953/54	131.8	79.5					30.8	44.3		286.5
1954/55	141.7	53.8					26.0	35.4		256.8
1955/56	66.4	40.1					12.8	16.0		135.4
1956/57	97.5	49.7					49.7	25.0		221.9
1957/58	101.8	31.7					23.9	19.5		176.9
1958/59	114.3	26.7					35.8	17.7		194.6
1959/60	129.4	25.2					31.9	18.1		204.6
1960/61	166.3	21.7					29.9	21.4		239.3
1961/62	243.0	34.1					24.0	22.4		323.5
1962/63	186.1	33.5					25.6	22.9		268.1
1963/64	142.0	33.0					30.8	30.9		236.6
1964/65	180.3	60.3					139.8	26.4		406.9
1965/66	254.3	44.3					93.8	18.7		411.2
1966/67	129.7	35.4					152.6	24.5		342.1
1967/68	107.9	22.4					79.1	23.3		232.7
1968/69	78.2	15.2					63.3	20.1		176.7
1969/70	155.6	18.0					85.2	17.9		276.7
1970/71	242.4	27.1					21.1	19.8		310.4
1971/72	107.7	22.0					33.8	19.7		183.3
1972/73	126.5	64.9					48.6	24.5		264.4
1973/74	172.8	74.8					41.8	31.7		321.1
1974/75	140.6	64.8					26.8	32.4		264.7
1975/76	162.2	22.1					9.2	51.2		244.7
1976/77	169.5	23.0					22.2	41.7		256.3
1977/78	142.5	29.4					20.1	45.1		237.1
1978/79			211.8					19.5		231.3
1979/80			239.9					24.9		264.8
1980/81			278.3					21.8		300.1
1981/82			229.1					21.0		250.1
1982/83			257.4					23.0		280.4
1983/84			195.7					24.4		220.1
1984/85				61.2	57.3	73.6	3.6	22.0		217.7
1985/86				62.8	38.3	79.2	1.9	24.7		207.0
1986/87				99.7	42.7	51.7	1.0	19.9		214.9
1987/88				117.7	60.2	58.5	1.1	20.0		257.6
1988/89				95.5	60.4	60.0	1.7	23.5	0.0	241.1
1989/90				91.9	50.5	62.1	1.0	21.8	0.4	227.6
1990/91				51.5	40.9	35.8	0.7	1.9	18.1	148.9
1991/92				42.8	49.1	27.5	2.9	2.2	33.2	157.7
1992/93				57.4	42.2	36.6	1.5	2.0	35.4	175.0
1993/94				69.9	39.8	32.1	4.5	4.0	17.0	167.3
1994/95				61.3	37.8	22.2	5.6	5.3	3.5	135.7
1995/96				62.6	37.9	27.8	7.1	4.4	1.2	141.1
1996/97				49.3	38.3	42.5	5.7	3.5	0.6	139.8
1997/98				79.1	62.0	0.2	3.5	10.4	0.9	156.0
1998/99				116.1	64.8	0.2	5.0	11.0	2.0	198.9
1999/00				69.6	61.1	0.1	2.9	12.2	2.4	148.2
2000/01				65.6	71.6	0.0	1.6	5.9	2.0	146.7
2001/02				57.8	67.6	0.0	1.9	5.6	2.3	135.4
2002/03				48.7	85.0	0.0	1.1	7.3	3.7	145.7
2003/04				62.5	73.3	0.0	2.2	8.7	3.5	150.1
2004/05				59.7	71.0	0.1	2.9	4.4	2.6	140.7
2005/06				55.8	67.6	0.0	1.3	7.1	2.0	133.9
2006/07				43.7	92.0	0.0	2.6	6.7	2.5	147.5
2007/08				46.9	105.1	0.0	2.6	10.1	1.4	166.1
2008/09				44.1	114.3	0.1	2.0	5.9	0.2	166.4
2009/10				38.3	92.1	0.0	1.0	0.5	14.6	146.4
2010/11				51.5	133.1	0.0	1.3	0.3	24.0	210.2
2011/12				26.1	124.2	0.0	1.4	0.1	9.9	161.6
2012/13				28.6	88.2	0.0	0.9	0.6	11.2	129.4
2013/14				26.4	74.8	0.0	0.6	0.8	12.4	115.0
2014/15				31.0	52.3	0.0	0.2	0.5	12.1	96.1
2015/16				25.8	59.7	0.0	0.7	0.6	13.1	99.9
2016/17				30.1	74.0	0.0	1.1	0.9	19.5	125.6
2017/18				28.3	96.5	0.0	0.5	0.5	20.3	146.2
2018/19*				29.9	83.3	0.0	0.8	0.3	9.3	123.5

Sectors and fishing methods

Since 1998, the proportion of Bluespotted Flathead commercial catch taken by the OPT has gradually decreased relative to that of the NFT (Figure 2 and Table 3). The recent decreases in commercial catches between 2010/11 and 2014/15 and then increases over the last 3 years have been due to fluctuations in the NFT sector. In 2018/19, the NFT accounted for 71.2% of the OTF catch of Bluespotted Flathead (Figure 2).

Catches in the offshore prawn sector have also been consistently higher than those in the inshore sector (Table 3); although reporting according to these endorsement codes is known to be quite inaccurate (Hall 2018b). Given that few Bluespotted Flathead are caught in waters >80 m depth, any records attributed to the deepwater endorsement are likely to be errors and have been excluded from these analyses.

The data in Figure 2 and Table 3 have been summarised according to the endorsement codes reported by fishers, rather than reported capture locations. However, endorsement codes are only available for data after July 2009, so for preceding years, the fish trawl catch in OZ6 was divided according to the average percentage of catch north and south of Barrenjoey Point in recent data, and the southern portion combined with data from OZ7–OZ10 to allocate a catch amount to the SFT based on capture location.

There has been considerable misreporting of catches (31.6% of the total Bluespotted Flathead catch) against non-permissible endorsement code and location combinations by OTF fishers since July 2009 (Hall 2018b). Therefore, if the fish trawl catches were allocated according to reported capture locations rather than endorsement codes, different annual totals for the two sectors would result than those presented in Figure 2 and Table 3. Similarly, the total catches of the inshore and offshore prawn sectors allocated according to reported capture locations rather than endorsement codes would also differ from those presented.

Management zones

Historically, commercial ocean catches were reported against 10 broad ocean zones (covering 1 degree latitude) along the NSW coast from the Queensland to Victorian borders (OZ1–OZ10, see Appendix Figure 1A). Recent catch data, since July 2009, have been collected at a finer spatial scale (0.1 degree C-square grid) and re-aggregated into the broad ocean zones to produce a longer time-series of data.

The distribution of OTF catches across the 10 ocean zones are related to the main fishing areas of the ocean trawl sectors (Figures 3, 4 and Table 4). Along the north coast (OZ1–OZ3), the OPT is the only sector permitted to fish, and catches have gradually decreased over time with the reduced effort in this sector. Catches in OZ2 historically dominated commercial catches of Bluespotted Flathead, but have substantially declined since 1997/98 (Figure 4).

In contrast, along the central coast (OZ4–OZ6), where the NFT are the only sector permitted to retain Bluespotted Flathead, catches have increased between 2006/07 and 2010/11, decreased to a minimum in 2014/15 and then increased again over the last 3 years (Figure 4). In particular, catches from OZ4 and OZ5 account for most of the recent increases in total commercial catches.

Catches along the south coast (OZ6–OZ10) have remained relatively stable, but only account for on average 10.6% of the total commercial catch. However, the catch quotas introduced for Bluespotted Flathead in May 2019 only apply to the OPT and NFT sectors north of Barrenjoey Point, so the unrestrained SFT catches south of Barrenjoey Point may increase.

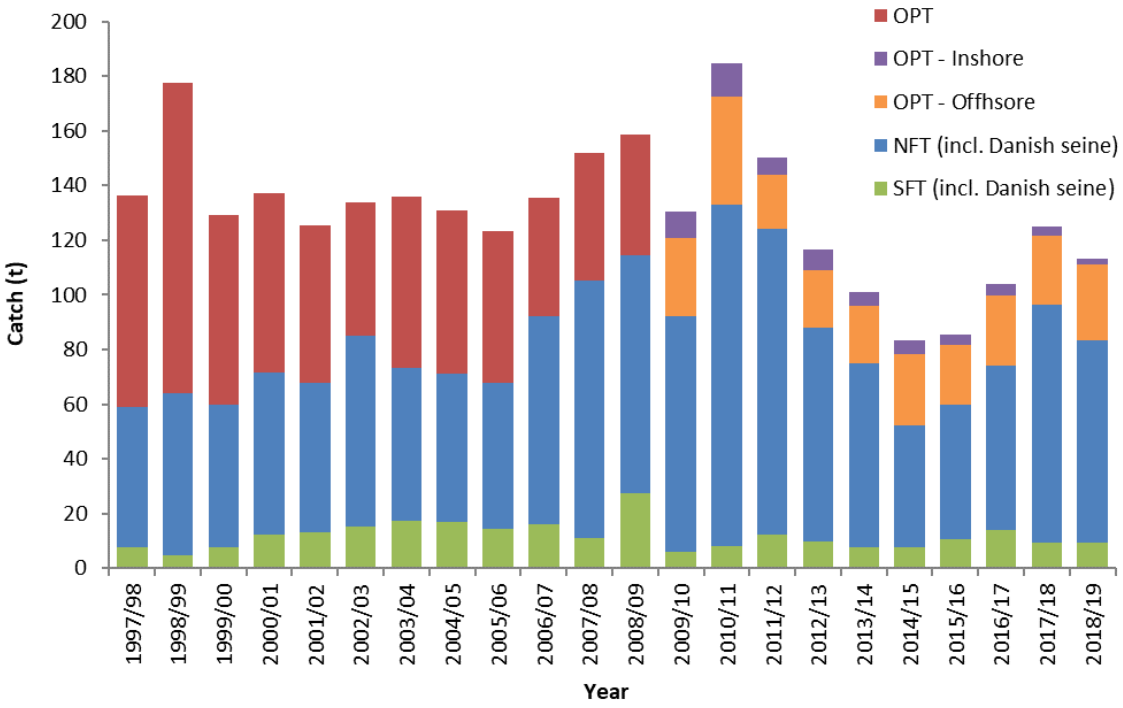


Figure 2 Annual commercial catches (tonnes) of Bluespotted Flathead in NSW waters (1997/98–2018/19) for different sectors and endorsements in the NSW Ocean Trawl Fishery. OPT=ocean prawn trawl, NFT=northern fish trawl, SFT=southern fish trawl.

Table 3 Annual commercial catches (tonnes) of Bluespotted Flathead in NSW waters (1997/98–2018/19) for different sectors and endorsements in the NSW Ocean Trawl Fishery (OTF). OPT=ocean prawn trawl, NFT=northern fish trawl, SFT=southern fish trawl.

Fiscal Year	NFT (incl. Danish seine)	SFT (incl. Danish seine)	OPT Inshore	OPT Offshore	OPT Total	Total Ocean Trawl Fishery	Total OTF (excl. SFT)
1997/98	51.2	7.6			77.7	136.5	129.0
1998/99	59.5	4.5			113.7	177.7	173.2
1999/00	52.0	7.8			69.2	129.0	121.2
2000/01	59.3	12.3			65.6	137.2	124.9
2001/02	54.4	13.2			57.8	125.5	112.3
2002/03	69.6	15.4			48.7	133.7	118.4
2003/04	55.9	17.4			62.5	135.8	118.4
2004/05	54.2	16.9			59.8	130.8	113.9
2005/06	53.1	14.5			55.9	123.5	109.0
2006/07	76.0	15.9			43.7	135.7	119.8
2007/08	93.9	11.1			47.0	152.0	140.9
2008/09	86.7	27.6			44.2	158.4	130.8
2009/10	86.2	5.9	9.5	28.7		130.3	124.4
2010/11	125.0	8.2	12.0	39.5		184.6	176.4
2011/12	111.9	12.3	6.5	19.5		150.2	138.0
2012/13	78.6	9.6	7.7	20.9		116.7	107.2
2013/14	67.2	7.6	5.4	21.0		101.2	93.6
2014/15	44.5	7.8	4.8	26.2		83.3	75.5
2015/16	49.0	10.7	3.9	21.9		85.5	74.8
2016/17	60.1	13.9	4.3	25.8		104.1	90.2
2017/18	87.1	9.4	3.1	25.3		124.8	115.4
2018/19	74.1	9.2	2.2	27.8		113.2	104.1

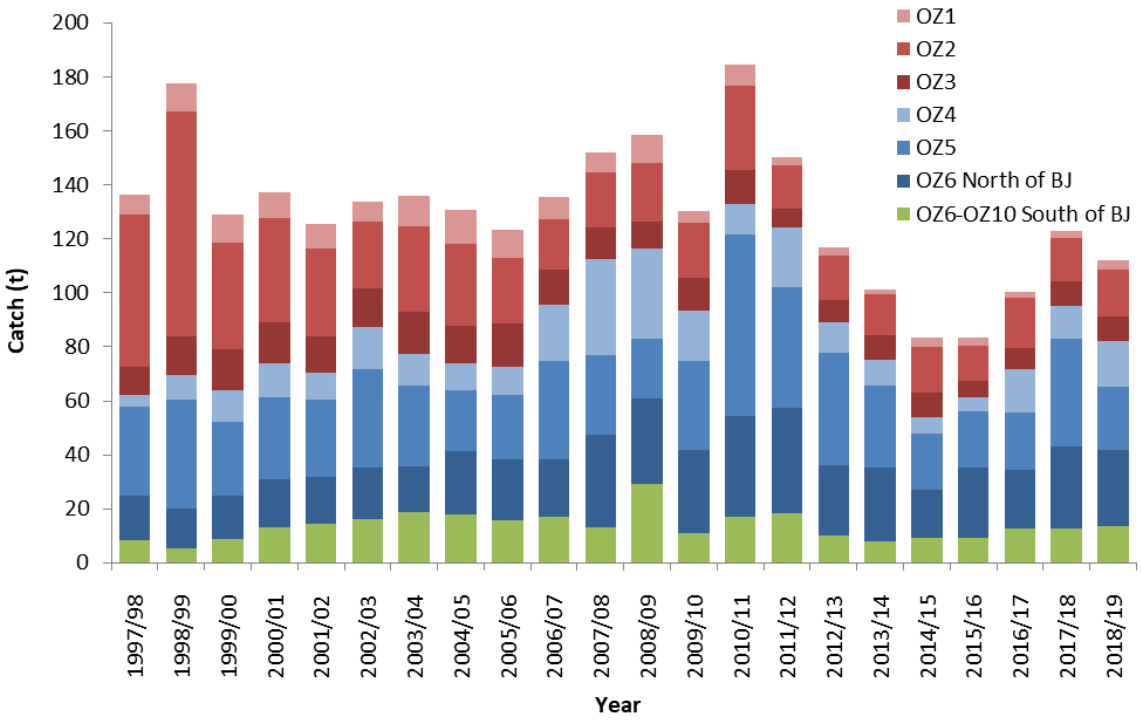


Figure 3 Annual commercial catches (tonnes) of Bluespotted Flathead from the NSW Ocean Trawl Fishery reported in different fishing zones (OZ1–OZ10), with catches in OZ6 divided into amounts taken from north and south of Barrenjoey Point (BJ) and zones south of BJ aggregated for confidentiality reasons.

Table 4 Annual commercial catches (tonnes) of Bluespotted Flathead from the NSW Ocean Trawl Fishery reported in different fishing zones (OZ1–OZ10), with catches in OZ6 divided into amounts taken from north and south of Barrenjoey Point (BJ) and zones south of BJ aggregated for confidentiality reasons.

Fiscal Year	OZ1	OZ2	OZ3	OZ4	OZ5	OZ6 North of BJ	OZ6-OZ10 South of BJ
1997/98	7.6	56.4	10.4	4.5	32.8	16.4	8.4
1998/99	10.5	83.5	14.1	9.3	40.1	14.7	5.5
1999/00	10.6	39.2	15.5	11.7	27.0	16.2	8.8
2000/01	9.6	38.6	15.2	12.6	30.1	17.9	13.2
2001/02	9.2	32.4	13.4	9.9	28.7	17.3	14.6
2002/03	7.2	24.9	14.4	15.5	36.4	19.1	16.3
2003/04	11.3	31.7	15.6	11.6	30.0	17.0	18.6
2004/05	12.6	30.6	13.5	10.3	22.3	23.4	18.1
2005/06	10.5	24.2	16.0	10.6	24.0	22.5	15.7
2006/07	8.3	18.7	13.3	20.6	36.3	21.3	17.2
2007/08	7.6	20.2	11.5	35.7	29.4	34.2	13.3
2008/09	10.2	21.7	10.0	33.3	22.4	31.6	29.2
2009/10	4.5	20.1	12.5	18.5	33.0	30.8	11.0
2010/11	7.7	31.5	12.6	11.1	67.3	37.4	17.0
2011/12	3.0	15.8	6.9	22.2	44.7	39.2	18.3
2012/13	2.9	16.7	7.9	11.6	41.4	26.1	10.0
2013/14	1.6	15.3	9.0	9.6	30.4	27.0	8.1
2014/15	3.2	17.2	9.2	5.8	21.1	17.6	9.3
2015/16	2.7	13.0	6.3	5.2	20.7	25.9	9.4
2016/17	1.9	18.7	7.6	16.2	21.4	21.8	12.5
2017/18	2.8	15.8	9.3	11.9	40.2	30.0	12.9
2018/19	3.5	17.3	9.1	16.9	23.7	28.1	13.5

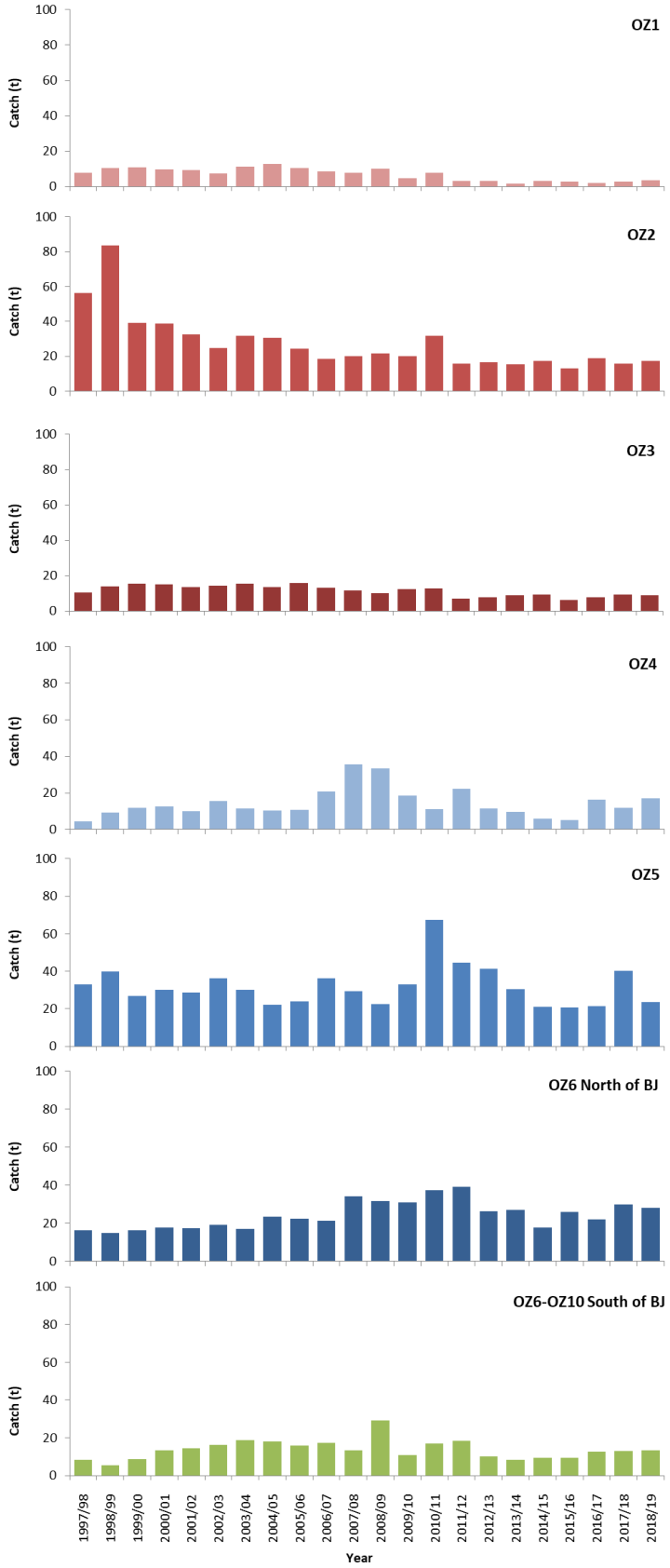


Figure 4 Annual commercial catches (tonnes) of Bluespotted Flathead from the NSW Ocean Trawl Fishery reported in different fishing zones (OZ1–OZ10), with catches in OZ6 divided into amounts taken from north and south of Barrenjoey Point (BJ) and zones south of BJ aggregated for confidentiality reasons.

Seasonal variation

Commercial catches of Bluespotted Flathead (pooled across sectors and zones in each year) tend to be higher in winter and spring and lower during summer and autumn, but this is not consistent across all years between 1997/98 to 2018/19 (Figure 5). Peaks in fishing activity associated with holiday periods, such as Christmas and Easter, and shifts in the targeting to different species by sectors in the OTF are likely to blur any seasonal variation that may be apparent in response to environmental factors or fish distribution. Bluespotted Flathead are taken primarily as a byproduct species to targeted fishing for Eastern King Prawn (*Melicertus plebejus*), Eastern School Whiting (*Sillago flindersi*) and Tiger Flathead (*Platycephalus richardsoni*).

2.1.2. Recreational and Aboriginal

Estimates of recreational catch are available from the *National Recreational and Indigenous Fishing Survey* in 2000/01 (Henry and Lyle 2003) and the NSW statewide surveys in 2013/14 (West et al. 2015) and 2017/18 (NSW DPI unpublished data) (Tables 5–7). Note, catches were reported by number of fish and harvest weights have been estimated by multiplying with the average weight of oceanic (0.462 kg) and estuarine (0.409 kg) fish derived from the charter boat observer program and recreational fishing haven surveys, respectively (Tables 6, 7). Recreational estimates also include chartered fishing events the anglers have undertaken during the survey period, so for years with recreational estimates, the charter logbook data should not be added to calculate the total NSW harvest. The recreational estimates for Bluespotted Flathead also include an unknown, but assumed to be small, quantity of Northern Sand Flathead (*Platycephalus endrachtensis*) and Southern Sand Flathead (*Platycephalus bassensis*).

In 2000/01, the estimated annual recreational catch of Bluespotted Flathead from NSW waters was 383 t (Henry and Lyle 2003), representing 74% of the total NSW harvest (when totalled with commercial catches). Within this estimate, a considerable portion of the catch was taken by interstate fishers, with the annual recreational catch of Bluespotted Flathead taken by NSW fishers alone in 2000/01 estimated as 278 t, representing 65.4% of the total NSW harvest. In 2013/14, the statewide survey estimated the annual recreational catch taken by NSW fishers had declined to 210 t (West et al. 2015), but as the commercial harvest had also declined by a similar proportion this still represented 64.6% of the total NSW harvest of Bluespotted Flathead.

The most recent survey in 2017/18 estimated that 109 t of Bluespotted Flathead was harvested by the 1–3 year recreational fishing licence holders and any other household members (NSW DPI unpublished data). This is a preliminary estimate and excludes catches by many other short-term licence holders and exempt categories of fishers, including those under 18 years of age and seniors. Therefore, while there appears to have been an over 50% decline in recreational harvest between 2013/14 and 2017/18, the latter estimate is only a partial amount of the total statewide catch and is not directly comparable. A comparable value (amount harvested by 1–3 year licence holders and other household members for the 2013/14 survey) is still being analysed, and will become the index that is routinely monitored for this sector in future biennial surveys.

Earlier estimates of recreational catches of Bluespotted Flathead in NSW waters covered more localised regions or single sectors. The most comprehensive of these was a survey of

marine trailer-boat fishers in 1993/94 and 1994/95, which estimated the annual ocean harvest of Bluespotted Flathead to be 229 t (59.9% of total NSW harvest) and 208 t (60.9%), respectively (Steffe et al. 1996). Scaling these estimates up to account for the missing estuarine and shore-based catches the total estimates would approximate around 65% of the total catch. Prior to 1993/94, no comprehensive estimates are available. Anecdotally, marine recreational fishing is thought to have mirrored the expansion in the number of trailer boats owned in NSW, which apparently increased from around the 1950s.

Recreational catches of Bluespotted Flathead in NSW waters are taken primarily by boat-based anglers in inshore ocean waters (<60 m depth) using lines with natural baits during the summer months (West et al. 2015). In 2013/14, the largest percentage of catches (39%) was taken in the mid south coast region (Figure 6). In 2017/18 the combined catches of the two southern regions accounted for 76.5% of the total recreational catch (Figure 6). This contrasts with the distribution of commercial catches, where on average only 10.6% of the catch is taken south of Barrenjoey Point.

A survey of Aboriginal cultural fishing in the Tweed River catchment identified Dusky Flathead (*Platycephalus fuscus*) as a significant component of finfish catches (Schnierer 2011) and remains have been identified in 4.4% of middens along the NSW coast (Schnierer and Egan 2016). Dusky Flathead were the only flathead species listed specifically on forms, so other common coastal and estuarine flathead species like Bluespotted Flathead and Northern Sand Flathead may have been included in the results. Certainly, flathead species and specifically Bluespotted Flathead, have been identified as culturally significant finfish groups for Aboriginal fishers in NSW (Schnierer and Egan 2016). Statewide estimates of the annual Aboriginal harvest of Bluespotted Flathead in NSW waters are unknown.

2.1.3. Charter boat

Bluespotted Flathead are one of the main target species in the NSW Charter Boat Fishery. Reported catches from this sector are available from logbook reporting from 2000/01 to 2018/19 (Figure 7, Table 8). Catches remained at <10 t in most years since 2000/01, until recent increases to 15.2–16.3 t over the last 3 years.

Previously, considerable under-reporting by this sector has been suspected because of an inability to reliably monitor reporting compliance prior to 2016. In 2016, the charter boat catch-and-effort reporting was integrated into the commercial systems and the requirement to submit a nil return for months when no fishing occurred was also introduced, which has improved current compliance. Therefore, the increase in reported catches over the last 3 years probably reflects improved reporting compliance rather than a genuine increase in catches.

Most catches in the Charter Boat Fishery are taken by handline and rods in coastal marine waters. Like recreational catches, charter boat catches are predominantly reported as taken from locations south of Barrenjoey Point rather than along the north coast, with the charter industry out of Sydney making up the bulk of operators. These reported data contrast with the results of a recent charter observer survey, which recorded higher catches in the north of the state (Gray and Kennelly 2018).

Note, catches were historically reported by numbers of fish only and harvest weights have been estimated by multiplying these by the average weight of fish sampled during the charter boat observer program (0.462 kg for ocean and 0.409 kg in estuaries).

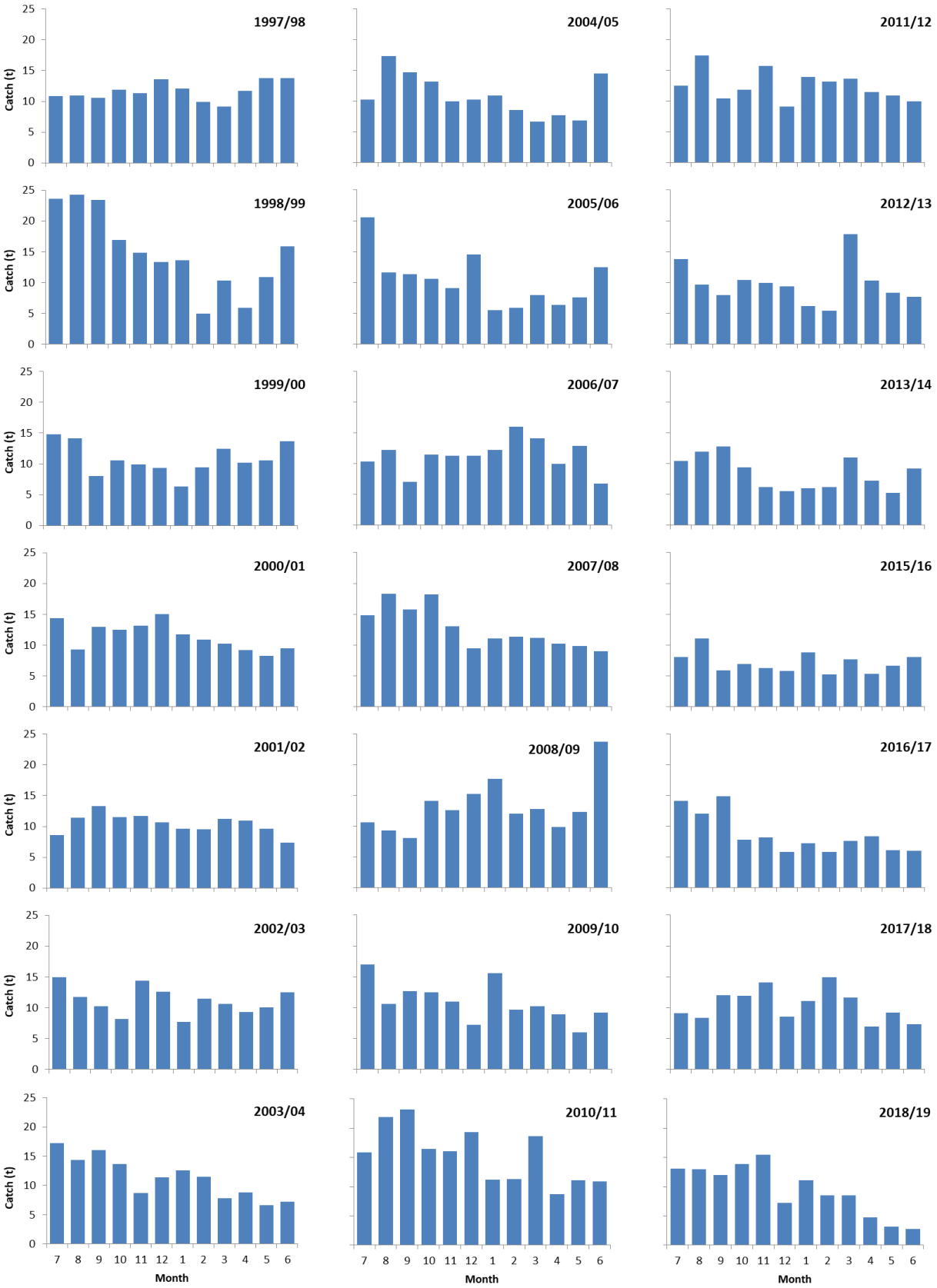


Figure 5 Monthly commercial catches (tonnes) of Bluespotted Flathead in the NSW Ocean Trawl Fishery (all methods combined) in each year between 1997/98 and 2018/19.

Table 5 Total estimated annual recreational catch (numbers of fish), harvest weight (tonnes) and discard weight (tonnes) of Bluespotted Flathead in all salt waters of NSW from surveys of recreational fishers. Data from Steffe et al. (1996) includes only boat-based fishing in ocean waters and data from 2017/18 includes only 1–3 year recreational fishing licence holders.

			All Saltwater			
Survey Year	No. fish retained	No. fish released	Estimated harvest wt (t)	Estimated discard wt (t)	% of Total catch (including commercial)	Reference
1993/94			229		59.9%	Steffe et al. 1996
1994/95			208		60.9%	Steffe et al. 1996
2000/01	694,378	689,767	278	277	65.4%	Henry and Lyle 2003
2000/01	with interstate catches included		383		74.0%	Henry and Lyle 2003
2013/14	440,763	522,129	210	247	64.6%	West et al. 2015
2017/18	237,628	290,540	109	132		NSW DPI unpublished

Table 6 Estimated annual recreational catch (numbers of fish), harvest weight (tonnes) and discard weight (tonnes) of Bluespotted Flathead in oceanic waters of NSW from surveys of recreational fishers. Data from Steffe et al. (1996) includes only boat-based fishing in ocean waters and data from 2017/18 includes only 1–3 year recreational fishing licence holders.

			Ocean			
Survey Year	No. fish retained	No. fish released	Estimated harvest wt (t)	Estimated discard wt (t)	Mean Kg/fish used	Reference
1993/94			229			Steffe et al. 1996
1994/95			208			Steffe et al. 1996
2000/01	694,378	689,767	278	277	0.402	Henry and Lyle 2003
2013/14	379,048	421,472	185	205	0.488	West et al. 2015
2017/18	220,519	254,442	102	118	0.462	NSW DPI unpublished

Table 7 Estimated annual recreational catch (numbers of fish), harvest weight (tonnes) and discard weight (tonnes) of Bluespotted Flathead in estuarine waters of NSW from surveys of recreational fishers. Data from Steffe et al. (1996) includes only boat-based fishing in ocean waters and data from 2017/18 includes only 1–3 year recreational fishing licence holders.

			Estuary			
Survey Year	No. fish retained	No. fish released	Estimated harvest wt (t)	Estimated discard wt (t)	Mean Kg/fish used	Reference
2000/01	-	-	0		0.402	Henry and Lyle 2003
2013/14	61,715	100,657	25	41	0.409	West et al. 2015
2017/18	17,109	36,098	7	15	0.409	NSW DPI unpublished

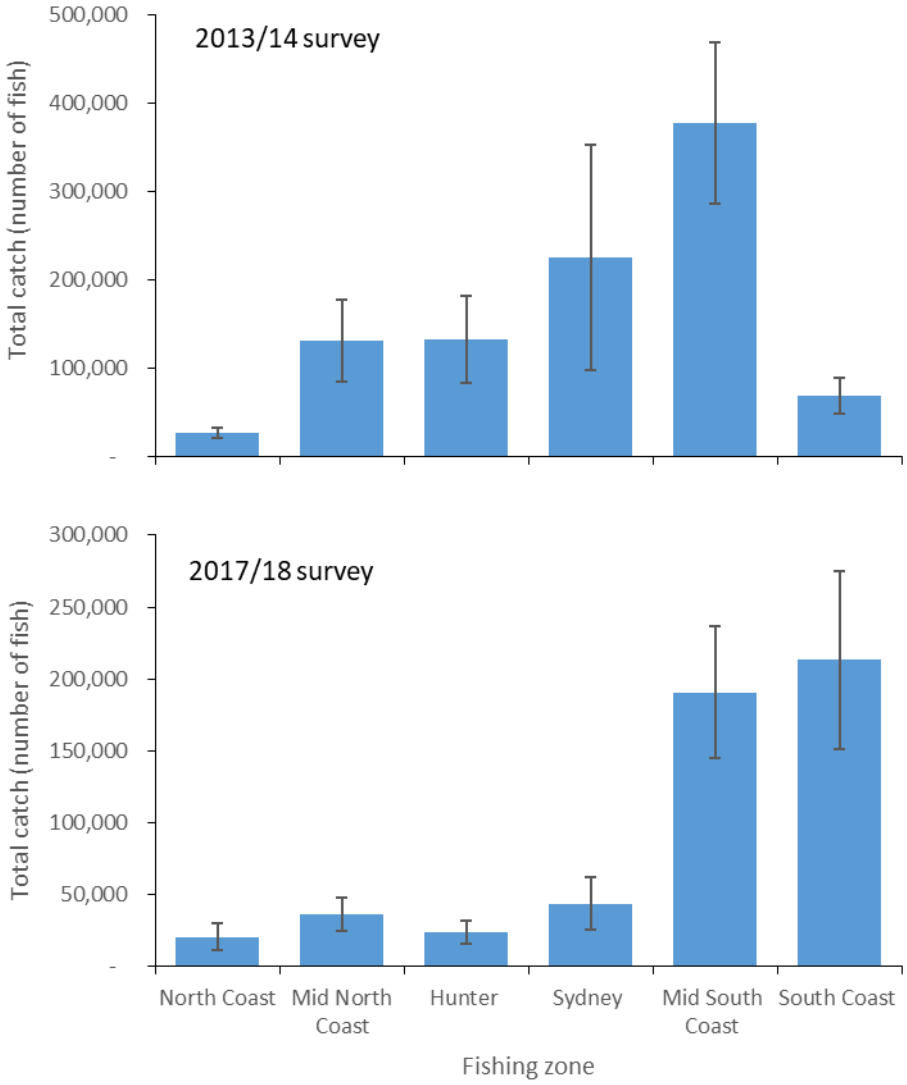


Figure 6 Estimated total recreational catch (kept and released numbers of fish) of Bluespotted Flathead by fishing zone from surveys of recreational fishers in 2014/13 (top) and 2017/18 (bottom). Data for 2014/13 from West et al. 2015; data for 2017/18 from NSW DPI unpublished, which comprises catch from 1–3 year recreational fishing licence holders only.

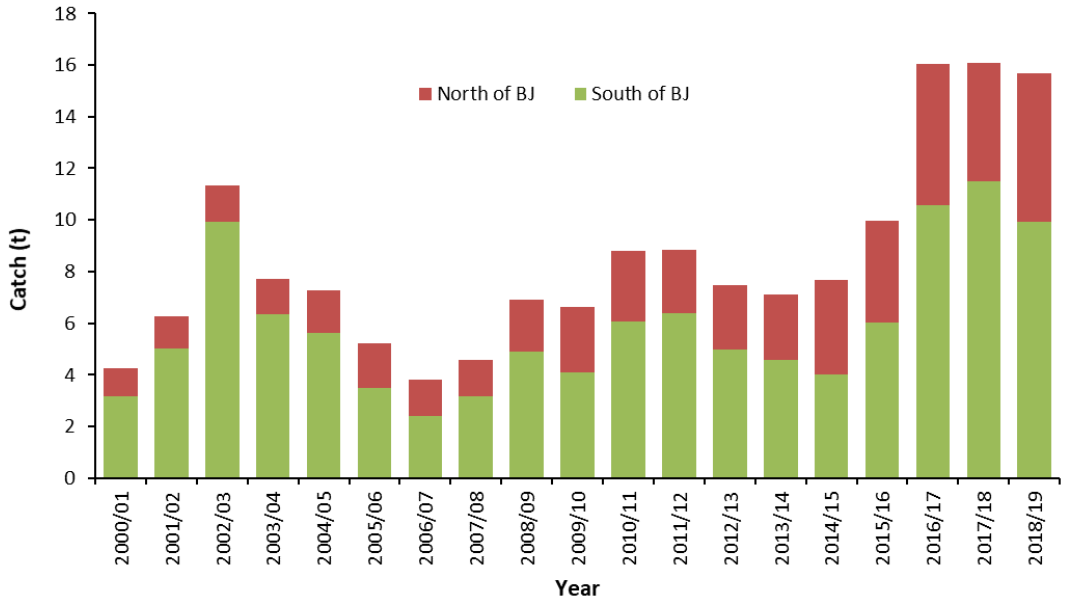


Figure 7 Estimated annual catch (tonnes) of Bluespotted Flathead in the NSW Charter Boat Fishery north and south of Barrenjoey Point (BJ). Catch weights were estimated from the numbers of fish reported multiplied by the estimated mean weight of fish (0.462 kg in ocean and 0.409 kg in estuaries).

Table 8 Annual reported catch (number of fish) and estimated harvest weight (tonnes) of Bluespotted Flathead in the NSW Charter Boat Fishery, with amounts taken north (NofBJ) and south (SofBJ) of Barrenjoey Point indicated. Harvest weights were estimated from the numbers of fish reported multiplied by the estimated mean weight of fish (0.462 kg in ocean and 0.409 kg in estuaries).

Year	No. fish NofBJ	No. fish SofBJ	Total No. fish	Estimated harvest wt NofBJ (t)	Estimated harvest wt SofBJ (t)	Total estimated harvest wt (t)
2000/01	2,392	6,905	9,297	1.1	3.2	4.3
2001/02	2,662	10,999	13,661	1.2	5.0	6.3
2002/03	3,033	21,524	24,557	1.4	9.9	11.3
2003/04	2,930	13,766	16,696	1.4	6.4	7.7
2004/05	3,576	12,177	15,753	1.7	5.6	7.3
2005/06	3,713	7,556	11,269	1.7	3.5	5.2
2006/07	3,064	5,232	8,296	1.4	2.4	3.8
2007/08	2,972	6,895	9,867	1.4	3.2	4.6
2008/09	4,337	10,585	14,922	2.0	4.9	6.9
2009/10	5,533	8,835	14,368	2.6	4.1	6.6
2010/11	5,947	13,141	19,088	2.7	6.1	8.8
2011/12	5,317	13,859	19,176	2.5	6.4	8.9
2012/13	5,354	10,816	16,170	2.5	5.0	7.5
2013/14	5,478	9,951	15,429	2.5	4.6	7.1
2014/15	7,963	8,648	16,611	3.7	4.0	7.7
2015/16	8,544	13,050	21,594	3.9	6.0	10.0
2016/17	11,857	22,878	34,735	5.5	10.6	16.0
2017/18	9,943	24,906	34,849	4.6	11.5	16.1
2018/19	12,440	21,511	33,951	5.7	9.9	15.7

2.1.4. Discards

Discard rates for the NSW OTF have been assessed for the prawn trawl sector in 1990–1992 (Table 9, Kennelly et al. 1998) and 2017–2019 (data still being analysed) and for the fish trawl sector in 1993–1995 (Table 10, Liggins 1996) and 2014–2016 (Table 11, Johnson 2018). Results from these projects indicate that discard rates were historically higher in the prawn trawl sector (60.4%) compared with the fish trawl sector (20–22%). This probably related to the larger quantity of small fish (<33 cm TL) found on the inshore prawn grounds along the north coast compared to the deeper waters of the south coast, different mesh sizes of the gears and variations in the market prices and catch rates of prawns (Liggins 1996; Graham and Wood 1997). In addition, prawn trawl fishers are not permitted to keep Bluespotted Flathead south of Smoky Cape (i.e., 100% discards including legal-sized fish), although there is less effort by the OPT fleet in that region. The historical discard estimates for the prawn trawl sector also preceded the introduction of BRDs into OTF nets in 1999, which would have affected the quantities of small fish by-catch and discards.

Data from the more recent prawn trawl observer survey in 2017–2019 are still being analysed, but preliminary results suggest that discard rates may have decreased (to approximately 30%, Johnson unpublished data). Furthermore, of the 1,484 shots observed during the survey, almost 50% did not contain any Bluespotted Flathead, most likely because the depth of fishing exceeded their habitat depth (45% of shots were in depths >80 m). Therefore, the decreased discard rates in the recent survey may relate to a combination of BRDs and changed fleet dynamics with fewer small vessels fishing in shallower northern waters.

Results from the recent fish trawl observer survey in 2014–2016, suggested that Bluespotted Flathead were discarded in response to both the size limit and trip limits in the SFT sector (Johnson 2018). In NSW waters, a minimum size limit of 33 cm TL has been in place for Bluespotted Flathead since at least 1971 (originally instated as 9 inches) (Pease and Grindberg 1995), and trip limits of <200 kg whole weight of all flathead species combined during each fishing trip have been applied to the SFT sector since 1996.

With the introduction of quota for a range of species in the NFT and OPT sectors in May 2009, discard rates are likely to change again. Fishers who do not hold quota for Bluespotted Flathead or who exhaust their quota allocation early may be forced to discard legal-sized fish at higher rates.

Large quantities of Bluespotted Flathead are also released by recreational fishers every year in response to bag and size limits (Henry and Lyle 2003; West et al. 2015). In 2013/14, in addition to the 210 t (440,763 individuals) of Bluespotted Flathead harvested, an additional 522,129 fish were released (i.e., 54.2% of the total catch by numbers; by weight this percentage is likely to be smaller due to inclusion of smaller undersized fish among discards). In 2017/18, a similar release rate (55.0%) of Bluespotted Flathead was recorded.

While post-release survival rates of Dusky Flathead and Southern Sand Flathead caught by anglers have been relatively high (91–97%) (Lyle et al. 2007; Butcher et al. 2008) these species are more commonly angled from shallow estuarine waters, and the deeper habitats from which Bluespotted Flathead are typically angled could potentially cause higher mortality rates through injuries associated with barotrauma. Although Bluespotted Flathead lack a swim bladder, expanded air trapped in other body cavities (e.g., behind the eyes and in the brain cavity) can still result in lethal complications associated with barotrauma in fish retrieved from

water depths of more than 10 m (Hannah et al. 2008). This question requires further scientific investigation for Bluespotted Flathead.

Charter boat fishers also reportedly release 53.7% of Bluespotted Flathead caught (Gray and Kennelly 2018); and these discards potentially suffer from barotrauma injuries associated with catch and release from deeper waters. Given the large quantities of Bluespotted Flathead released by recreational and charter boat fishers, quantifying the likely discard mortalities of caught-and-released fish is an important question for future research, because this could represent a significant unaccounted mortality from the stock.

Table 9 **Estimated retained and discarded catches (number of fish) of Bluespotted Flathead from prawn trawls observed in the NSW Ocean Trawl Fishery over 2 years between winter 1990 and autumn 1992. The estimated retained and discarded weights (kg) and percentage of each component were estimated from the mean total length (TL) of fish and equivalent weight from the length–weight relationship. SE=standard error. Reproduced with modification from Kennelly et al. (1998).**

Catch component	No. fish	SE No. fish	Mean TL of fish (cm)	Estimated equivalent Wt of fish (kg)	Estimated component wt (kg)	% wt
Retained	194200	82	40.5	0.446	86613	39.6%
Discarded	1972700	238	22.1	0.067	132171	**60.4%**

Table 10 **Estimated retained and discarded catches (tonnes) of Bluespotted Flathead from fish trawls observed in the NSW Ocean Trawl Fishery over 3 years (1993–1995). Data reproduced from Liggins (1996).**

Period	Total catch (t)	Retained catch (t)	Estimated discard wt (t)	% discard wt
1993	11 ± 2	9 ± 2	2 ± 0	15%
1994	16 ± 2	12 ± 2	4 ± 1	23%
1995	12 ± 2	10 ± 1	3 ± 1	21%
Mean	**13 ± 2**	**10 ± 1**	**3 ± 0**	**20%**

Table 11 **Reported catch and estimated total discard weight (kg) and mean percentage of catch discarded for Bluespotted Flathead from fish trawls observed in the NSW Ocean Trawl Fishery between spring 2014 and winter 2016. Data from three fishing zones (OZ4–OZ6) combined. Johnson, unpub. data.**

Period	Reported catch (kg)	Estimated discard wt (kg)	SE discard wt (kg)	% discard wt
Sep 14 - Aug 15	85872	12884	4306	22.5%
Sep 15 - Aug 16	94337	13216	2900	21.6%
Mean				**22.0%**

2.1.5. Illegal, unregulated and unreported

The level of illegal, unregulated and unreported (IUU) fishing is unknown; however, there is likely to be significant misreporting of bluespotted flathead as 'Unspecified Flathead' or 'Flathead (other)' in NSW waters (Hall 2018b). To partially account for this discrepancy, the prawn trawl component of these unspecified catches has been included in the historical catch series. In 2018/19 this equated to 9.3 t, but has been as high as 24 t in 2010/11 and 35.4 t in 1992/93 (Table 2).

The 'Unspecified flathead' species category was originally included on catch returns in July 1990 for fishers in the Commonwealth SESSF to report mixed flathead catches landed at NSW ports. NSW fishers were still required to report flathead landings by individual species. However, significant quantities of 'Unspecified flathead' were reported by OPT fishers in ports north of the Barrenjoey Point from 1990 onwards (Pease and Grindberg 1995; Hall 2018b).

The 'Flathead (other)' species category was introduced into logbook reporting during the changes in July 2009 that transferred reporting from monthly to daily records, to capture catches of other flathead species not individually listed in the species codes. However, some fishers misinterpreted this as a similar category to the obsolete 'Unspecified flathead' and still reported mixed catches of flathead against this species code.

In prawn trawl catches taken from northern NSW waters, a large proportion of this combined species group is likely to be Bluespotted Flathead, along with some Northern Sand Flathead and Deepwater Flathead (*Platycephalus conatus*) that are legitimately reported to this code. Whereas, in fish trawl catches taken from the central and south coasts, a large proportion is likely to be Tiger Flathead, with smaller quantities of Bluespotted Flathead, Southern Bluespotted Flathead and Southern Sand Flathead. For this reason, only the mixed flathead catches reported by the prawn trawl sector have been added to the Bluespotted Flathead catch totals. There is also likely to be an unknown quantity of Bluespotted Flathead reported by the fish trawl sector in these combined species groups that is missing from catch totals.

2.1.6. Other jurisdictions

The quantities of Bluespotted Flathead taken by fisheries in other jurisdictions are unknown, but are assumed to be small. These are generally reported against an undifferentiated flathead group code (e.g., in Queensland fisheries) or included in with catches of other sympatric flathead species (e.g.,Tiger Flathead in Commonwealth waters and Southern Bluespotted Flathead, *Platycephalus speculator*, in Victorian fisheries).

In historical commercial catches of Bluespotted Flathead from NSW waters, large quantities were reported from offshore waters (>3 nm from the coastline) south of Barrenjoey Point until July 1990. After this Commonwealth catches were removed from NSW catch-and-effort reporting and the quantity of Bluespotted Flathead taken south of Barrenjoey Point decreased dramatically to near current levels. This suggests that Commonwealth vessels historically reported large quantities of Bluespotted Flathead that:

- are currently reported as Tiger Flathead in Commonwealth logbook reporting;
- dramatically disappeared from catches after 1990 through a population collapse in that area;
- were inshore catches of Bluespotted Flathead misreported on offshore logsheets; or

- were Tiger Flathead (or other flathead species) catches misreported as Bluespotted Flathead on NSW logsheets.

The available evidence suggests that the last explanation is the most likely, given that early fish trawl observer studies and independent trawl surveys completed by the *FRV Kapala* around that time caught few Bluespotted Flathead in offshore waters deeper than 60 m depth (Graham et al. 1995; Graham et al. 1996; Liggins 1996). However, these studies were completed in 1993–1995, after the offshore population may have already collapsed. If that were the case, the timing of the collapse would be remarkably coincidental with the removal of Commonwealth catches from NSW reporting.

Consequently, historical catches of Bluespotted Flathead have been adjusted in this stock assessment to only include catches reported from inshore waters (between 1947/48 and 1977/78) and the equivalent portion (13.8%) of ocean catches south of Barrenjoey Point (between 1978/79 and 1989/90). The portion of ocean catch to include was derived from the average percentage of catches south of Barrenjoey Point in the 6 years after July 1990 and retrospectively applied to earlier catches. North of Barrenjoey Point all catches were left as reported, because Bluespotted Flathead in northern fishing zones is known to occur much further offshore over the wider continental shelf (Graham and Wood 1997).

2.2. Effort information

2.2.1. Commercial

The total number of active fishing businesses (i.e., that have reported any fishing activity for any species) in the OTF has declined from 247 in 1997/98 to 85 in 2018/19 (Figure 8). Following a similar trend, the number of active fishing businesses that reported catches of Bluespotted Flathead in each year has also steadily declined from 171 in 1997/98 to 68 in 2018/19. On average, 67.9% of the active fishing businesses in the OTF have reported catches of Bluespotted Flathead in any given year and this proportion has changed little over time, except in 2018/19 when it rose to 80%.

Reported effort in total days and hours fished for Bluespotted Flathead by OTF fishers increased from 13,785 days and 125,213 h in 1997/98 to a maximum of 15,946 days and 160,958 h in 2002/03, before declining rapidly until 2009/10 (Figure 9). Pronounced declines in effort were associated with the structural reforms in 2006/07, that first transitioned the fishery to share management. Reported effort in 2019/18 was just 4,863 days and 49,231 h, which represents 30.5% and 30.2%, respectively, of the amount of effort that was reported during 2002/03.

Effort time series data in NSW fisheries are problematic due to several changes in logbook reporting requirements and challenges in accurately allocating daily effort among species for a given multi-species fishing method. Changes in reporting occurred in July 1997 and again in July 2009 that potentially affected the consistency of the data series and have implications for interpreting trends in these metrics through time. In particular, in July 2009, catch-and-effort reporting changed from monthly records (with effort reported in total days and hours fished per month) to daily or event records (with effort reported in hours fished per day or event).

After this change, some fishers continued to report monthly catches as a single fishing event, often with the total hours for the month indicated. Other fishers who regularly complete multi-day trips also entered these as a single event, with total hours for the entire trip indicated. The way these erroneous 'daily' records were interpreted and entered in the database appears to have varied between data entry clerks and over time, with many in 2009 and 2010 entered as a single fishing event with an average 10 h effort allocated, and in more recent years as a single fishing event with the actual total hours entered.

When these data are re-aggregated into monthly fishing records to produce a longer time series of data, event date has been counted as a single day's fishing, so these multi-day trips and monthly data entered as a single day have resulted in massive catches recorded against a single day and an overall decrease in the total number of days fished in those years. For data that have been entered with the correct total number of hours, it was possible to detect these records (filtered for >12 h of effort) and estimate a more reasonable number of days by dividing the total effort by 12 h. However, for any records where a standard 10 h was allocated to a multi-day event this was not possible.

Records with suspected multi-day trips reported against a single fishing event accounted for on average 17.5% of the total annual Bluespotted Flathead catch and this percentage has improved little over the last 9 years. This misreporting is still occurring. However, when the multi-day trips are split into more than one event, there was only a marginal increase in the re-aggregated effort for monthly records since 2009/10 (Figure 9). In contrast, the effort (in hours fished) summed across only the Bluespotted Flathead daily records was consistently lower than the longer time series, because extra days in each month with no Bluespotted Flathead catch were omitted.

Effort series in total hours fished, should theoretically be less impacted by this misreporting, assuming that most records for which the total hours fished for multi-day trip events were entered correctly into the database. However, in 2009 and 2010 it seems many of these were allocated a standard 10 h, and considerable manual data validation is required to find and correct these entries.

One encouraging observation, is that the rapid decline in effort in response to the structural reforms between 2002/03 and 2006/07 preceded the logbook reporting changes, and clearly reflected the decrease in number of active fishing businesses (Figures 8, 9). By 2008/09 effort had reached levels only marginally higher than those in 2009/10 after the reporting changes. This suggest that the impact of the reporting changes may not have been as significant as suspected and that the recent reduction in effort is legitimate. After the correction for the identified multi-day trips, there was only a marginal increase in effort across recent years, which lends further support to this possibility.

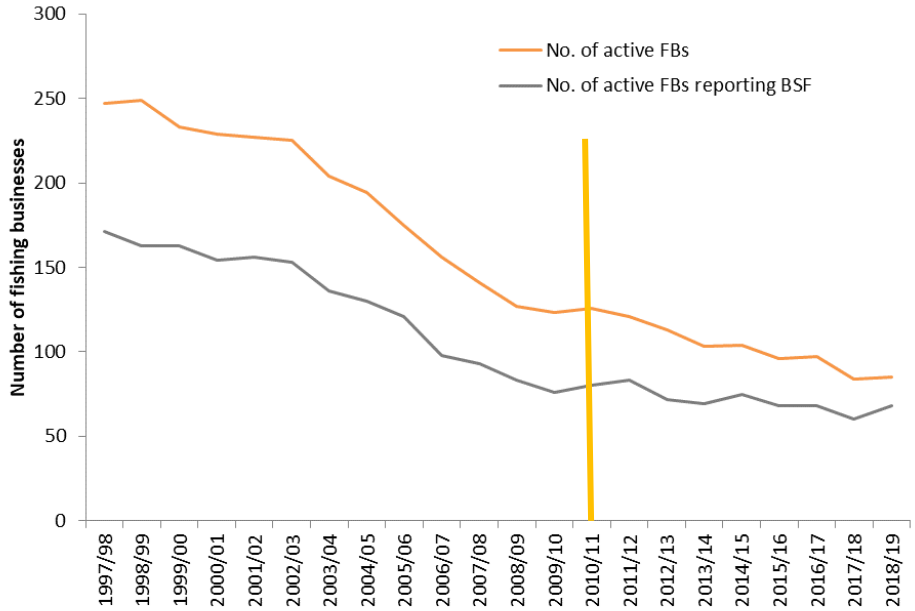


Figure 8 Number of NSW Ocean Trawl Fishery (OTF) fishing businesses (FBs) that were active (i.e., reported catches of any species) or reported catches of Bluespotted Flathead (BSF) in each fiscal year from 1997/98 to 2018/19. Vertical line indicates reporting change from monthly to daily records.

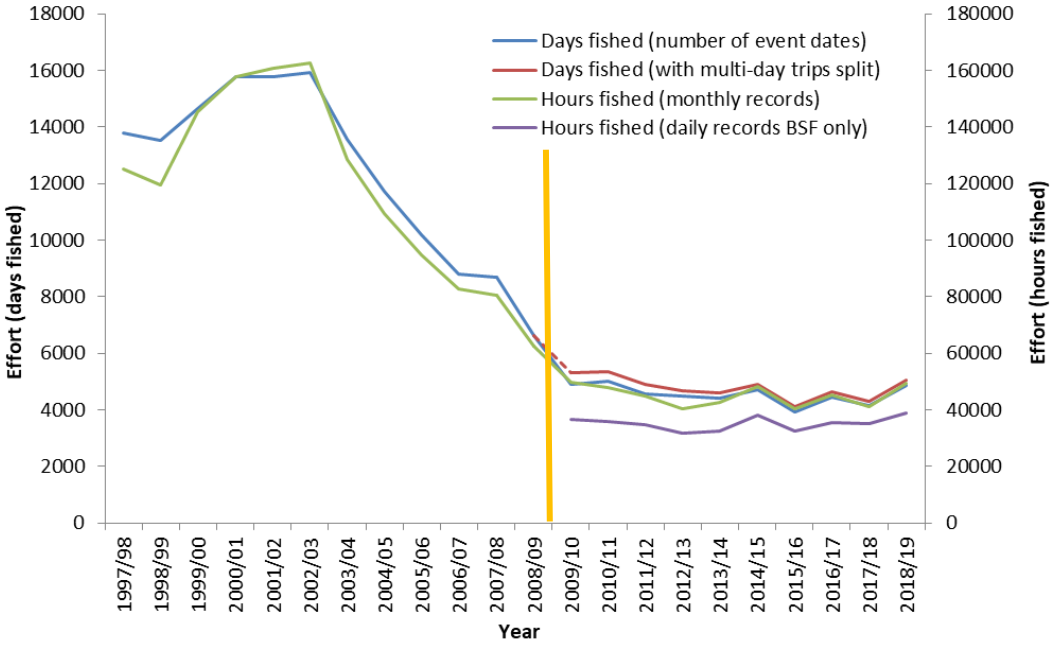


Figure 9 Annual effort (days and hours fished) for NSW Ocean Trawl Fishery (OTF) fishers that reported landing Bluespotted Flathead (BSF) on at least one day in a given month. Days fished for: (a) July 1997 to June 2009 were taken from the number of days fished by each method, as entered on monthly catch returns; (b) July 2009 to present were estimated from the number of distinct fishing dates entered on daily catch returns for each fisher in each month where the method was used, irrespective of whether the species was reported on all days, to be consistent with earlier reporting (blue line); and (c) 2009/10 to present were adjusted for multi-day trip reporting on a single daily event record (red line). Vertical line indicates reporting change from monthly to daily records.

Sectors and fishing methods

Of the active fishing businesses in the OTF, fewer are endorsed in the fish trawl sector (23 active fishing businesses in 2018/19) than in the OPT sector (72), but on average a greater percentage (71.9%) of fish trawl businesses than prawn trawl businesses (57.4%) report catches of Bluespotted Flathead (between 1997/98 and 2018/19).

Similar to the overall trends in the OTF, the total number of active fishing businesses in the prawn trawl sector have declined rapidly from 213 in 1997/98 to 71 in 2018/19, and the number reporting Bluespotted Flathead catches also declined from 129 to 49 (Figure 10). Consequently, total effort (in days fished) for Bluespotted Flathead has decreased, and follows a similar rapid decline during the mid-2000s to that in the total effort of the OTF (Figure 11). Since 2009/10, effort in the OPT sector has remained more stable. The reported effort in 2018/19 was 3,953 days and 41,000 h, which represents just 39.3% and 40.9%, respectively, of the effort reported in 1997/98.

The total number of active fishing businesses in the fish trawl sector also declined from 69 in 1997/98 to 23 in 2018/19, and the number reporting Bluespotted Flathead catches has decreased from 50 to 18 (Figure 12). However, the declines in effort in the fish trawl sector have occurred more evenly over time than in the prawn trawl sector (Figure 13).

2.2.2. Recreational

The NSW statewide survey in 2013/14, suggested that recreational fishing participation rates by NSW residents had decreased by 30% from over 1 million participants (16.6% of population) in 2000/01 to 836,632 (11.7%) in 2013/14 (West et al. 2015). Concurrently, estimated fishing effort also decreased by 37% from over 5 million fisher days (and 5.6 days per fisher) in 2000/01 to 3.2 million (and 4.3 days per fisher) in 2013/14. Effort statistics from the most recent survey in 2017/18 are not yet available.

2.2.3. Charter boat

The number of charter boat fishing businesses that reported Bluespotted Flathead catches almost halved from a maximum of 82 in 2001/02 to 44 in 2007/08, and then increased rapidly to 96 in 2016/17 and was 87 in 2018/19 (Figure 14). The total number of trips that caught Bluespotted Flathead and effort in total hours fished and angler hours show similar trends, with recent increases over the last 3 years (Figures 14, 15). As noted for the catch data of this sector, it is difficult to decipher whether the recent increases are due to improved reporting compliance or a genuine increase in fishing effort. The considerable drop in effort in the 2000s could have resulted from half the operators not submitting logsheets, as opposed to not targeting flathead or being active during that time.

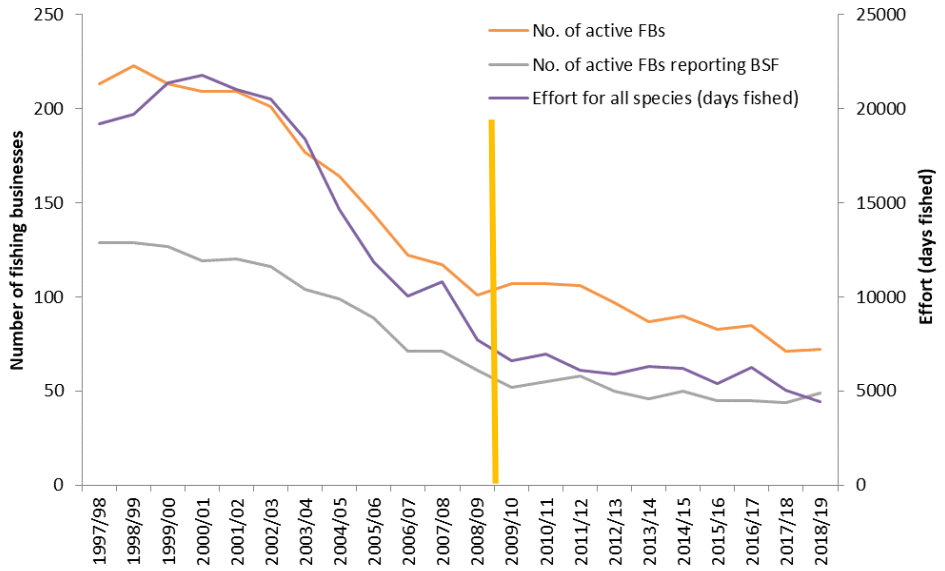


Figure 10 Number of NSW Ocean Trawl Fishery (OTF) fishing businesses (FBs) that were active (i.e., reported catches of any species) or reported catches of Bluespotted Flathead (BSF) in the prawn trawl sector, and their total effort (for all species, in days fished) in each fiscal year from 1997/98 to 2018/19. Vertical line indicates reporting change from monthly to daily records.

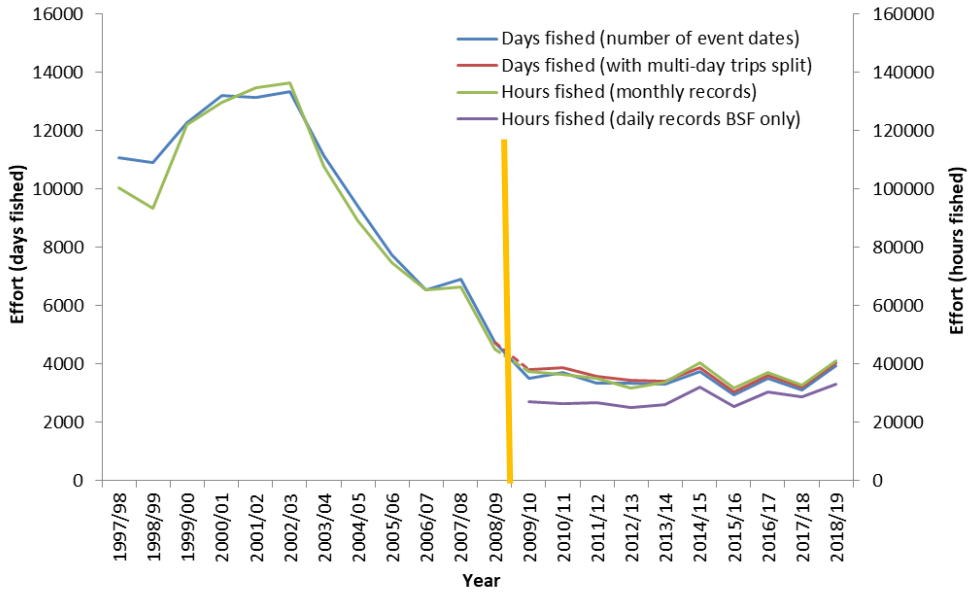


Figure 11 Annual effort (days and hours fished) for prawn trawl fishers that reported landing Bluespotted Flathead (BSF) on at least one day in a given month. Days fished for: (a) July 1997 to June 2009 were taken from the number of days fished by each method, as entered on monthly catch returns; (b) July 2009 to present were estimated from the number of distinct fishing dates entered on daily catch returns for each fisher in each month where the method was used, irrespective of whether the species was reported on all days, to be consistent with earlier reporting (blue line); and (c) 2009/10 to present were adjusted for multi-day trip reporting on a single daily event record (red line). Vertical line indicates reporting change from monthly to daily records.

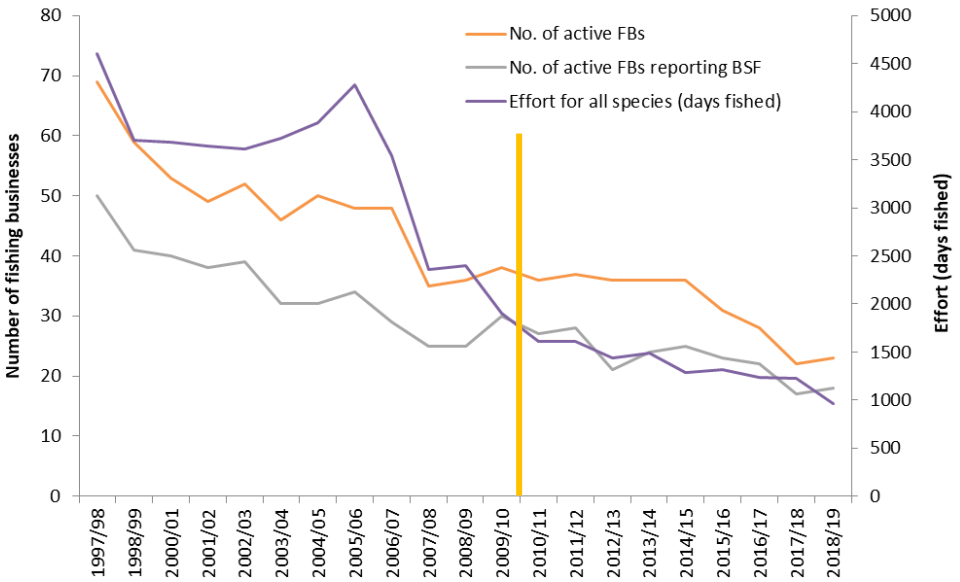


Figure 12 Number of NSW Ocean Trawl Fishery (OTF) fishing businesses (FBs) that were active (i.e., reported catches of any species) or reported catches of Bluespotted Flathead (BSF) in the fish trawl sector, and their total effort (for all species, in days fished) in each fiscal year from 1997/98 to 2018/19. Vertical line indicates reporting change from monthly to daily records.

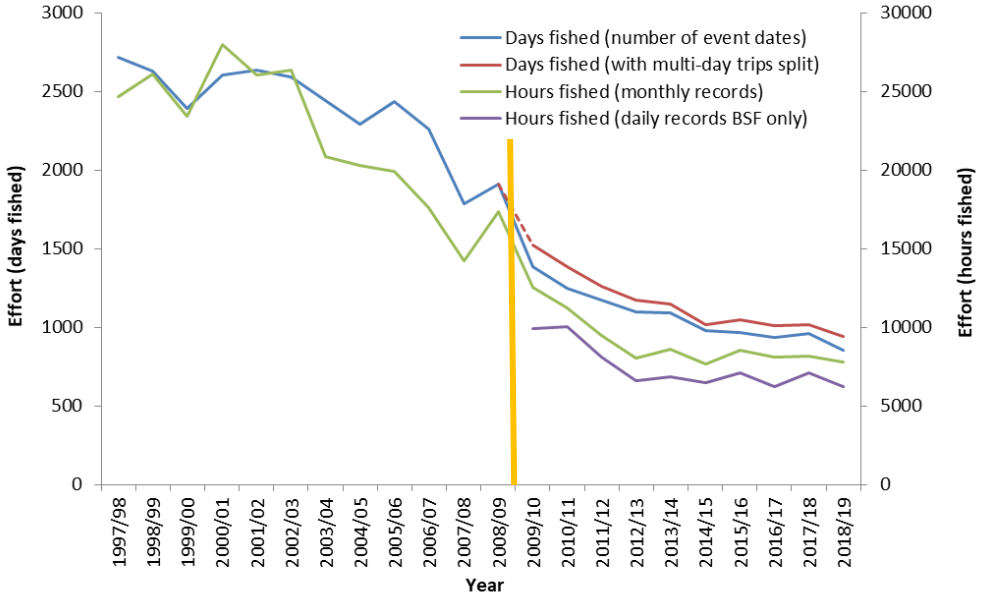


Figure 13 Annual effort (days and hours fished) for fish trawl fishers that reported landing Bluespotted Flathead (BSF) on at least one day in a given month. Days fished for: (a) July 1997 to June 2009 were taken from the number of days fished by each method, as entered on monthly catch returns; (b) July 2009 to present were estimated from the number of distinct fishing dates entered on daily catch returns for each fisher in each month where the method was used, irrespective of whether the species was reported on all days, to be consistent with earlier reporting (blue line); and (c) 2009/10 to present were adjusted for multi-day trip reporting on a single daily event record (red line). Vertical line indicates reporting change from monthly to daily records.

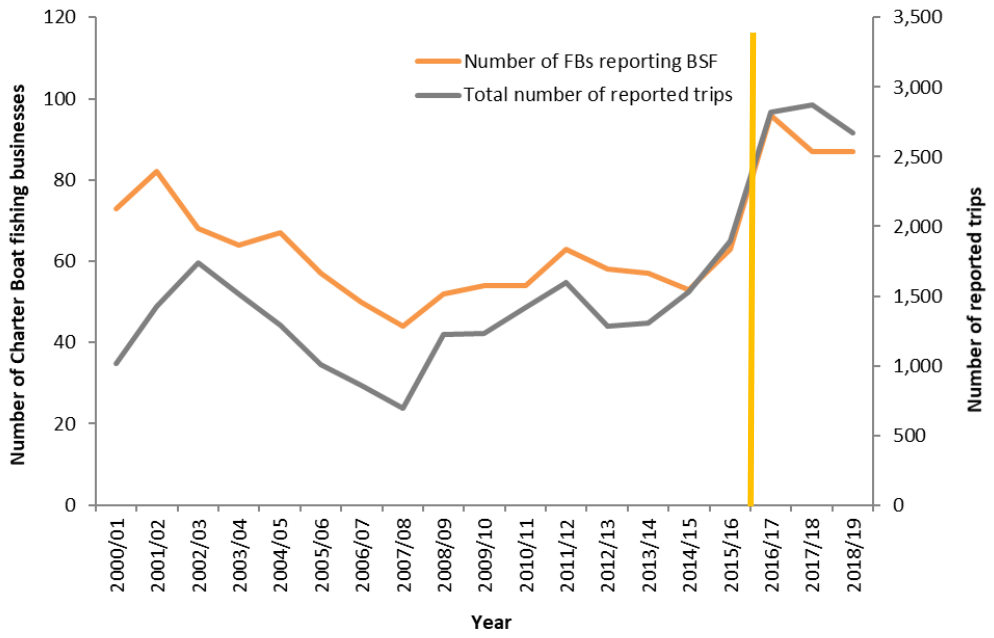


Figure 14 Number of NSW Charter Boat fishing businesses (FBs) and number of reported trips that included catches of Bluespotted Flathead (BSF) each year between 2000/01 and 2018/19. Vertical line indicates reporting change with increased compliance.

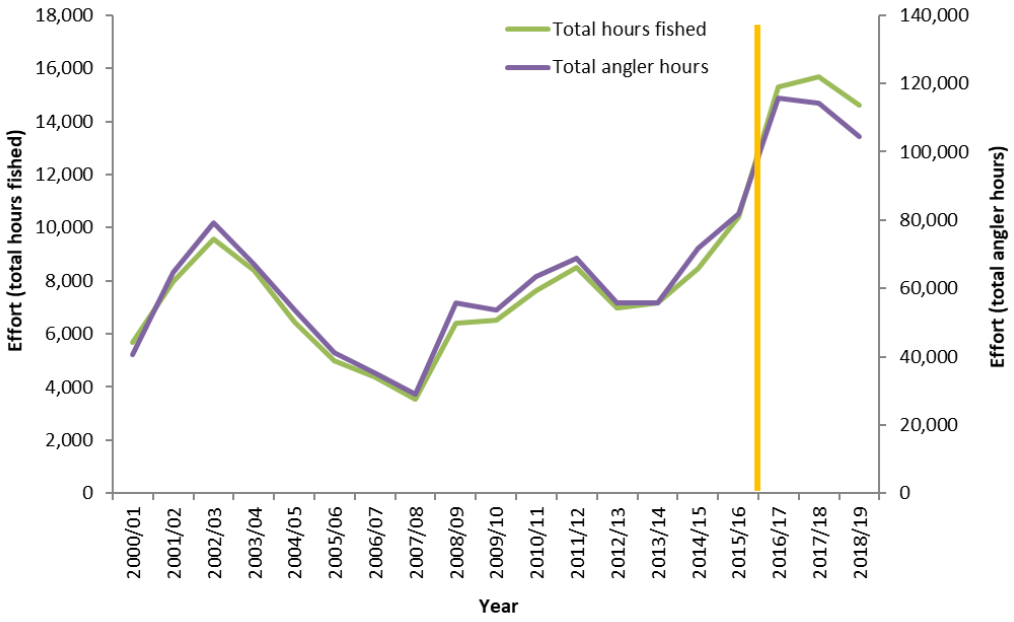


Figure 15 Annual effort (total hours fished and total angler hours) of operators in the NSW Charter Boat Fishery that reported landing Bluespotted Flathead during a fishing trip. Vertical line indicates reporting change with increased compliance.

3. Assessment information

3.1. Assessment approach

A weight-of-evidence approach has been used for this stock assessment of Bluespotted Flathead in NSW waters. It incorporates the results from three different analyses:

1. Standardised catch rates for the two main commercial fishing fleets, fish trawl (otter trawl, excluding Danish seine) and prawn trawl (otter trawl), analysed by whole fleet and ocean zones, and the handline and rod sector of the Charter Boat Fishery;
2. Length-converted catch-curve analyses using annual length frequency data from 27 years to estimate annual fishing mortality levels (updated in 2019, but analyses of historical data were completed in 2018, refer to Hall 2018b); and
3. Modified Catch-MSY analyses of 12 different historical catch series (1947/48 to 2016/17), comprising varying commercial, discard, charter boat and recreational catch scenarios for comparison (completed in 2018, refer to Hall 2018b).

The methods, assumptions, data inputs, data quality and considerations, and results from catch-rate and catch-curve analyses are presented below, followed by a brief overview and summary of the results from the modified Catch-MSY analyses. For full details of the latter analyses refer to Hall (2018b).

3.2. Catch-rate standardisations

3.2.1. Method and assumptions

Although the integrity of the historical effort series for commercial fisheries in NSW are compromised by several issues (as described in section 2.2), the following analyses investigated whether satisfactory annual catch-rate series (catch-per-unit-effort, CPUE) could be produced from the available fisher-dependent data through standardisation. Mean annual catch rates were standardised using general linear models fitted to daily and monthly records for each fisher using a range of correlated factors [cede v. 0.0.4, \Haddon, 2018 #8985}.

Factors selected to standardise monthly data (in kg day^{-1}) were calendar year, month, fishing business ID and boat length or power, with ocean zone added for the whole fleet analyses. Factors selected to standardise daily event data (in kg h^{-1}) were as above, but with depth also included. While fishers do not report capture depths on logsheets, the finer spatial resolution of the daily recorded data, permitted depth to be assigned to each record according to the mean depth of each C-square grid code.

For the daily data from the Charter Boat Fishery (in fish angler h^{-1}) the factors analysed were calendar year, month, fishing business ID and ocean zone. This was the first time that these data had been standardised as a trial run, but future analyses could also include a regional breakdown according to ocean zone.

Assumptions:

These analyses assume that the annual catch rates are a relative index of abundance and are not unduly influenced by other factors that are not accounted for through standardisation.

3.2.2. Data inputs

The following raw data inputs were used in these analyses (see also Table 12):

- Monthly catch rates (catch-per-unit-effort, CPUE in kg day^{-1}) calculated from commercial logbook data provided by fishers of the OTF for two methods – prawn trawl (otter trawl) and fish trawl (otter trawl) by calendar years (1998–2018).
- Daily catch rates (CPUE in kg h^{-1}) calculated from commercial logbook data provided by fishers of the OTF for two methods – prawn trawl (otter trawl) and fish trawl (otter trawl) by calendar years (2010–2018).
- Data were also divided into separate catch-rate series for each ocean zone (OZ1–OZ7), to analyse for any regional variation indicative of localised depletions.
- Daily catch rates (CPUE in fish angler h^{-1}) calculated from reported catch-and-effort data provided by fishers of the Charter Boat Fishery for the handline and rod fishing method by calendar years (2001–2018).

Note that the catch-rate 'series are reported by individual fishing methods, because of their variation in fishing efficiency. Consequently, the fish trawl catch rates only include records for the otter trawl fleet and exclude those of the Danish seine operators. Given there are less than six Danish seine operators in NSW waters, no catch-rate series have been compiled for that fishing method. Catch rates are presented by calendar year to facilitate standardisations.

3.2.3. Data quality and considerations

Commercial catch rates – low quality – considerable uncertainty in effort data, particularly after July 2009 when logbook reporting changes potentially caused an exaggerated decrease in total effort; multi-species fishery, with no attempt made to distinguish targeted Bluespotted Flathead fishing events from others, all 'fit-for-purpose' records indicating a catch of Bluespotted Flathead were included in analyses.

Charter boat catch rates – low quality – multi-species fishery, with no attempt made to calibrate effort for targeted Bluespotted Flathead fishing only, all 'fit-for-purpose' records indicating a catch of Bluespotted Flathead were included in analyses.

3.2.4. Data preparation

Any individual daily event record for which the effort quantity exceeded 12 h were assumed to be for a multi-day trip and a more realistic estimate of the number of days fished was derived by dividing the total number of hours for the event by 12. Effort quantities of <12 h, were assumed to represent a single day's fishing and were left as reported. The total number of days per month was then summed for each fisher that reported a catch of Bluespotted Flathead on any day in that month (even for days when the species was not reported) to re-aggregated data consistent with the way monthly records were reported prior to July 2009. In contrast, for the analyses of the shorter time series of daily catch rates, only effort quantities of events where the fisher reported a catch of Bluespotted Flathead were included.

Further data cleaning involved removing zero effort records and verifying any catch amounts that exceeded the 98% quantile of all catches between 2009 and 2018. Records with missing location information were also removed. For OTF records that did not include a boat licence number, the largest vessel licenced to that fisher ID was assigned to the record. The assumption that the largest vessel would be the trawl vessel for any given fishing business

was checked and validated for a random subset of records. Power and length of each boat were then assigned to each monthly and daily record. No boat licence information was available for many charter boat records, so those catch rates were not standardised for boat length or power.

Approximate capture depth (m) was assigned to each daily record using the mean depth of the C-square grid codes. Depths >300 m were rounded down to 300 m to reduce the right-tail skew of the data, given that Bluespotted Flathead are not recorded in depths >80 m.

All catch rates were log-normally (Ln) transformed before standardisation to normalise the data (Figures 16–20). and analyses were completed by calendar year to simplify coding. To further simplify the analyses, the continuous factors of boat length, boat power and capture depth were subdivided into intervals to convert them into categorical variables. Given that boat length and boat power are correlated, only one was selected for each model. Initial data exploration suggested that fish trawl CPUE data showed a stronger positive correlation with boat length; whereas, prawn trawl CPUE data was more positively correlated with boat power, so these were the factors chosen, respectively.

Table 12 **Number of monthly and daily records included in catch-rate analyses for Bluespotted Flathead for the prawn trawl (otter trawl) and fish trawl (otter trawl) sectors of NSW Ocean Trawl Fishery in each ocean zone and whole fleet, and the handline and rod sector of the Charter Boat fishery.**

		Monthly records (kg day^{-1}) 1998–2018		Daily records (kg h^{-1}) 2010–2018	
Sector (method)	Ocean zone	Number of records	Number of FBs	Number of records	Number of FBs
OTF Prawn trawl (otter trawl)	OZ1	3,982	113	11,321	66
	OZ2	9,780	135	21,917	84
	OZ3	4,376	108	10,611	50
	All	18,992	183	55,748	131
OTF Fish trawl (otter trawl)	OZ4	576	26	375	13
	OZ5	2,114	47	4,339	24
	OZ6	2,230	38	4,367	25
	OZ7	747	20	1,583	13
	All	6,018	83	12,504	48
Charter boat (handline and rod)	All			28,122 (fish angler h^{-1})	321 (some duplicated)

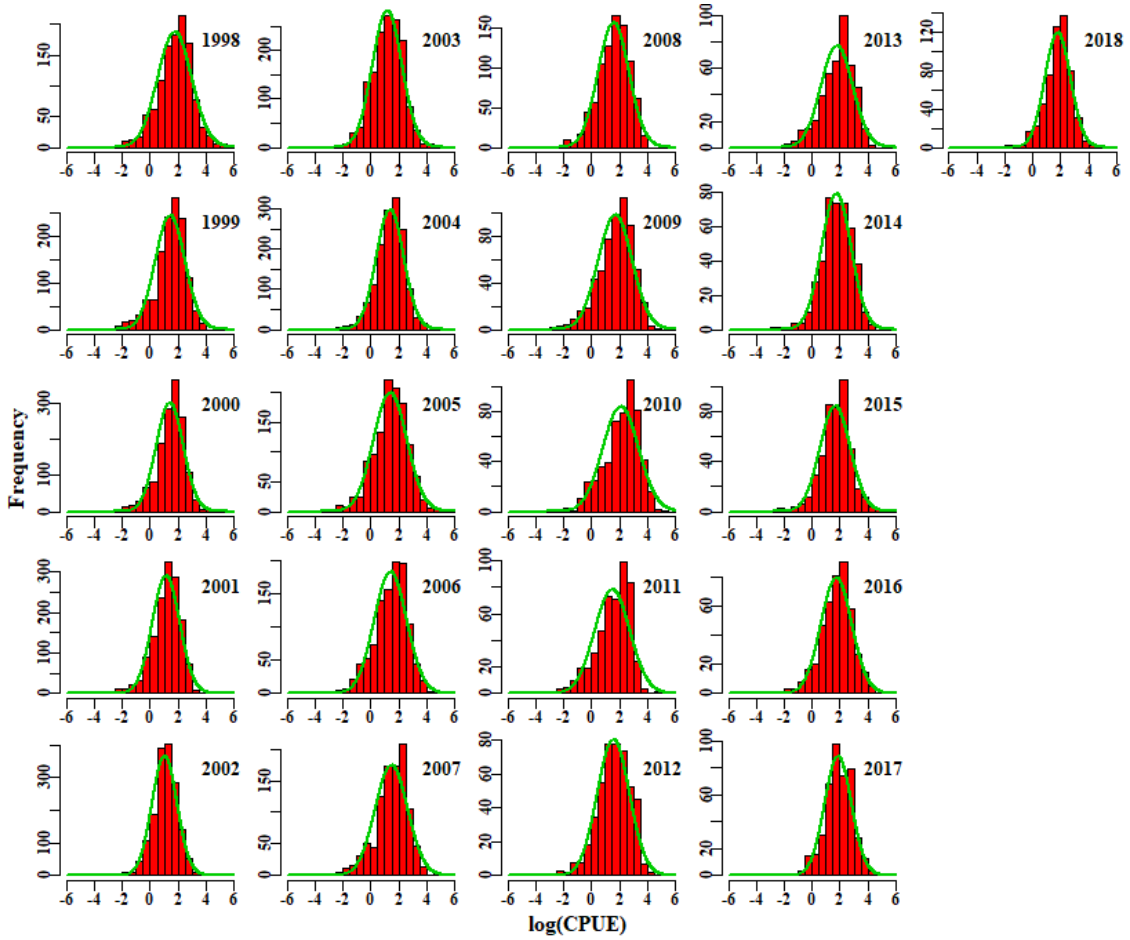


Figure 16 Distribution of prawn trawling catch rates (Ln CPUE kg h^{-1} from monthly records) of Bluespotted Flathead for the NSW Ocean Trawl Fishery.

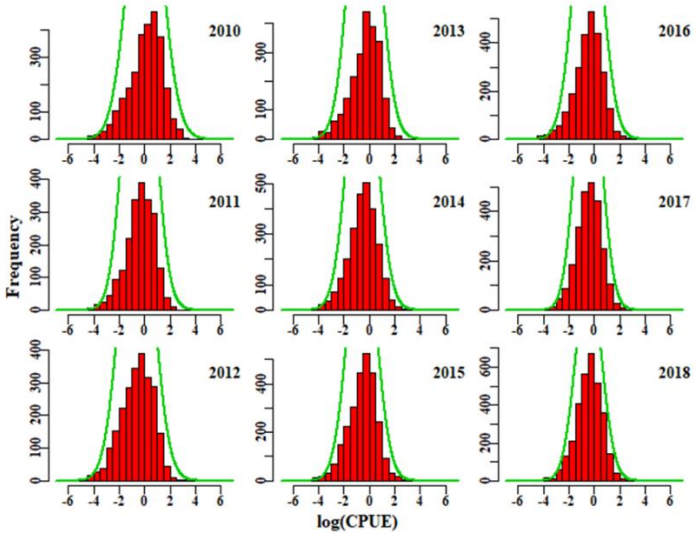


Figure 17 Distribution of prawn trawling catch rates (Ln CPUE kg h^{-1} from daily records) of Bluespotted Flathead for the NSW Ocean Trawl Fishery.

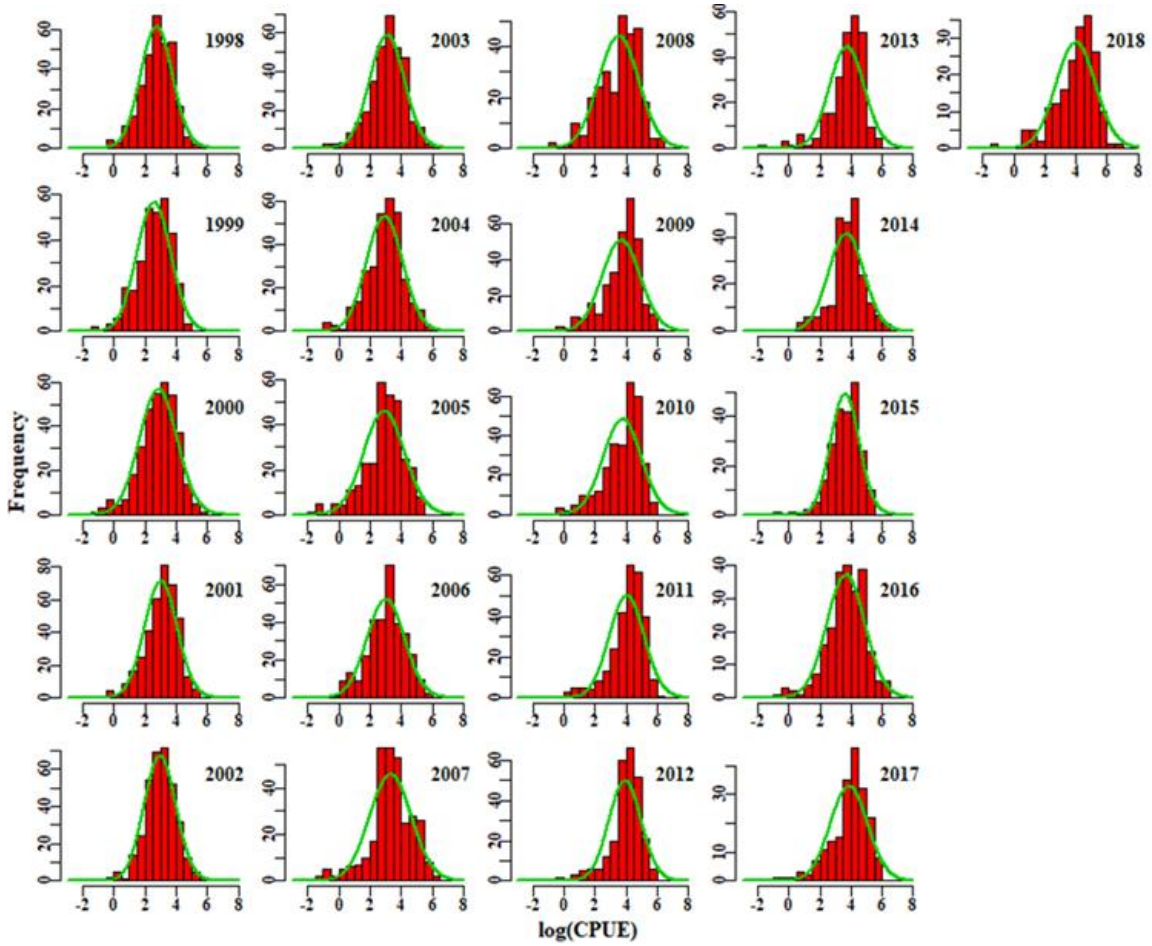


Figure 18 Distribution of fish trawling catch rates (Ln CPUE kg day^{-1} from monthly records) of Bluespotted Flathead for the NSW Ocean Trawl Fishery.

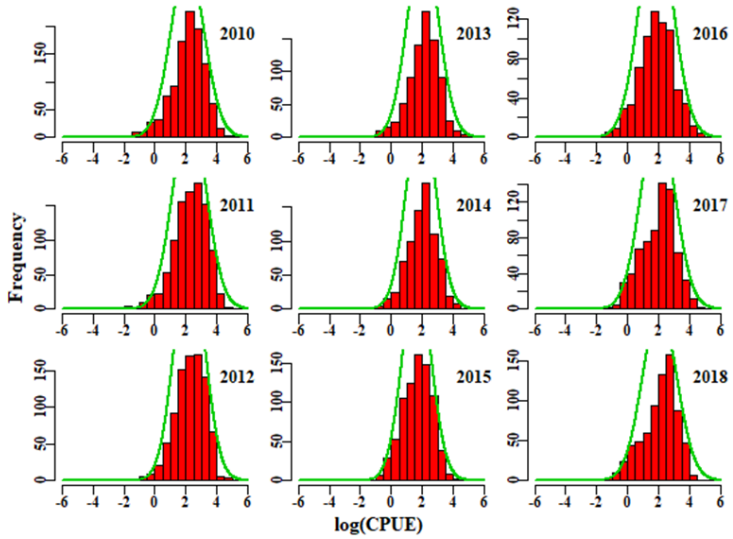


Figure 19 Distribution of fish trawling catch rates (Ln CPUE kg h^{-1} from daily records) of Bluespotted Flathead for the NSW Ocean Trawl Fishery.

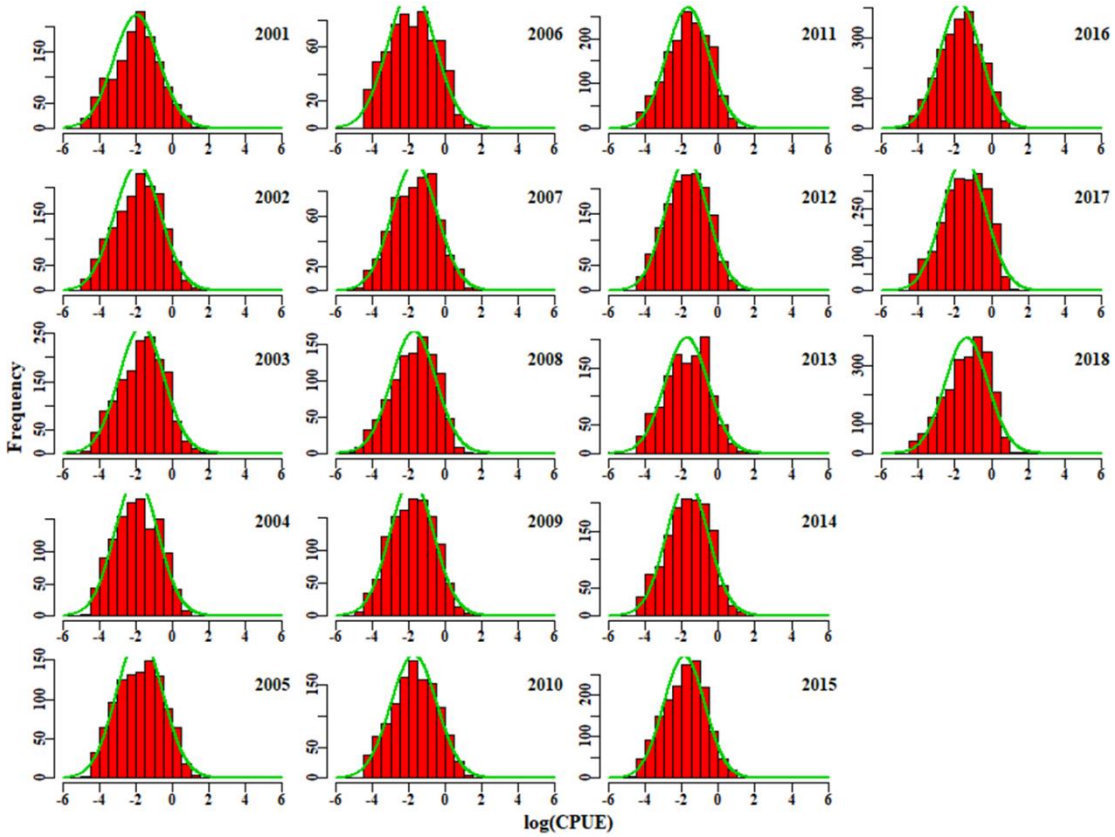


Figure 20 Distribution of handline and rod catch rates (Ln CPUE number of fish per angler hour from daily records) of Bluespotted Flathead for the NSW Charter Boat Fishery.

3.2.5. Results

For all series analysed, two or more of the factors significantly influenced the catch rates, and in many cases all factors analysed were significant, including boat length or power and capture depth (Tables 13, 14).

While the mean CPUE series following the standardisations tended be smoother across years with less extreme values than the geometric means, rarely was the trend reversed or greatly changed (Figures 21–25).

Sectors and fishing methods

The fish trawl (otter trawl) sector achieve much higher mean catch rates (21-year average of 61.2 kg day^{-1}) than the prawn trawl (otter trawl) sector (21-year average of 8.1 kg day^{-1}) (Figure 21). The two sectors operate in different ocean zones, use different gears and vary in their targeted fishing practices, which could account for these differences.

The longer time series of standardised monthly catch rates (in kg day^{-1}, available from 1998 to 2018, with recent daily data re-aggregated into monthly records) for the commercial prawn trawl and fish trawl sectors of the OTF, suggest that recent catch rates have been above the 21-year average for at least 6 years; while, catch rates prior to 2008 were consistently below the long-term average (Figure 21).

Prawn trawl catch rates rapidly declined by over 50% from 1998 to a minimum in 2002, after which they stabilised for several years before a rapid increase between 2007 and 2010 up to a peak of 12 kg day^{-1} (Figure 21). In 2011, catch rates declined abruptly and have slowly increased since to remain just above the long-term average. In comparison, fish trawl catch rates were relatively stable between 1998 and 2006, after which they rapidly rose to reach a peak of 100 kg day^{-1} in 2011, and then declined consistently for 4 years towards the long-term average, before rebounding again rapidly over the last 3 years (Figure 21).

Recent data analysed as mean daily catch rates (in kg h^{-1}, available from 2010 to 2017), show similar trends over the last 9 years; however, recent catch rates have remained below the 9-year average (Figures 22). The prawn trawl catch rates show a rapid decline from 2010 to 2011, and then have remained stable over the last 8 years; while, the fish trawl catch rates declined consistently each year from 2011 to 2015, and although they have risen over the last 3 years, still remain below the 9-year average (Figure 22).

Management zones

Regional variation in mean annual prawn trawl catch rates were fairly consistent across the three main ocean zones (OZ1 to OZ3) (Figure 23) and reflect those described above for the OPT data pooled across all zones. Of particular interest, in OZ2 where reported catches have decreased from 1997/98 to 2018/19, recent catch rates have increased from 2011 to 2018; however, there was a rapid decline in catch rates between 1998 and 2002 that coincided with a substantial decline in catches.

Trends in fish trawl catch rates across the four central ocean zones (OZ4 to OZ7) have been more variable (Figure 24). Monthly catch rates in OZ4 have increased substantially over the last 3 years, but were highly variable between the relatively small number of fishers resulting in very large confidence intervals. In contrast, daily catch rates appear to be more stable, with smaller fluctuations around the long-term average.

The longer-term trends in OZ5 suggest that catch rates over the last 8 years have remained elevated above the long-term average; whereas the daily catch rates indicate an opposing trend, with lower means over the last 4 years than the preceding 5 years. Similarly, the long-term trends in OZ6 suggest that after a period of decreasing rates between 2011 and 2016 recent catch rates have increased rapidly over the last 2 years; whereas, the daily catch rates suggest a much slower increase with current rates still below the 9-year average. The trends in OZ7 are similar to those in OZ6, although the daily catch rates have risen above the 9-year average over the last 2 years.

The reason for the differences in trends between the more recent daily catch rates and the monthly re-aggregated data in the fish trawl sector are not clear, but these differences highlight the uncertainty in the catch-and-effort data and the caution needed in interpreting annual catch rates as relative indices of abundance for this largely byproduct species. Further discussion regarding the uncertainties in the catch-rate data are provided in section 3.2.

One positive outcome, however, is that all catch-rate indices, irrespective of fishing method, frequency of reporting or ocean zone, showed relatively stable or increasing trends over the last 3 years, which suggests that the current biomass of Bluespotted Flathead is unlikely to be declining. Longer-term trends, especially those across the 2009/10 catch-and-effort reporting change, require more circumspect interpretation.

Table 13 Analysis of variance table for general linear models to standardise monthly catch rates (catch-per-unit-effort, CPUE in kg day^{-1}) for the prawn trawl (otter trawl) and fish trawl (otter trawl) sectors of the Ocean Trawl Fishery (OTF) in each ocean zone. Factors that significantly influenced the mean CPUE (P<0.05) are indicated with an asterisk (*).

Sector (method)	Ocean Zone	Factor	df	F Value	P (>F)
OTF Prawn trawl (otter trawl) Monthly records (kg day^{-1})	OZ1	Year	20	9.82	<0.001*
		Month	11	51.35	<0.001*
		FBNo	86	9.95	<0.001*
		Boat Power	7	0.57	0.779
	OZ2	Year	20	54.22	<0.001*
		Month	11	183.17	<0.001*
		FBNo	109	27.01	<0.001*
		Boat Power	10	1.74	0.067
	OZ3	Year	20	19.94	<0.001*
		Month	11	43.61	<0.001*
		FBNo	87	15.95	<0.001*
		Boat Power	9	2.74	0.003*
	All	Year	20	64.41	<0.001*
		Month	11	246.63	<0.001*
		FBNo	140	37.28	<0.001*
		Ocean Zone	9	12.36	<0.001*
		Boat Power	11	3.89	<0.001*
OTF Fish trawl (otter trawl) Monthly records (kg day^{-1})	OZ4	Year	20	7.20	<0.001*
		Month	11	1.68	0.08
		FBNo	22	7.00	<0.001*
		Boat Length	2	0.57	0.41
	OZ5	Year	20	19.71	<0.001*
		Month	11	1.90	<0.001*
		FBNo	42	24.92	<0.001*
		Boat Length	7	0.66	0.71
	OZ6	Year	20	27.54	<0.001*
		Month	11	7.07	<0.001*
		FBNo	32	38.51	<0.001*
		Boat Length	8	3.91	<0.001*
	OZ7	Year	20	13.05	<0.001*
		Month	11	2.26	0.01*
		FBNo	14	8.24	<0.001*
		Boat Length	6	6.47	<0.001*
	All	Year	20	56.00	<0.001*
		Month	11	5.68	<0.001*
		FBNo	63	41.59	<0.001*
		Ocean Zone	9	4.49	<0.001*
		Boat Length	9	6.03	<0.001*

Table 14 Analysis of variance table for the general linear model to standardise daily catch rates (catch-per-unit-effort, CPUE in kg h^{-1}) for the prawn trawl (otter trawl) and fish trawl (otter trawl) sectors of the Ocean Trawl Fishery (OTF) in each ocean zone, and the handline and rod sector of the Charter Boat Fishery (in CPUE fish angler h^{-1}). Factors that significantly influenced the mean CPUE ($P<0.05$) are indicated with an asterisk (*).

Sector (method)	Ocean Zone	Factor	df	*F* Value	*P*
OTF Prawn trawl (otter trawl) Monthly records (kg h^{-1})	OZ1	Year	8	32.82	<0.001*
		Month	11	27.89	<0.001*
		FBNo	48	16.92	<0.001*
		Boat Power	3	2.81	0.04*
		Depth	5	6.71	<0.001*
	OZ2	Year	8	83.34	<0.001*
		Month	11	235.33	<0.001*
		FBNo	69	51.30	<0.001*
		Boat Power	4	2.53	0.03*
		Depth	6	8.77	0.067
	OZ3	Year	8	41.10	<0.001*
		Month	11	64.71	<0.001*
		FBNo	40	41.48	<0.001*
		Boat Power	3	3.46	0.02*
		Depth	5	9.84	0.003*
	All	Year	8	115.39	<0.001*
		Month	11	289.27	<0.001*
		FBNo	85	69.41	<0.001*
		Ocean Zone	5	25.11	<0.001*
		Boat Power	4	6.66	<0.001*
		Depth	6	16.00	<0.001*
OTF Fish trawl (otter trawl) Monthly records (kg h^{-1})	OZ4	Year	8	11.30	<0.001*
		Month	11	4.14	<0.001*
		FBNo	10	3.39	<0.001*
		Depth	4	2.31	0.06
	OZ5	Year	8	16.95	<0.001*
		Month	11	10.43	<0.001*
		FBNo	23	56.19	<0.001*
		Boat Length	6	2.43	0.02*
		Depth	9	5.87	<0.001*
	OZ6	Year	8	38.99	<0.001*
		Month	11	23.00	<0.001*
		FBNo	20	60.46	<0.001*
		Boat Length	8	3.48	<0.001*
		Depth	8	8.06	<0.001*
	OZ7	Year	8	10.79	<0.001*
		Month	11	3.62	<0.001*
		FBNo	8	20.95	<0.001*
		Boat Length	5	2.29	0.04*
		Depth	7	1.59	0.14
	All	Year	8	39.50	<0.001*
		Month	11	21.26	<0.001*
		FBNo	40	63.33	<0.001*
		Ocean Zone	7	15.07	<0.001*
		Boat Length	9	2.92	0.002*
		Depth	10	4.83	<0.001*
Charter boat (handline and rod) Daily records (fish angler h^{-1})	All	Year	17	43.70	<0.001*
		Month	11	24.99	<0.001*
		FBNo	320	38.63	<0.001*
		Ocean Zone	11	16.88	<0.001*

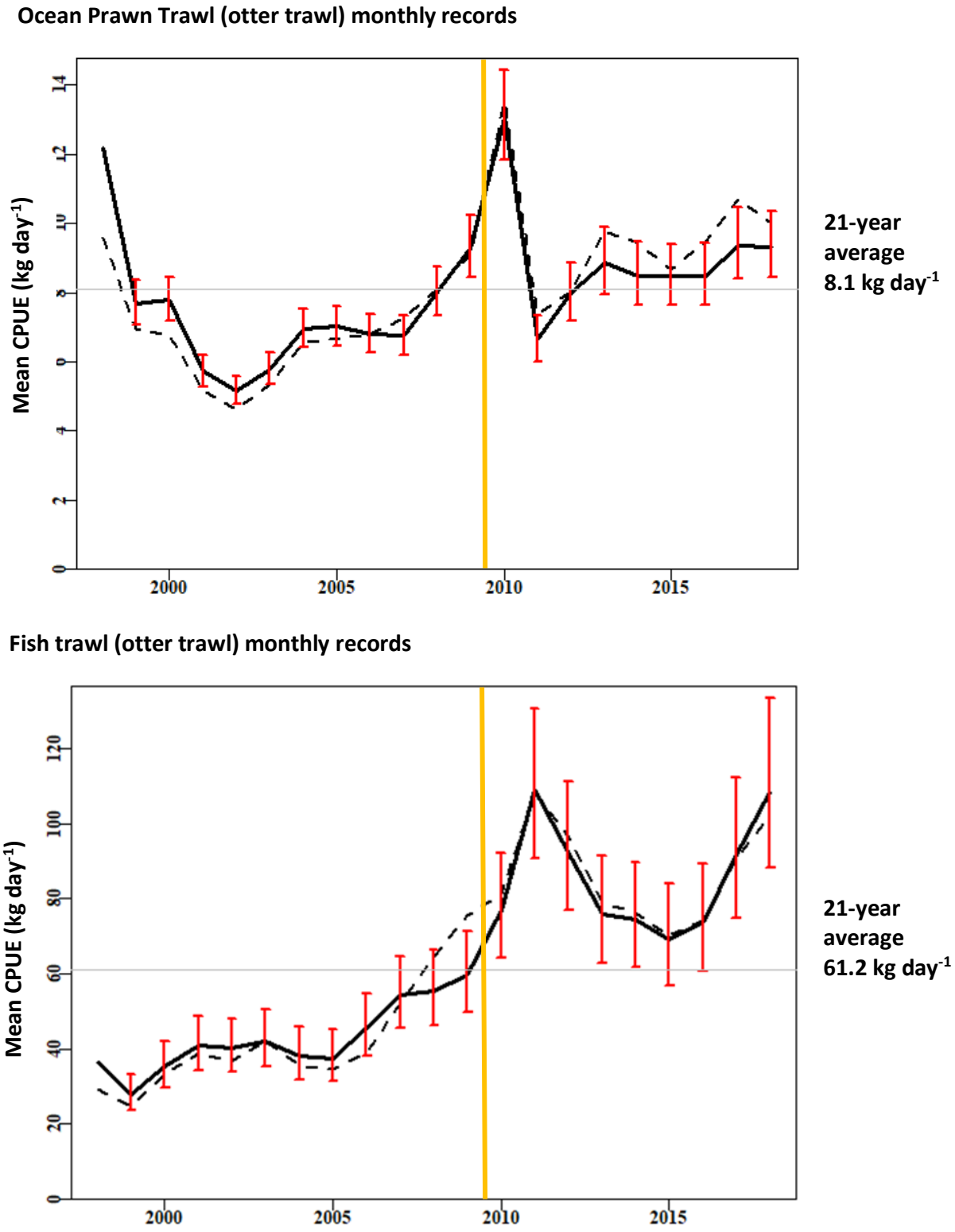
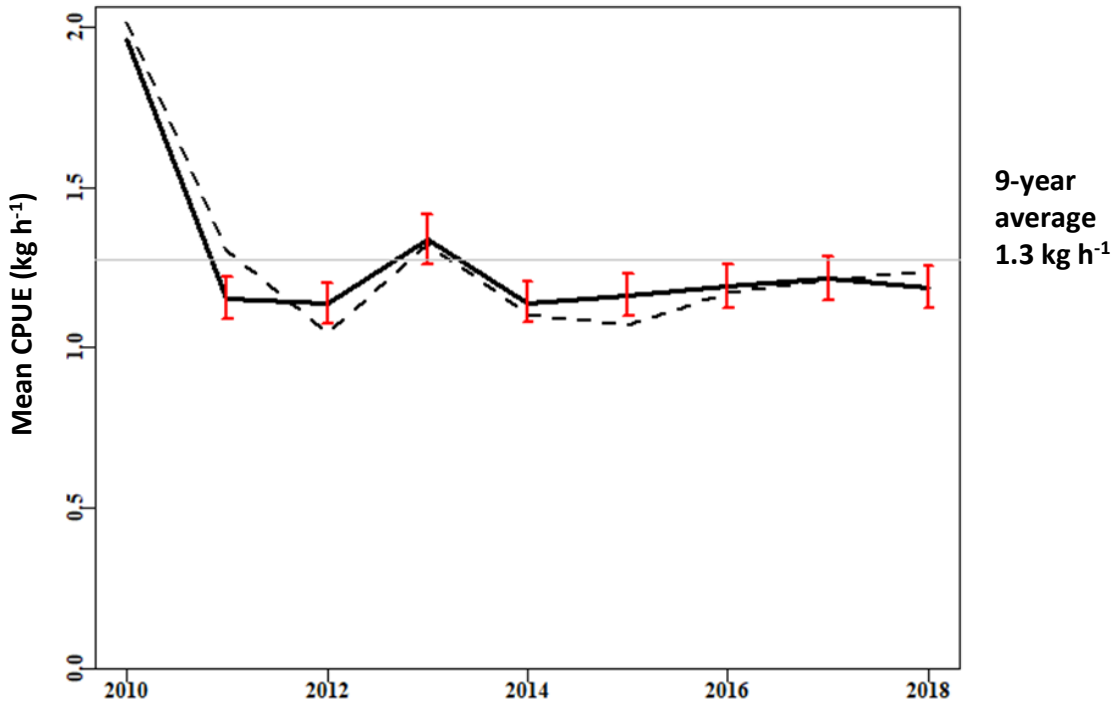


Figure 21 Mean standardised catch rates (catch-per-unit-effort, CPUE in kg day^{-1} from monthly records 1998–2018) for Bluespotted Flathead reported by the ocean prawn trawl (otter trawl, top) and fish trawl (otter trawl, bottom) sectors in the NSW Ocean Trawl Fishery. The dashed and solid lines indicate the geometric mean CPUE and standardised CPUE (± 95% confidence intervals), respectively. The horizontal grey lines indicate the long-term (21-year) average catch rates and the vertical lines indicate the reporting change from monthly to daily records.

Ocean Prawn Trawl (otter trawl) daily records



Fish trawl (otter trawl) daily records

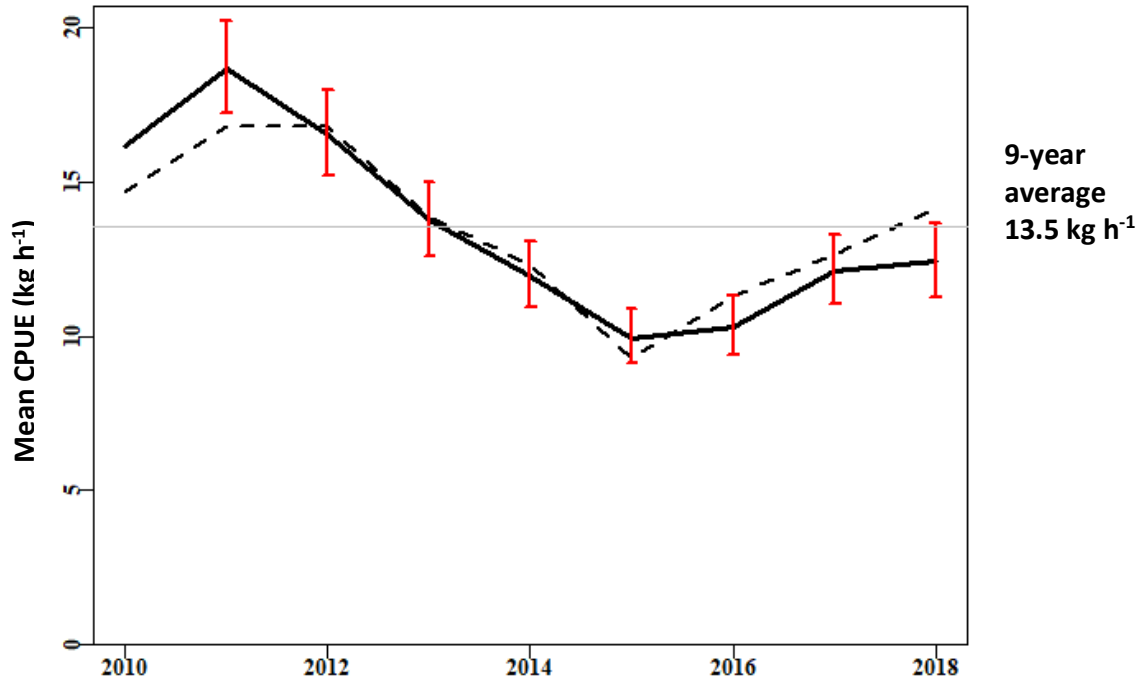


Figure 22 Mean standardised catch rates (catch-per-unit-effort, CPUE in kg h^{-1} from daily records 2010–2018) for Bluespotted Flathead reported by the ocean prawn trawl (otter trawl, top) and fish trawl (otter trawl, bottom) sectors in the NSW Ocean Trawl Fishery. The dashed and solid lines indicate the geometric mean CPUE and standardised CPUE (± 95% confidence intervals), respectively. The horizontal grey lines indicate the 9-year average catch rates.

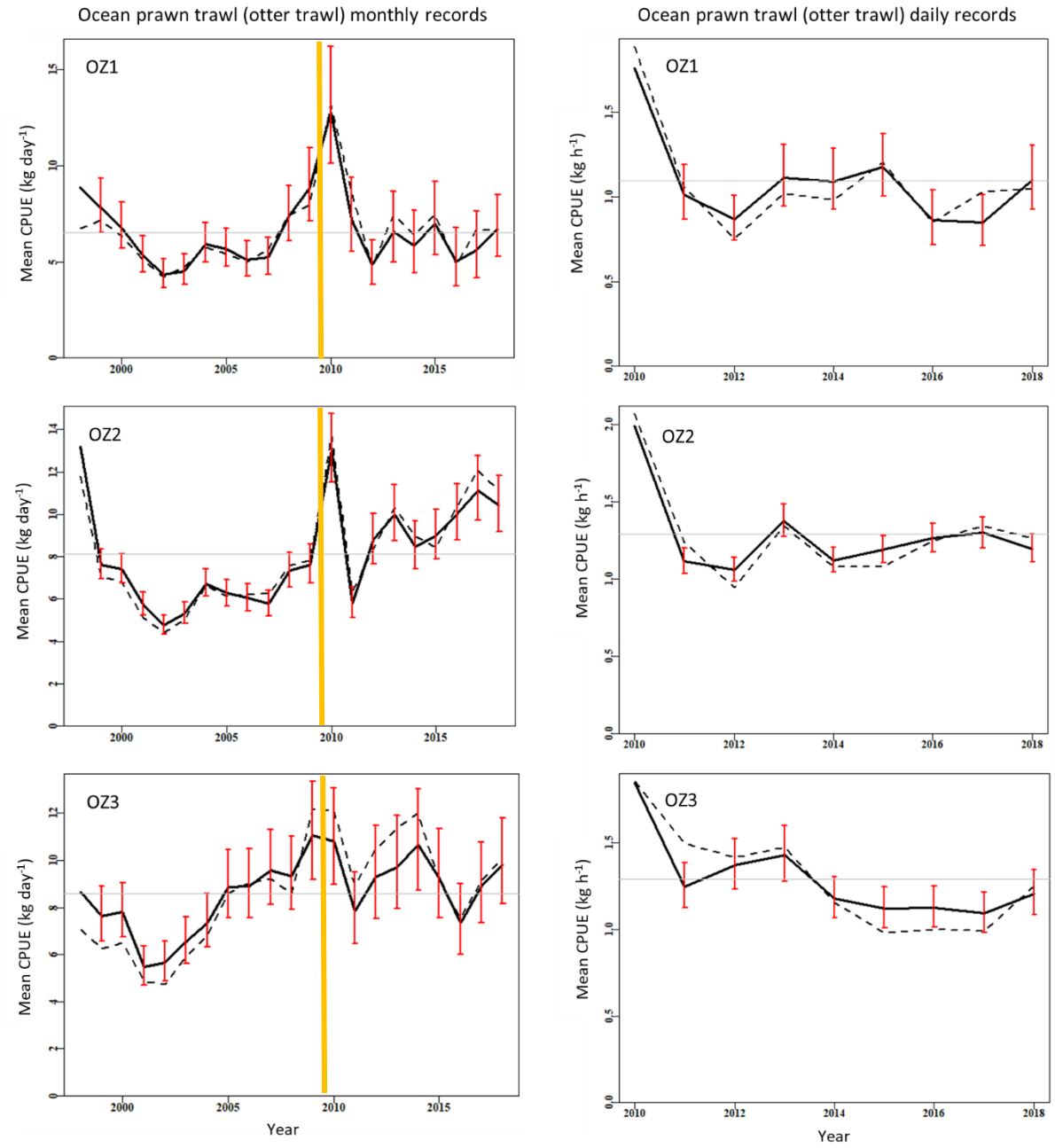


Figure 23 Ocean prawn trawl (otter trawl) mean standardised catch rates (catch-per-unit-effort, CPUE in kg day^{-1} from monthly records 1998–2018 left graphs and kg h^{-1} from daily records 2010–2018 right graphs) for Bluespotted Flathead in each ocean zone (OZ) of the northern NSW Ocean Trawl Fishery. The dashed and solid lines indicate the geometric mean CPUE and standardised CPUE (± 95% confidence intervals), respectively. The horizontal grey lines indicate the long-term average catch rates and the vertical lines indicate the reporting change from monthly to daily records.

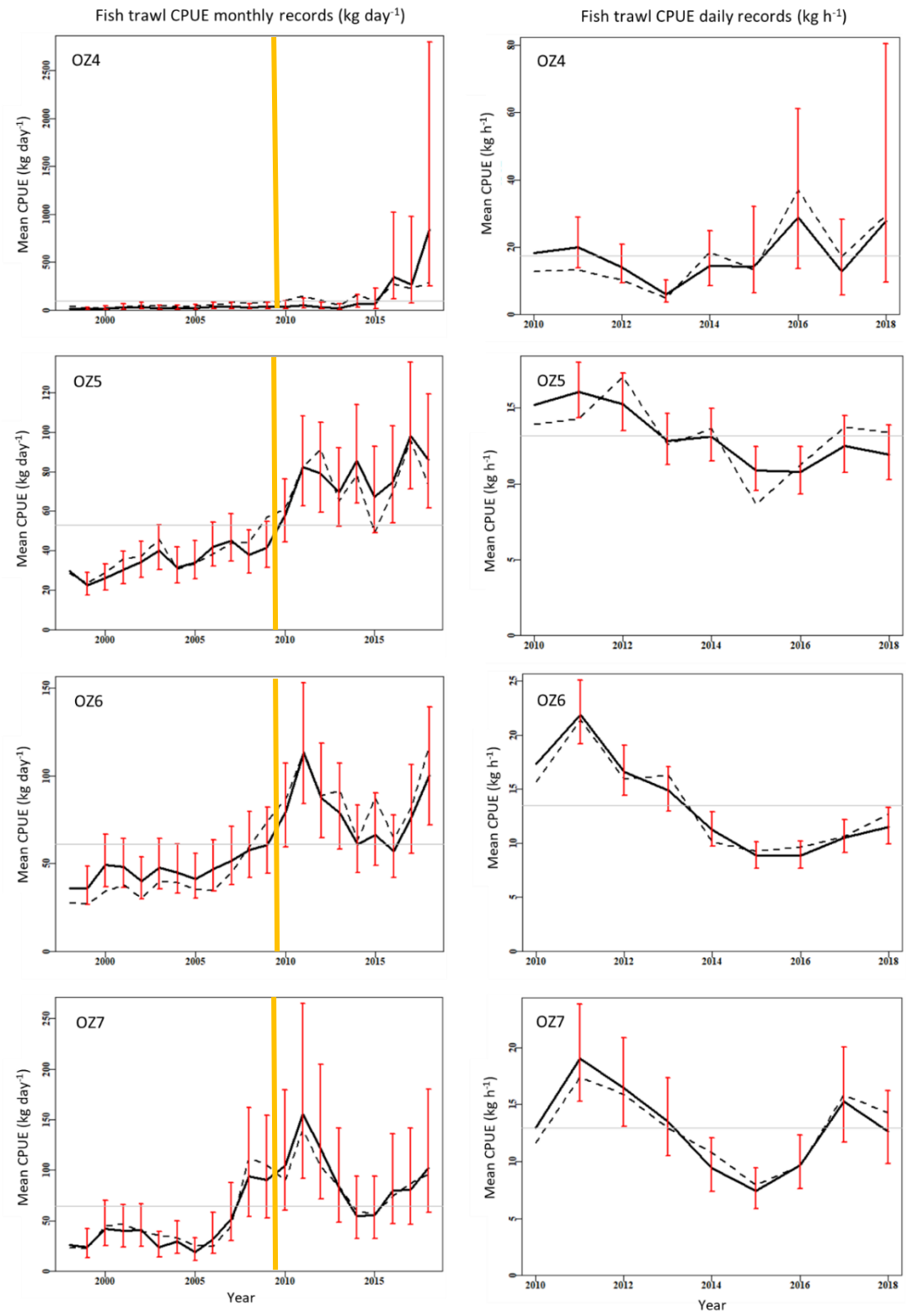


Figure 24 Fish trawl (otter trawl) standardised catch rates (catch-per-unit-effort, CPUE in kg day^{-1} from monthly records 1998–2018 left graphs and kg h^{-1} from daily records 2010–2018 right graphs) for Bluespotted Flathead in each ocean zone (OZ) of the central NSW Ocean Trawl Fishery. The dashed and solid lines indicate the geometric mean CPUE and standardised CPUE (± 95% confidence intervals), respectively. The horizontal grey lines indicate the long-term average catch rates and the vertical lines indicate the reporting change from monthly to daily records.

3.2.6. Recreational

Catch rates in the recreational sector (in number of fish per fisher day) are only available for combined flathead species, of which Bluespotted Flathead is likely to be one of the main component in ocean waters (Table 12). These data suggest that there has been a slight increase in catch rates of ocean flathead between 2000/01 and 2013/14, from 1.1 to 1.3 fish per fisher day. These data are considered highly uncertain given changes to survey methods between estimates and the grouping of all flatheads together for combined catch rates. Data from the recent 2017/18 survey are still being analysed.

3.2.7. Charter boat

Catch rates for the Charter Boat Fishery (in number of fish per angler hour) also show a slight increase over the last 18 years for which data are available (2001–2018, Figure 20). However, catch rates in this sector are very low because total effort for each trip is used in their calculations, and flathead may not necessarily be targeted for the entire trip. For example, most of the trip may occur over deeper reef areas and only move over shallower sandy habitats for a short period towards the end, but the total effort for the trip is included for catch rate calculations.

Table 15 Recreational catch-rate data (number of fish per fisher day) for combined flathead (of which Bluespotted Flathead is one of the main species) in NSW waters estimated from recreational surveys in 2000/01 (data from Henry and Lyle 2003) and 2013/14 (data from West et al. 2015). SE=standard error.

			Ocean		Estuary		All Saltwater	
Survey Year	Species Group	Total catch (No fish)	Catch rate (No. fisher day^{-1})	SE	Catch rate (No. fisher day^{-1})	SE	Catch rate (No. fisher day^{-1})	SE
2000/01	Flatheads	3,339,716	1.08	0.19	0.71	0.07	0.71	0.09
2013/14	Flatheads	2,095,595	1.3	0.19	0.69	0.08	0.69	0.07

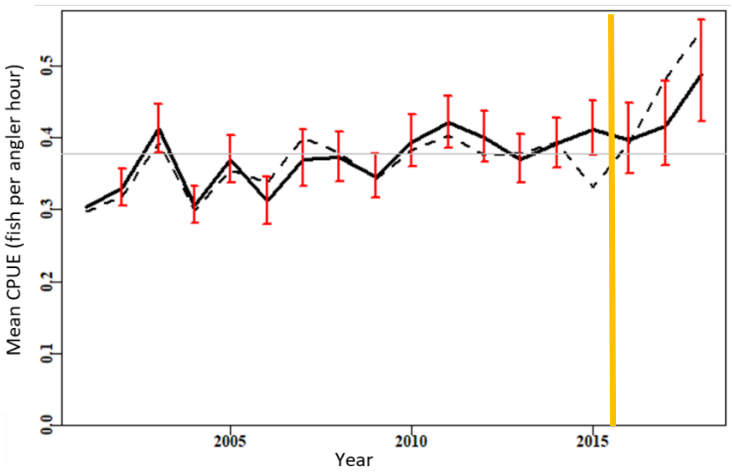


Figure 25 Standardised catch rates (fish per angler hour) of Bluespotted Flathead in the NSW Charter Boat Fishery (2001-2018). The dashed and solid lines indicate the geometric mean CPUE and standardised CPUE (± 95% confidence intervals), respectively. The horizontal grey line indicates the long-term average catch rate and the vertical line indicates the reporting change to include greater compliance.

3.2.8. Uncertainties

While the quality of the catch-rate series were improved through standardisation, the pronounced spikes immediately following the logbook reporting changes in the monthly prawn trawl data and consistent elevation of post-2009 catch rates relative to pre-2009 are still issues of concern. All catch-rate series for Bluespotted Flathead are subject to the same complications as those outlined for the effort series, which relate to the changes in catch reporting from monthly to daily records in July 2009. Because effort further declined following this change, standardised monthly catch rates in both kg h^{-1} and especially kg day^{-1} are generally higher after the change than before. There is no way to verify whether the current higher catch rates reflect a genuine increase in population biomass levels or are an artefact of the influence of logbook reporting changes on the effort data. While recreational fishing and charter boat catch rates also show marginal increases over similar time periods, there is even greater uncertainty associated with those data compared to the commercial catch rates.

Of the commercial catch rates analysed, the CPUE in kg h^{-1} from daily records is likely to be the most reliable indicator of relative abundance, because it is least likely to be affected by the misreported effort following the logbook reporting changes. However, these data were still affected by the multi-day trips for which effort was allocated as a single day of 10 h, which occurred most frequently in 2009 and 2010.

An observation in defence of using the longer time series data, even after documenting the many uncertainties, is that catch rates in both the fish and prawn trawl sectors had already increased over several years prior to the catch reporting changes, which suggests that recent catch rates may have been higher than historic rates despite the reporting changes. The higher catch rates in 2009/10 also coincided with an increased total catch of Bluespotted Flathead, which was followed by several years of declining catches, which are also reflected in the CPUE trends. Certainly the trends over the last three years are unaffected by the historic reporting changes, and they show relatively consistent results across all indices analysed. Nevertheless, until greater confidence in the integrity of the effort series can be achieved through careful validation and scrutiny of individual records there seems little benefit in attempting a more complex CPUE-based assessment (e.g., Little et al. 2011) or population modelling (e.g., Punt et al. 1995) using the longer monthly catch rate series as a basis.

In addition to further validation work, the monthly catch-rate series could potentially be extended back further to 1985 (to gain an extra 13 years of historical data) using the subset of records where Bluespotted Flathead was taken by a single fishing method. But this would only include records for between 67.3% and 81.7% (mean 75.1%) of the total catch in each year (the remainder were taken by two or more methods in each month). This would extend the series back far enough to include the reference period (between 1986 and 1995) typically chosen for Commonwealth assessments of SESSF species when catches were relative stable (Little et al. 2011). However, the doubts about whether current CPUE rates are comparable to historic values, given the reporting changes in 1997 and 2009, would still apply.

3.3. Catch-curve analyses

3.3.1. Method and assumptions

In the 2018 stock assessment, traditional catch curves were fitted to numbers-at-age data derived from re-weighted length frequencies obtained from a range of sample sources and methods over a period spanning 45 years (1969–2015, not inclusive, Hall 2018b). In the current stock assessment, the same method was applied to new length frequency data collected during port monitoring of commercial catches in 2018/19.

The method involves re-weighting the annual length frequency data (using Pisces v. 1.0.6646.28297) (Scandol 2008) according to sample weights relative to total catch weights for each fisher on each sampling date, and then according to the total reported landings for that fishing method, region and month.

An age–length key was derived from the age frequency of sectioned otoliths collected in 2006–2007 (using fishmethods v. 1.10-4) (Nelson 2017) to determine the proportions of each age in each size class. Numbers-at-age data were then estimated by converting the re-weighted length frequency into an age frequency using the age–length key. The resulting numbers-at-age data were analysed by traditional catch-curve analyses (using simpleSA v. 0.1.13) (Haddon et al. 2018) to determine total mortality estimates (Z).

Fishing mortality (F) estimates were calculated from these by subtracting natural mortality (M) estimates (derived from empirical equations that use either longevity or growth parameters) from Z according to the fundamental equation:

$$Z = F + M$$

Assumptions:

Fishing mortality estimates derived from catch-curve analyses are highly dependent on the availability of a sound estimate for natural mortality, which in the absence of alternative information is generally assumed to remain constant across years. Greater uncertainty and a positive bias (overestimation of Z) are known to occur when using age structures derived from converted length frequencies for catch-curve analyses (Pauly et al. 1995).

3.3.2. Data inputs

The following data inputs were used in the current analysis (for details of the historical data refer to Hall 2018b):

- Length composition of commercial catch samples via port monitoring (n=7,329 fish; July 2018–June 2019);
- Numbers-at-age data from the converted re-weighted length frequency;
- Age–length key developed from sectioned otoliths collected from fish sampled during independent prawn trawl sampling using a chartered commercial fishing vessel at two locations along the NSW coast (Yamba and Newcastle, 2006–2007), supplemented with 80 larger fish aged during 2011.

Natural mortality estimates were derived using the updated Hoenig and Pauly equations recommended in Then (2014) and a maximum age of 9 years (Barnes et al. 2011) and von Bertalanffy growth parameters determined through a reanalysis of the data from (Barnes et al. 2011) for both sexes combined (Table 1). The updated Hoenig equation resulted in an

estimate of M=0.33 and the updated Pauly equation an estimate of M=0.65. Given the disparity in these estimates, the average of M=0.49 was also used in analyses to provide a third comparison.

3.3.3. Data quality and considerations

Length composition – medium quality – samples covered a representative range of capture locations and fishing methods across all months of the year.

Numbers-at-age from converted lengths – low quality – the age–length key was determined from a limited range of samples collected over a single period with few large fish included.

Age–length key – medium quality – good sample size of fish with both sexes equally represented, but were collected over a single period with few large fish included.

3.3.4. Summary of Results

The age and size structures, and mean length of Bluespotted Flathead sampled from commercial catches has varied little over the 45-year period over which the historical data span (Hall 2018b). Analyses of the recent fish sampled during 2018/19 showed similar results to these historical data and suggested that the age structure is still comprised primarily of 3–4 year old fish (Table 16 and Figure 26).

The slight truncation of the Bluespotted Flathead age structures in commercial catches may be an artefact of using an age–length key from a single period when few large, old fish were sampled. These were supplemented with 80 larger fish collected during 2011 to try to alleviate some of the bias, but this was not ideal. New otolith samples are currently being collected from both the prawn trawl observer program and port monitoring of other commercial catches to produce an updated age–length key with a more robust regional and size representation.

The analyses are further complicated by using length frequency data, which have both sexes combined and required a single age–length key. For a sexually dimorphic species, such as Bluespotted Flathead, where older males are much smaller than females, there can be two sizes classes present for any given age in the population, which would be better analysed using separate age–length keys for each sex.

Among the historical data, estimates of Z showed little variation across years (ranging from 0.86 to 1.07), although estimates since the early 2000s were marginally lower than those during the 1970s and 1990s (Hall 2018b). The analysis of the 2018/19 data produced a Z estimate of 0.92, which was slightly lower than other recent estimates (Table 17 and Figures 27, 28).

The magnitude of F estimates, and the ratio between F and M varies considerably depending on the level of M selected (Hall 2018b). The two methods recommended to estimate M (one using maximum age and the other based on the von Bertalanffy growth parameters) produced vastly different estimates (0.33 and 0.65, respectively). If the lower value of M was used to predict F (i.e., subtracted from Z) and as a reference for comparison, F estimates were all much higher than M (basically double). However, if the higher value of M was selected the opposite resulted, with F estimates approximately half of M (Hall 2018b). By selecting the average of the two recommended estimates (M = 0.49), F estimates were approximately equal to M (Figure 27).

3.3.5. Uncertainties

There are concerns about the representativeness of the length frequency samples in some years, particularly for those collected between 2008 and 2014 that were primarily sampled from a single location (Forster). Likewise, an updated age–length key that covers a more representative range of ages and sizes would help strengthen these analyses.

Traditional catch curves were applied in this instance, rather than more sophisticated updated methods that include information on gear selectivity (Wayte and Klaer 2010), because in some years samples were pooled from multiple gears to obtain sufficient sample sizes.

Greater certainty in the appropriate level of natural mortality for this species is required before a more formal assessment to determine an estimated recommended biological catch for the stock (e.g, using similar methods to those developed Wayte and Klaer 2010) is worth attempting.

Table 16 Length samples and statistics (total length, TL in cm) of Bluespotted Flathead in 2018/19 used for catch-curve analyses. Samples were obtained through the port monitoring of commercial catches from a representative range of ocean zones and fishing methods, including fish and prawn trawls, demersal fish traps and handlines. Min=minimum, Max=maximum, SD=standard deviation.

Year	No. Samples	Sample Type	No. Fish	Min TL (cm)	Max TL (cm)	Mean TL (cm)	SD TL (cm)
2018/19	55	Mixed	7329	28	70	41.1	2.9

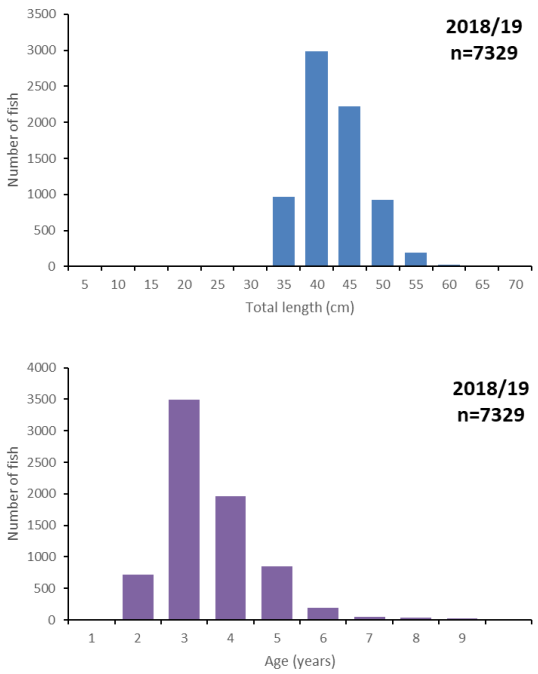


Figure 26 Re-weighted length frequency (total length in cm, top) and length-converted age structure (age classes in years, bottom) for Bluespotted Flathead in 2018/19 (n=7329 fish) sampled from the commercial catch through port monitoring.

Table 17 Estimated total mortality (Z) and fishing mortalities (F) of Bluespotted Flathead in NSW waters in 2018/19 derived using a length-converted catch curve and a range of natural mortality (M) levels.

Year	Estimated Z	Estimated F (M=0.65)	Estimated F (M=0.49)	Estimated F (M=0.33)
2018/19	0.92	0.27	0.43	0.59

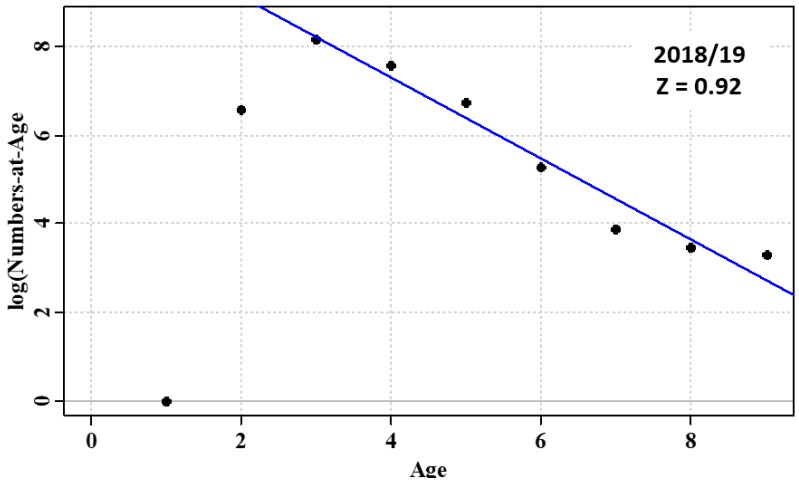


Figure 27 Length-converted catch curve for Bluespotted Flathead in 2018/19 (n=7,329 fish) sampled from NSW commercial catches through port monitoring.

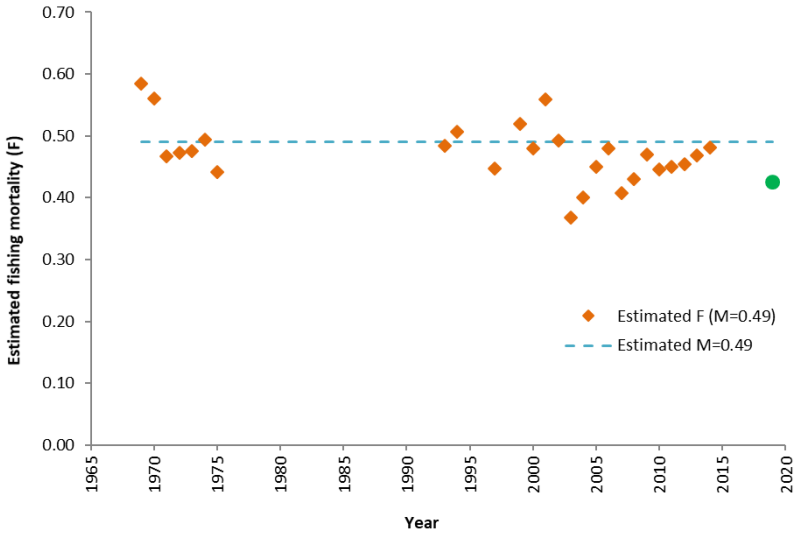


Figure 28 Estimated fishing mortality (F) from length-converted catch curves for Bluespotted Flathead in each calendar year (orange diamonds) and the 2018/19 fiscal year (green dot), using an average natural mortality level (M=0.49). Sample numbers and sizes and fishing methods and locations have varied among the calendar years (for details refer to Hall 2018b).

3.4. Modified Catch-MSY

3.4.1. Method and assumptions

In the 2018 stock assessment, a modified Catch-MSY method was used to characterise the productivity of the stock (by estimating the population growth rate, *r*, and maximum population size, *K*) and to predict current biomass depletion, harvest rates and the maximum sustainable yield (MSY) for Bluespotted Flathead using 12 different historical annual catch scenarios (simpleSA v. 0.1.13, Haddon et al. 2018).

The modified Catch-MSY method uses the relatively simple discrete Schaefer surplus production model to describe the underlying dynamics of a stock:

$$B_{t+1} = B_t + r\,B_t\,(1 - B_t/K) - C_t$$

where B_t represents the stock biomass in year t, *r* represents the population growth rate that includes the balance between recruitment and mortality, *K* is the maximum population biomass (carrying capacity), and C_t is the catch in year t. An *a priori* estimate of resilience, based on the life-history characteristics of the species, is used to define pre-determined ranges of *r* and *K* from which the parameters are randomly selected in combination with initial depletion levels to project how the stock might respond for a given catch history through a form of stock reduction analyses (Martell and Froese 2013). The mean of all possible biomass trajectories that do not collapse or exceed the carrying capacity and fall within pre-determined final depletion ranges are used to estimate the current depletion, and MSY is estimated from the mean parameter estimates according to the equation:

$$\text{MSY} = (r\,K)/4$$

Assumptions:

Note, this is a model-assisted data-poor method that does not statistically fit an index of relative abundance and use known life-history parameters to model the underlying population biomass. Rather it uses a form of stock reduction analysis where the productivity of the stock (in terms of its unfished biomass and population growth rate) is characterised within pre-determined parameter ranges using a relatively simple mathematical model to estimate how the stock might respond given the known history of catches. The model is quite dependent on the resilience level and hence lower bound of *r* selected, and includes many other assumptions associated with the use of the simple Schaefer surplus production model, such as no variation in many parameters over time. For more information on the method and its assumptions please refer to Martell and Froese (2013) and Haddon (2018).

3.4.2. Summary of Results

Twelve historical catch series were analysed, that differed with respect to whether or not the inshore commercial catches south of Barrenjoey Point and estimated discards were included, and the magnitude and temporal variation of recreational catch histories (Hall 2018b). A resilience level of 'medium' was initially selected for Bluespotted Flathead on the basis of its life-history characteristics (i.e., maximum age of 9 years, early age-of-maturity and average natural mortality estimate of M=0.49, Froese et al. 2002); however, the analyses failed to produce any valid combinations of *r* and *K*. So, the resilience was altered to "low", which produced many successful trajectories (Hall 2018b).

The resulting modified Catch-MSY models produced consistent mean estimates of population growth rate (*r* between 0.11 and 0.13) that might be considered too small for such a short-lived species. However, in these simplistic models, *r* and *K* tend to be inversely correlated and because of the overall lower productivity of Australian stocks relative to other areas, estimates of *K* and hence *r* tend to be lower than for similar stocks elsewhere.

The mean estimated biomass trajectories and phase plot analyses suggested that historical harvest rates for Bluespotted Flathead in NSW waters were initially low and then oscillated near or exceeded the limit reference point for many years. These higher harvest rates gradually eroded the biomass to near the limit reference point in some scenarios, but all had recovered to between 32.7–34.0% of the estimated maximum biomass by 2017. Irrespective of which catch series was analysed, recent harvest rates (0.054-0.088) were estimated to be well below the limit reference point of FMSY (0.079-0.098).

Varying the specific catch components included in the historical catch series for analyses had little effect on the mean estimated population growth rate or mean estimated current depletion levels. However, the mean estimated maximum biomass (*K*) and MSY varied considerably in relation to the magnitude of the catch history analysed and the temporal variation in the individual components (Hall 2018b)

When the components were varied in a constant proportion to the underlying commercial catch history they made little difference to the exploitation trends because the overall pattern of removals did not change. The estimated maximum biomass and mean total MSY were higher under the higher recreational catch scenarios, but the estimated commercial component of the MSY did not change and the projected depletion levels after 5 years of constant catches were similar across all series with discards and recreational catches applied at a constant rate (Hall 2018b).

In contrast, when the pattern of recreational exploitation was varied historically (i.e., when scaled in proportion to the historical NSW population size) the overall catch series pattern changed, and initial historical catches were much lower relative to current catches than under the constant percentage scenarios, which resulted in lower predicted carrying capacities, lower MSY estimates and slower recovery from depletion under constant catch projections (Hall 2018b).

These results agree with the findings of Griffiths and Fay (Griffiths and Fay 2015), who investigated the integration of recreational fisheries data into a data-poor management strategy (i.e., Tier 4 Commonwealth assessment methods with standardised catch rates) for Blue-eye Trevalla (*Hyperoglyphe antarctica*). Their findings also indicated that the temporal trends in recreational fisheries data had the greatest influence on the stock assessment and harvest strategy management outcomes. Zhou et al. (2017) also noted that constant components of catch (e.g., consistent under-reporting) will proportionally vary *K* and MSY, but not affect *r* or depletion estimates.

Under all scenarios, excluding those with the varying 65% or 74% recreational catches, maintaining 2017 catch levels (of 78 t) over the subsequent 5 years resulted in an increase of the projected depletion levels back to 40%; whereas, under the varying recreational catch scenarios the 2017 catch levels would not allow an already depleted biomass to recover sufficiently.

The modified Catch MSY approach recommended a TACC equivalent to the lower bound of MSY (95% confidence limit) for stocks that are currently at or above 50% of the maximum biomass (Martell and Froese 2013). Given that the Bluespotted Flathead stock was estimated to be depleted well below this level, it was recommended that the TACC of the NSW OTF should not exceed the lower bound of MSY, which was equivalent to approximately 164 t (with all 'Flathead (other)' in the prawn trawl sector included) to ensure no further depletion of the stock (Hall 2018b). Results from the analyses also suggested that a TACC of <109 t would be required to recover the biomass to 40% estimated depletion within 5 years and that the TACC should not exceed approximately 80 t if temporal variation in recreational catches (like that analysed) was considered probable (Hall 2018b).

3.4.3. Uncertainties

There are many uncertainties associated with these analyses. First and foremost, this method employs a very simple surplus production model that encompasses many basic assumptions, and does not formally fit more comprehensive data in a statistical sense. In particular, the method relies on and is sensitive to the *a priori* definition of the expected *r* and *K* parameter ranges.

Changes in logbook reporting and fishing tactics may have affected the time series of catches in ways that are independent of the dynamics of the biomass (e.g., the large decline in catches in 1990 that was only partially corrected by data adjustment).

Likewise, there could be potential effects to catches of other management changes, e.g., inflation of catches due to the fishery going to catch quota management, evident in 2006 (before the logbook changes in 2009) and again in recent catches leading up to the current introduction of catch quotas that are independent of biomass dynamics.

However, the main uncertainty concerns the unknown magnitude and temporal variation in historical recreational catches and discard rates which may critically influence the interpretation of the model outcomes.

4. Fishery interactions

The OTF trawl fishing gears interact with other commercial and non-commercial by-catch marine species, a range of endangered, threatened and/or protected (ETP) species and marine habitats. The OTF share management plan mandates that otter trawl nets must be fitted with at least one BRD of an approved design to reduce the by-catch of small prawns and juvenile fish. Mesh size and other gear restrictions are regulated to increase the target species selectivity of otter trawl and Danish seine nets and cod ends. Research results to date suggest that these measures significantly decrease the levels of by-catch associated with these fishing gears (Broadhurst and Kennelly 1996; Broadhurst et al. 1996 ; Broadhurst et al. 1997; Broadhurst et al. 1999 ; Broadhurst et al. 2005; Broadhurst et al. 2006).

Interactions with animals protected under the *Environment Protection and Biodiversity Conservation Act* 1999 include marine mammals (dolphins, seals and sea lions), seabirds, some shark species, and seahorses and pipefish (sygnathids). The ETP species that interact with the OTF were subjected to a detailed risk assessment in the environmental impact statement (EIS) for the fishery (NSW DPI 2004). Of the 11 ETP species identified in the EIS, all were considered to be at moderate/low or low risk. An updated threat and risk assessment for all components of the NSW marine estate was completed in 2017 (Fletcher and Fisk 2017). The OTF was considered a moderate threat to ETP species along the north coast and a low threat to ETP species along the south coast. Interactions with grey nurse sharks and sygnathids were identified as the main concerns.

Compulsory reporting in commercial logbooks of all interactions with ETP species was mandated for the OTF in 2005 and these are reported annually to the Department of Environment and Energy (NSW DPI 2017). Data on incidental interactions with by-catch, ETP species and associated mortalities were also collected for the fish trawl sector during a recent observer survey (2014–2016) and are currently being assessed for the prawn trawl observer survey (2018–2019).

The majority of available trawl ground in NSW waters is likely to be dominated by sandy habitat with little reef structure, and fishers typically try to avoid high topography, hard, structured habitats to prevent net damage. Large areas within NSW marine parks are closed to trawling and provide areas for habitat protection. The use of bobbins on ground ropes of fish trawl nets is prohibited north of Seal Rocks and the maximum size of bobbins is limited south of Seal Rocks to minimise damage to reef habitats. More information on the potential effects of trawl gears on the soft seabed biota is warranted, as impacts to these less protected habitats are likely to be more significant.

5. Conclusions

5.1. Status indicators and limit reference levels

5.1.1. Biomass indicator or proxy

None specified in a formal harvest strategy.

In the interim, for the purposes of this stock assessment a weight-of-evidence approach was used, which included: the mean estimated biomass depletion (as a percentage of the estimated maximum biomass, *K*) from modified Catch-MSY analyses (e.g., Martell and Froese 2013); and standardised catch rates from the fish trawl (otter trawl) and ocean prawn (otter trawl) sectors of the Ocean Trawl Fishery.

5.1.2. Biomass limit reference level

None specified in a formal harvest strategy.

In the interim, for the purposes of this stock assessment the following were selected: 20% of the estimated maximum biomass for the limit reference point (B_{lim}) and 48% of the estimated maximum biomass as the target reference point (B_{targ}), in line with the Harvest Strategy Framework for the Commonwealth Southern and Eastern Scalefish and Shark Fishery (AFMA 2017); and significant declines in catch rates over more than 3 years as a trigger reference point.

5.1.3. Fishing mortality indicator or proxy

None specified in a formal harvest strategy.

In the interim, for the purposes of this stock assessment a weight-of-evidence approach was used, which included: the estimated mean annual harvest rate from modified Catch-MSY analyses; and fishing mortality estimates from length-converted catch-curve analyses of commercial catch composition data.

5.1.4. Fishing mortality limit reference level

None specified in a formal harvest strategy.

In the interim, for the purposes of this stock assessment the following were selected: estimated harvest rate corresponding to 20% of estimated maximum biomass for the limit reference point (H_{lim}) and the estimated harvest rate corresponding to when the stock is a 48% of estimated maximum biomass for the target reference point (H_{targ}), in line with the Harvest Strategy Framework for the Commonwealth Southern and Eastern Scalefish and Shark Fishery (AFMA 2017); and significant increases in fishing mortality estimates over more than 3 years as a trigger reference point..

5.2. Stock assessment results

5.2.1. Biomass status in relation to limit

Results of the modified Catch-MSY modelling suggest that the current biomass of Bluespotted Flathead in NSW waters is depleted to 32.6–34.2% of the estimated maximum biomass, irrespective of which historical catch series was used in the analyses. This is below the B_{targ} reference point of 48% of estimated maximum biomass, but above the B_{lim} reference point of 20%.

Standardised catch rates have been above or near the long-term (21-year) averages for the last 10 years for monthly recorded data, but near or below shorter-term (9-year) averages for the last 6 years for daily recorded data. In all cases, however, increasing or stable trends are evident in catch rates over the last 3 years. The longer-term catch rates must be interpreted with caution due to the potential influence of catch reporting changes in July 2009.

Annual length frequencies of fish sampled from the commercial catch over a period spanning 45 years suggest that the size structure of the population has remained stable.

The weight of evidence indicates that the biomass of the stock is unlikely to be recruitment overfished and that current harvest rates are permitting some biomass recovery towards Bt_{arg}.

5.2.2. Fishing mortality in relation to limit

Results of the modified Catch-MSY modelling suggest that the current harvest rate of Bluespotted Flathead in NSW waters is below H_{lim} and either close to or below H_{targ}, depending on which historical catch series was analysed.

The fishing mortality estimates from the length-converted catch-curve analyses supported this finding when the average estimate of natural mortality (M=0.49) was used. However, these latter results are very sensitive to the assumed value of M and should be treated with caution.

The weight of evidence indicates that the current level of fishing pressure is unlikely to cause the stock to become recruitment overfished.

5.2.3. Previous SAFS stock status

Bluespotted Flathead was previously assessed as a **sustainable stock** under the SAFS framework in 2018.

5.2.4. Current stock status

Bluespotted Flathead is currently assessed as a **sustainable stock** on the basis of this updated NSW stock assessment.

5.3. Discussion

Despite the many uncertainties in the datasets and stock assessment methods used, there were some encouraging consistencies among the results produced from a range of data sources. All CPUE indices, including those from two different commercial trawl fleets across seven ocean zones and the charter boat fishery, showed similar recent trends that suggest stock biomass is stable or increasing. These trends in catch rates support the outcomes of the modified Catch-MSY modelling completed in 2018, which also suggested that current biomass is gradually recovering from a period of greater fishing between 1947/48 and 1989/90.

The size structure of the stock continues to be stable and recent fishing mortality estimates (M=0.43 for 2018/19) from length-converted catch curves are below the average natural mortality estimate (M=49) and slightly lower than historical levels from the 1960s and 1970s. These results provide further evidence that current harvest rates are lower than in the past and support the outputs of the modified Catch-MSY analyses, which estimated that harvest rates during the 1990s and earlier were higher and exceeded the limit reference levels, but that recent harvest rates since 2014 have been well below H_{lim} and at a level that should permit further biomass recovery. Certainly, there has been a clear reduction in effort in the OTF for Bluespotted Flathead since 1997/98 through a decrease in the number of active fishing vessels.

Despite these positive indications, the outcomes of the assessment suggest that further recovery of the stock biomass towards B_{targ} is still required and it is difficult to predict how current harvest rates and discard rates will respond to the introduction of catch quotas for the species in May 2009. Other uncertainties in the data sets analysed and assessment approaches used have been discussed in detail within the preceding fisheries statistics and assessment sections, and current issues or concerns that are important considerations for TACC determination are also highlighted in the executive summary.

5.4. Recommendations for future stock assessments

Following are planned or suggested options that could help improve the accuracy and utility of future stock assessments for Bluespotted Flathead:

- Further cleaning and validation of commercial catch-and-effort data to try to produce a catch-rate series that can be used as a reliable index of relative abundance.
- In particular, the effects of removing data from fishers that consistently report multi-day trips as single fishing events and manually checking the approach used to enter these data in 2009 and 2010 could be explored further.
- NSW DPI is currently undertaking an FRDC-funded project to quantify error types and rates in existing commercial catch-and-effort data and to assess their influence on stock assessment outputs, which will help improve analyses of these data in future.
- In addition, options to extend the catch-rate time series back a further 13 years to 1985 could be explored, by including only data for catches that were taken by a single fishing method between 1997/98 and 1983/84.
- Formulating a robust series of catch rates would permit the application of more complex data-rich population biomass dynamics modelling approaches (e.g., Stock Synthesis) that would better utilise the extensive size structure dataset and produce

more reliable estimates of biomass and recommended biological catch than the generic modelling approaches used in the current assessment.

- Increased education or compliance of commercial fishers to alleviate ongoing catch-and-effort misreporting might help improve the accuracy of data currently being collected (including more reliable location information).
- Including depth of capture for each fishing event in logbook reporting would also increase the accuracy of those data for catch-rate standardisations.
- The port monitoring program is currently collecting otoliths from commercial catches to update the age–length key with a more representative sample.
- Ongoing age-structure sampling that does not rely on length conversion would increase the accuracy of any age-structured population modelling approaches in the future by permitting sexes to be separated in models, but this is an expensive option.
- Updated estimates of discard rates from the prawn trawl sector are currently being analysed from the recent observer survey (2017–2019) and should be available for the next assessment.
- Regular biennial estimates of statewide recreational catch are planned in the future, using consistent indices that permit relative comparisons across time.
- Research to investigate the post-release survival rates of Bluespotted Flathead angled from deeper ocean waters would also contribute towards estimating unaccounted fishing mortalities of the recreational and charter boat sectors.
- Increased knowledge of the stock structure of the species, especially with respect to finer-scale movement patterns, the possible connection of estuarine and oceanic populations and the importance of the recruitment that occurs in northern waters towards maintaining the biological stock, would assist spatial management considerations.

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APPENDIX I: Fisheries information relevant for data interpretation

Commercial fisheries management

The Ocean Trawl Fishery (OTF) consists of two main sectors, which differ in their gear configurations and targeting: (i) the ocean prawn trawl (OPT) sector, which primarily targets Eastern King Prawn (*Melicertus plebejus*), Eastern School Prawn (*Metapenaeus macleayi*) and to a lesser extent Royal Red Prawn (*Haliporoides sibogae*), but retains significant quantities of finfish and cephalopod species as byproduct; and (ii) the fish trawl sector, which targets a range of finfish species, primarily flatheads, whitings and Silver Trevally (*Pseudocaranx georgianus*), but also retain a range of other species as byproduct.

The OPT sector operates along the entire NSW coastline, but most of the catch is taken north of Barrenjoey Point, where fishers are permitted to operate out to the 4000 m depth contour (Figure 1). South of Barrenjoey Point fishers are restricted to NSW state waters which only extend to 3 nm from the coastline. Prawn trawlers are not permitted to retain any finfish species with a size restriction south of Smoky Cape.

The fish trawl sector is divided into: (i) the northern fish trawl (NFT), which operates between Smoky Cape to Barrenjoey Point (Figure 1) out to the 4000 m depth contour; and (ii) the Southern Fish Trawl (SFT) restricted fishery, which operates south of Barrenjoey Point to the Victorian border in waters out to 3 nm from the coastline. South of Barrenjoey Point the Commonwealth has jurisdiction over trawl fishing in offshore waters (>3 nm from the coastline), which forms part of the Southern and Eastern Scalefish and Shark Fishery (SESSF). There are current negotiations to transition the NSW SFT sector into the Commonwealth SESSF.

Vessels in the OTF primarily use otter trawl nets, with a limited number of Danish seiners operating intermittently in the fish trawl sector. For more detail of permitted gears and regulations refer to the *Fisheries Management (Ocean Trawl Share Management Plan) Regulation* 2006 and the NSW DPI commercial fishing website (www.dpi.nsw.gov.au/fishing/commercial/fisheries/ocean-trawl).

The Ocean Trap and Line Fishery (OTLF) targets demersal and pelagic finfish along the entire NSW coast, in continental shelf and slope waters out to the 4000 m depth contour. The fishery uses a variety of methods, including baited fish traps, handlines and setlines. For more detail on permitted gears and regulations refer to the *Fisheries Management (Ocean Trap and Line Share Management Plan) Regulation* 2006 and the NSW DPI commercial fishing website (www.dpi.nsw.gov.au/fishing/commercial/fisheries/otl-fishery).

The Ocean Hauling Fishery (OHF) targets approximately 20 finfish species using commercial hauling and purse seine nets from sea beaches and in ocean waters within 3 nautical miles of the coast. The fishery is broken up into 7 broad regions along the NSW coastline. For more detail on the permitted gears and regulations refer to the *Fisheries Management (Ocean Hauling Share Management Plan) Regulation* 2006 and the NSW DPI commercial fishing website (www.dpi.nsw.gov.au/fishing/commercial/fisheries/ ocean-hauling).

The Estuary General Fishery (EGF) is a diverse multi-species, multi-method fishery that is permitted to operate in 76 of the NSW's estuarine systems that are aggregated into 7 broad regions along the coastline. It is the most diverse commercial fishery in NSW and includes all forms (17 gear types) of commercial estuarine fishing other than estuary prawn trawling. For

more detail of permitted gears and regulations refer to the *Fisheries Management (Estuary General Share Management Plan) Regulation* 2006 and the NSW DPI commercial fishing website (www.dpi.nsw.gov.au/fishing/commercial/fisheries/egf).

The Estuary Prawn Trawl Fishery (EPTF) operates in three large estuaries (the Clarence, Hunter and Hawkesbury rivers) targeting prawns, squid and a limited number of permitted bycatch species using otter trawl gears. For more detail of permitted gears and regulations refer to the *Fisheries Management (Estuary Prawn Trawl Share Management Plan) Regulation* 2006 and the NSW DPI commercial fishing website (https://www.dpi.nsw.gov.au/fishing/commercial/fisheries/ept-fishery).

Bycatch reduction devices (BRDs) were introduced into the OTF and EPTF in 1999, and have become more effective over time, which has likely influenced temporal variation in byproduct retention, escapement and discard rates and associated mortalities.

Catch-and-effort logbook reporting changes

NSW catch-and-effort logbook data vary spatially and temporally across different eras, delineated by changes in catch reporting requirements and management. This section briefly summarises the catch-and-effort data available for each era and associated limitations and caveats (also refer to Table A1).

(1) Historical data (Pre-1984) – annual catches (kg) reported by port of landing or individual estuaries, which can be aggregated into the 10 broad ocean zones and 7 estuary regions used in later eras (Figure 1). No information on fisher, vessels or effort is available, and catch could only be assigned to individual methods if a single method was used by a fisher in any given month. Given the lack of appropriate effort data for this era, it is not possible to compile a CPUE series for any species in NSW State waters prior to July 1984.

(2) Historical data (July 1984 to June 1997) – monthly catches (kg) reported by 10 broad ocean zones or individual estuaries (Figure 1). Details on fishers, boats and effort by gear type (in days fished per month) are available. Catch could only be assigned to individual methods if a single method was used by a fisher in any given month. Therefore, CPUE data for this period, include only a subset of catch records for each species. No depth information is available. Trawl catches taken in offshore Commonwealth waters south of Barrenjoey Point and landed at a NSW port were included on NSW logsheets.

(3) Recent data (July 1997 to June 2009) – monthly catches (kg) reported by 10 broad ocean zones or individual estuaries (Figure 1). Details on fishers, boats and effort by gear type (in days fished per month) are available. Method was assigned to all catches. No depth information is available. Trawl catches taken in offshore Commonwealth waters south of Barrenjoey Point and landed at a NSW port were no longer included on NSW reporting. Catch, effort and CPUE data (in kg per fisher day) are available for this era.

(4) Recent data (July 2009 to present) – daily catches (kg) reported to individual estuaries and a finer spatial scale (0.1° x 0.1° C-square grid) for ocean waters. Many species complexes were split and catches reported by individual species. Details on fishers, boats and effort by gear type (by a single effort unit, e.g., hours fished, number of hooks or traps, or net length). Depth information is not reported by fishers, but could be interpolated from location data (i.e., from the mean depth of the reported C-square).

To construct a longer time series of data (i.e., from 1984/85 or 1997/98 to present), daily records are re-aggregated into monthly catches (kg) by fisher and gear type, with effort in days per month estimated from the number of distinct fishing dates in each month where the method was used, irrespective of whether the species was reported on those days, to be consistent with earlier reporting. Catch, effort and CPUE data (in kg per effort unit or kg per fisher day, using re-aggregated data) are available for this era. Significant reductions in effort (and consequently spikes in CPUE) are evident in some species' data following these logbook changes in July 2009; long-time series of CPUE that cross this period need to be interpreted with caution.

NB: Mixed zone reporting – Prior to July 2009, some catches were reported against mixed ocean zones (e.g. OZ1 and OZ2 combined). To report by zones, these catch-and-effort data are divided and reallocated evenly to each of the zones involved. Most of the mixed zone records were for just two zones and <3% involved three or more zones. After June 2009, all catches were reported according to the finer-scale C-squares.

Table A1 Summary of the main data sources of commercial fishery records and changes to fisher reporting requirements through time.

Time period	Data source	Reporting requirements
Pre-1984	HCatch	Catch unit – kg per month No fisher, vessel or effort information available Spatial scale – port of landing or individual estuaries
July 1984–June 1997	ComCatch	Catch unit – kg per month Effort unit – days fished per month, total number of shots and total hours trawled per month Catch data not linked to individual methods, therefore, effort only assigned to catches when a single method was used in a given month. Spatial scale – 10 broad ocean zones (1 degree latitude) or individual estuaries in 7 broad estuary regions
July 1997–June 2009	ComCatch	Catch unit – kg per month Effort unit – days fished per month, total number of shots and total hours trawled per month Catch data provided for each method used. Spatial scale – 10 broad ocean zones (1 degree latitude) or individual estuaries in 7 broad estuary regions
July 2009–present	FishOnline	Catch unit – kg per fishing event (within each day) Effort unit – various, one unit per method, e.g., hours fished or number of shorts per event, net length or number of traps, hooks or lures (days fished per month can be extracted from re-aggregated daily data) Catch data provided for each method used Spatial scale – 0.1° x 0.1° C-square ocean grid or individual estuaries (re-aggregated into broad ocean zones or estuary regions) Voluntary E-reporting of catch records since 2011 Compulsory E-reporting for quota reconciliation since 2019

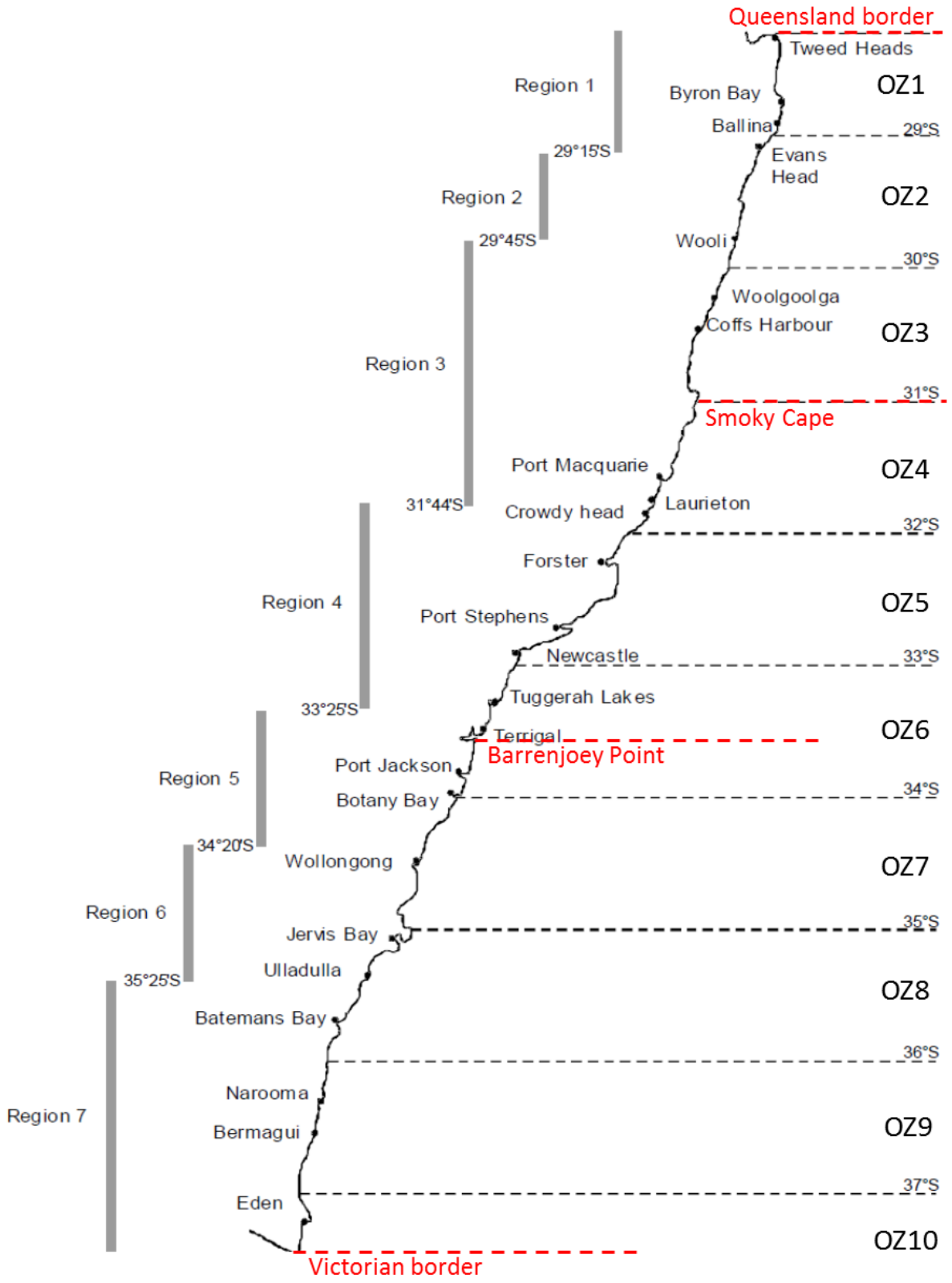

Figure A1 Map of NSW coastline indicating the main ports of landing, broad ocean fishing zones (OZ1 to OZ10) and estuary fishing regions (Region 1 to 7) for catch-and-effort reporting. Important management landmarks, including Smoky Cape, Barrenjoey Point and the Queensland and Victorian borders are also indicated by dashed red lines.

NSW Recreational fishing surveys

The NSW recreational fishing surveys vary in several key design features between the 2013/14 and 2017/18 surveys. In particular, the 2013/14 survey randomly sampled the entire NSW population to provide a statewide estimate; whereas, the 2017/18 survey sampled only the 1–3 year recreational fishing licence holders. Other differences between the two surveys are detailed below in Table A2.

Table A2 Summary of the main differences in design features of the NSW recreational fishing surveys completed in 2013/14 and 2017/18 (outlined in red).

SURVEY DESIGN SPECIFICATION	2013/14 SURVEY	2017/18 SURVEY
Sampling Frame*	Households listed in White Pages	People listed in the NSW Recreational Fishing Fee (RFF) Licence database (1-3 yr licence holders only)
Primary Sampling Unit*	Household	Person (1-3 yr RFF licence holder)
Sampling Design	Stratified random sample (selection from 10 Australian Bureau of Statistic (ABS) defined geographic areas)	
Residency of Persons in Scope*	NSW/ACT residents only	NSW/ACT residents & interstate (Qld & Vic) residents fishing in NSW/ACT waters
Age of Persons in Scope	> 5 years old	
Platforms	Shore- & boat-based	
Methods	All fishing methods including line fishing, diving, hand collection, netting, potting and spearing	
Geographic Scope	State-wide across 10 geographic areas (in waterbodies classified as offshore oceanic, inshore oceanic, estuarine or freshwater)	
Temporal Scope	12 month coverage; 24 hours per day	
Expansion of Survey Outputs*	Expanded to ABS population bench marks with non-response adjustments	Expanded to RFF Licenced population bench marks with non-response adjustments

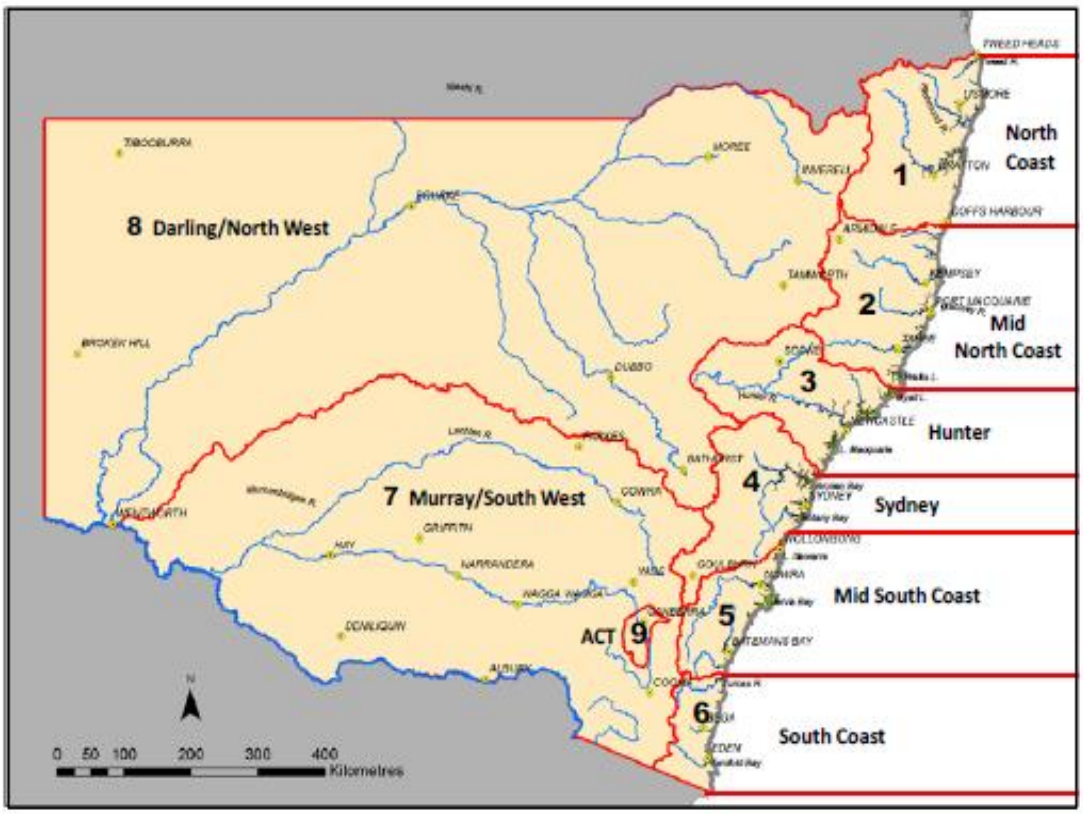

Figure A2 Map of NSW indicating the nine broad regions used for recreational survey data summaries (outlined in red).