Stock Status Summary 2021

NSW Stock Status Summary – Yellowtail Kingfish
(Seriola lalandi)

Assessment Authors and Year

Hughes, J. M. Stewart, J. 2020. NSW Stock Status Summary 2018/19 – Yellowtail Kingfish (*Seriola lalandi).* NSW Department of Primary Industries. Fisheries NSW. 27 pp.

Stock Status

Current stock status	On the basis of the evidence contained within this assessment, Yellowtail Kingfish is currently assessed as **Sustainable** for the NSW component of the stock.

Stock Structure

Yellowtail Kingfish are a highly mobile pelagic species with a widespread distribution extending throughout temperate waters of the Atlantic, Pacific and Indian Oceans [Nugroho et al. 2001]. In Australian waters, the species occurs along the entire southern seaboard of the continent from North Reef in southern Queensland (23°S) to Trigg Island in Western Australia (32°S) including the east coast of Tasmania, and around Lord Howe and Norfolk Islands [Love and Langenkamp 2003].

The estimated size at which 50% of females and males are mature is 83 cm and 47 cm fork length (FL) respectively corresponding to an age of less than 1 year old for males and 3-4 years for females [Gillanders et al. 1999]. Yellowtail Kingfish are spring-summer spawners with pelagic eggs that are about 1.4 mm in diameter [Gillanders et al. 1999, Poortenaar et al. 2001]. Larval kingfish hatch within 2-3 days at 4 mm in length. Large schools of juveniles can be found in nearshore coastal waters as well as in offshore waters around the continental shelf and solitary or small groups of adults can be found near rocky shores, reefs and islands to depths of more than 300 m [Stewart and Hughes 2008]. Growth is rapid, being nearly linear between 1 and 11 years old, with fish reaching the 65 cm total length (TL) minimum legal length (MLL) at around 2-3 years of age [Stewart et al. 2001]. Yellowtail Kingfish can attain approximately 190 cm TL and can weigh up to 70 kg with a maximum recorded age of 21 years [Stewart et al. 2001].

Yellowtail Kingfish is an important commercial and recreational target species in New South Wales (NSW) [Hughes et al. 2018]. The Ocean Trap and Line Fishery (utilizing line fishing methods) reports the entire catch in the commercial sector. The commercial harvest of kingfish decreased from around 600 t in the mid-late 1980s to around 100 t in the late 1990s. An MLL of 60 cm TL was imposed for Yellowtail Kingfish in NSW waters in 1990. In 2007 the MLL for Yellowtail Kingfish in NSW was increased further to 65 cm TL.

Genetic analyses have shown Yellowtail Kingfish in Australia to be divisible into two stocks; the population in Western Australia – the "Western Australia" biological stock – being genetically distinct from the Yellowtail Kingfish found in south-eastern Australia (southern Queensland to South Australia (SA), including NSW, Victoria and Tasmania) – the "Eastern Australia" biological stock [Miller et al. 2011, Green at al. 2020]. Yellowtail Kingfish in New Zealand (NZ) are genetically similar to the "Eastern Australia" stock [Miller at al. 2011]. These findings confirm results from previous analyses that found no evidence of genetic differentiation between NZ and NSW Yellowtail Kingfish [Smith et al. 1991] and results of tagging studies which show that Yellowtail Kingfish undergo bi-directional movements between NSW and SA [NSW Gamefish Tagging

Program, unpublished data] and between eastern Australia, NZ and Lord Howe Island [Gillanders et al. 2001, Holdsworth et al. 2016].

The data presented in this summary were collected from NSW waters only but relate to the assessment of the entire "**Eastern Australia**" biological stock.

Stock Status – New South Wales

Catch Trends - Commercial fisheries

Prior to the 1980s, the commercial catch of Yellowtail Kingfish in NSW was approximately 200 t per year taken primarily using line fishing methods. In the early 1980s, pelagic fish traps ('kingfish' traps) were developed and resulted in landings increasing to an average of approximately 550 t per year in the period 1983/84 to 1989/90 (Fig. 1). The catch declined dramatically through the 1990s and pelagic fish traps were banned in 1996. Since then, the catch has fluctuated considerably around an average of approximately 150 t per year (range ~250 - <100 t). In recent history, a continuous decline in landings has been recorded from 266 t in 2009/10 to 76 t in 2018/19. The entire catch is reported by the Ocean Trap and Line Fishery (OTLF).

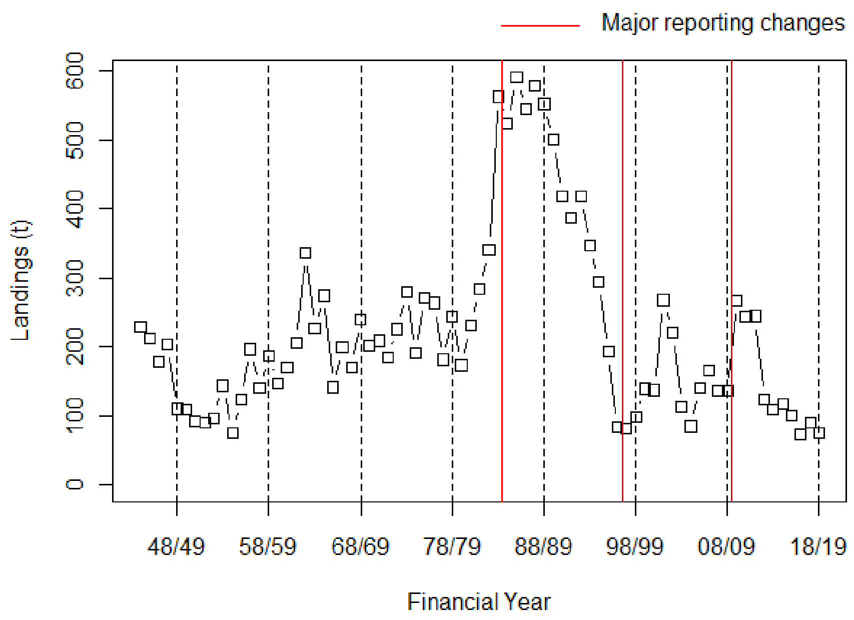


Figure 1. Commercial landings (including available historical records) of Yellowtail Kingfish for NSW from 1944/45 to 2018/19 for all commercial fishing methods.

Recreational

The most recent estimate of the recreational harvest of Yellowtail Kingfish in NSW was approximately 45,000 fish weighing an estimated 129 t during 2017/18 (Fig. 2; Murphy et al., 2020). This estimate only encompassed harvest from NSW households within which a long-term (1-3 year) Recreational Fishing Fee licence holder resided (RFL household). Re-analysis of the previous survey done during 2013/14 (West et al., 2015) for all NSW residents, to allow a comparison with the recent survey, produced an estimate of approximately 41,000 Yellowtail Kingfish harvested by RFL households during 2013/14 (Murphy et al., 2020). In 2000/01 the

National Recreational and Indigenous Fishing Survey (Henry and Lyle, 2003) estimated a recreational harvest by all fishers in NSW waters (including interstate visitors) at approximately 59,000 fish. While these survey results are not directly comparable due to different sampling frames, they likely represent a slight decline in recreational harvest through time but do indicate that the recreational harvest in 2017/18 (129 t) was greater than the commercial catch (91 t) in the same period (Fig. 1).

Indigenous

There are no data on the indigenous harvest of Yellowtail Kingfish in NSW.

All sectors

Total historical harvest of Yellowtail Kingfish in NSW was reconstructed by estimating recreational harvest prior to, and between, recreational survey estimates (Fig. 2). Hindcasting the recreational harvest prior to 2000/01 was done using estimates of national recreational marine fishing effort reported in Kleisner et al. (2015), which used coastal population statistics from the Australian Bureau of Statistics (ABS) with linear interpolation between census years. Estimates of recreational harvest were made by applying the relative recreational fishing effort each year relative to 2000 by the estimated harvest in 2000/01. This estimate was made using the numbers as reported in Henry & Lyle (2003) and NSW DPI unpublished estimates of the proportion of Yellowtail Kingfish within the survey species group (which included Amberjack and Samsonfish) as being 79% in ocean waters and 100% in estuary waters, with average weights being 2.9 and 2.8 kg respectively. After 2000/01, harvest was assumed to follow a linear path between each survey, with the estimate for 2018/19 being set as the same as in 2017/18.

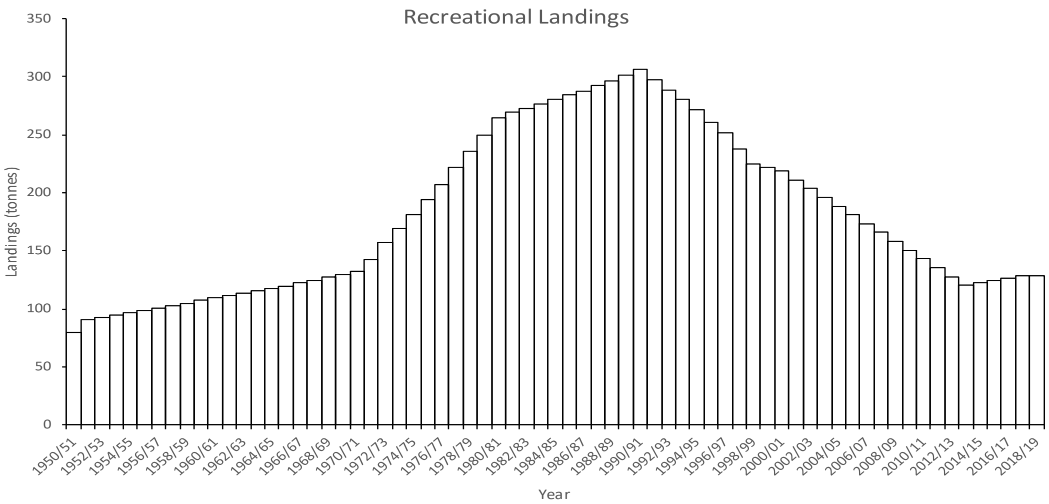


Figure 2. Recreational catch reconstruction for Yellowtail Kingfish in NSW using an estimated recreational catch of 219 t for 2000/01. The green bars represent recreational survey estimates.

The recreational harvest of Yellowtail Kingfish was estimated to have increased rapidly during the 1970s and 1980s, peaking in 1990/91 (Fig. 2). There was a decline in recreational harvest between the surveys in 2000/01 and 2013/14 (noting that the minimum legal length was increased from 60 to 65 cm total length in 2007), and a slight increase between 2013/14 and 2017/18. Harvest from the NSW Charter Fishery is included within the recreational survey estimates.

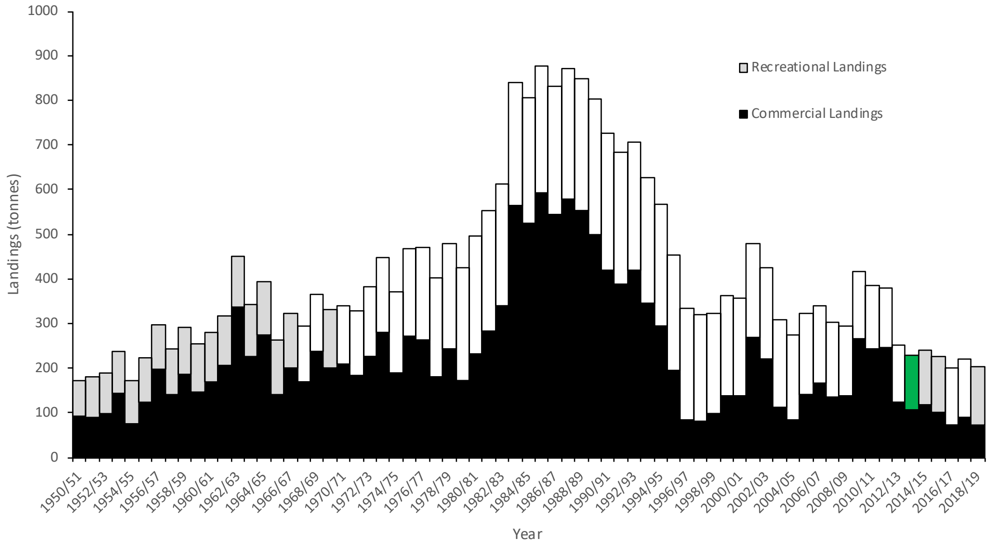


Figure 3. Reconstructed total catch history for Yellowtail Kingfish in NSW 1950/51 to 2018/19.

Combining the NSW commercial and recreational harvest estimates indicate that the fishery increased during the 1970s and early 1980s, peaking during the mid-1980s (Fig. 3). Total harvest since the mid-1990s has been considerably lower with harvest over recent years being among the lowest estimated for the species.

Fishing effort trends

Effort line-fishing (all methods) in the OTLF initially increased following the banning of pelagic fish traps in 1996 from 5,900 days in 1997/98 to 7,900 days per year in 2001/02. This was followed by a steady decline over the ensuing 3 years to 3,900 days in 2004/05. A gradual decrease has been reported since to a historic low of 2,446 days in 2018/19 (Fig. 4).

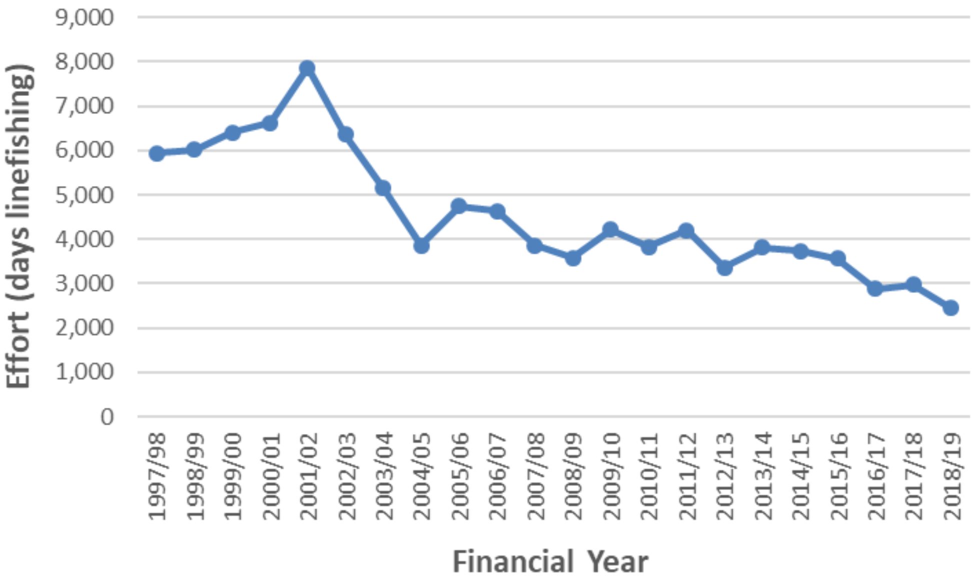


Figure 4. Annual reported days fished for Yellowtail Kingfish (all commercial lining methods) 1997/98 to 2018/19.

Catch rate trends

Standardised Commercial CPUE

Standardised catch per unit effort (kg.day^{-1}) for the four main commercial methods used to land Yellowtail Kingfish – handlining, jigging, trolling and droplining, was estimated using a general linear model (LM) constructed using the 'cede' package (Haddon et al., 2018) in 'R' statistical software. CPUE was standardised for variations across months, areas and fishers to a mean estimate of CPUE by year from 1997/98 to 2018/19. These four methods comprised 95% of the landed commercial catch of Yellowtail Kingfish during the reporting period.

1997/98 – 2018/19

Handlining has accounted for the majority (48%) of total reported commercial Yellowtail Kingfish catch since 1997/98. The resulting standardised CPUE for handlining shows an overall increase between 1997/98 and 2018/19 (Fig. 5). It shows an increase from its lowest value in the reporting period in 1997/98 to a peak in 2010/11 followed by a decline to its 2018/19 value.

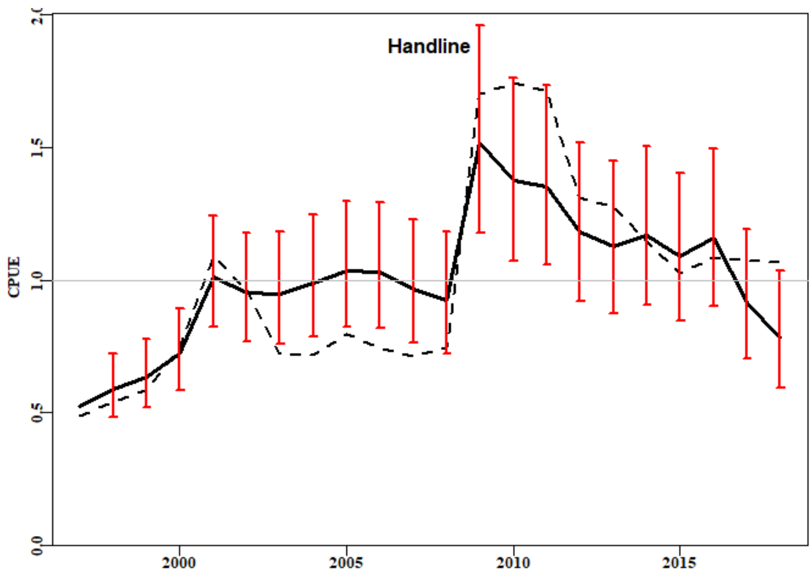


Figure 5. Standardised catch per unit effort in days (kg.day^{-1}) handlining for Yellowtail Kingfish for years 1997/98 to 2018/19 in NSW. The dashed line is the geometric mean CPUE while the solid line with 95% confidence intervals is the standardised CPUE. The horizontal line represents the average catch rate.

Trolling has accounted for 31% of the total Yellowtail Kingfish catch since 1997/98. There is no clear trend in standardised CPUE during the available reporting period (Fig. 6) and the 95% confidence intervals surrounding these values are relatively large and overlap with those from other years.

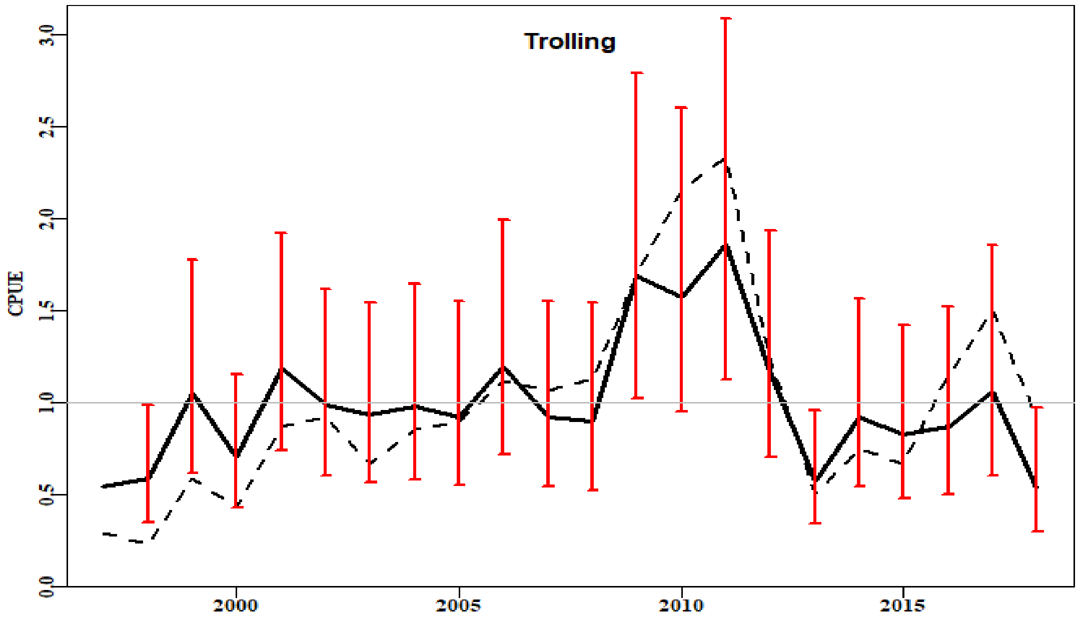


Figure 6. Standardised catch per unit effort in days (kg.day^{-1}) trolling for Yellowtail Kingfish for years 1997/98 to 2018/19 in NSW. The dashed line is the geometric mean CPUE while the solid line with 95% confidence intervals is the standardised CPUE. The horizontal line represents the average catch rate.

Jigging has accounted for 8% of the total Yellowtail Kingfish catch since 1997/98. There is no clear trend in standardised CPUE over the available reporting period (Fig. 7) and the 95% confidence intervals surrounding these values are large and overlap with those from other years.

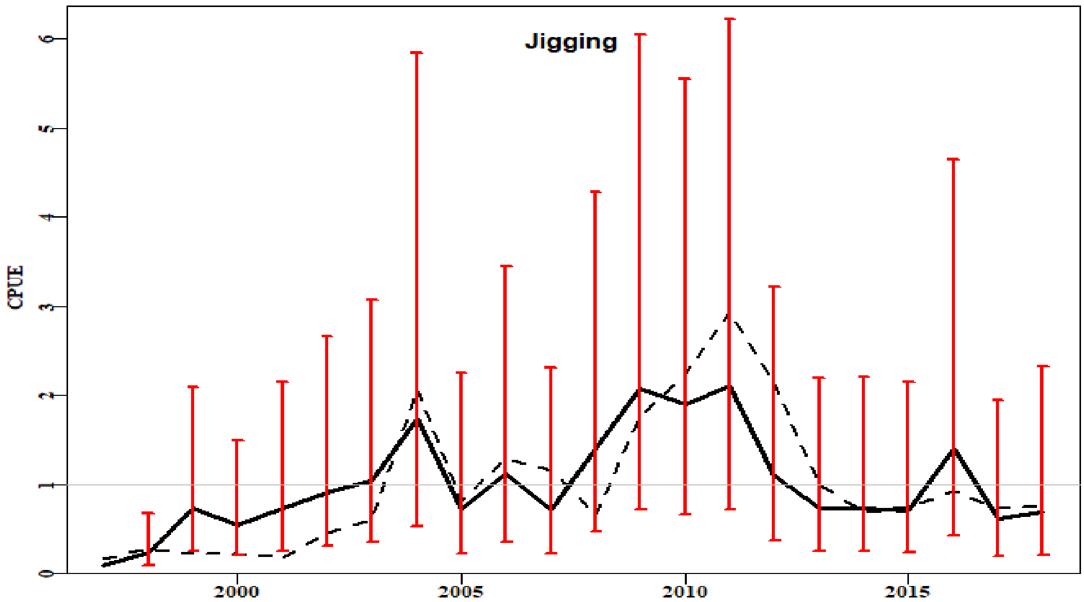


Figure 7. Standardised catch per unit effort in days (kg.day^{-1}) jigging for Yellowtail Kingfish for years 1997/98 to 2018/19 in NSW. The dashed line is the geometric mean CPUE while the solid line with 95% confidence intervals is the standardised CPUE. The horizontal line represents the average catch rate.

Droplining has accounted for 8% of the total Yellowtail Kingfish catch since 1997/98. There is no clear trend in standardised CPUE over the available reporting period (Fig. 8) and the 95% confidence intervals surrounding these values are large and overlap with those from other years.

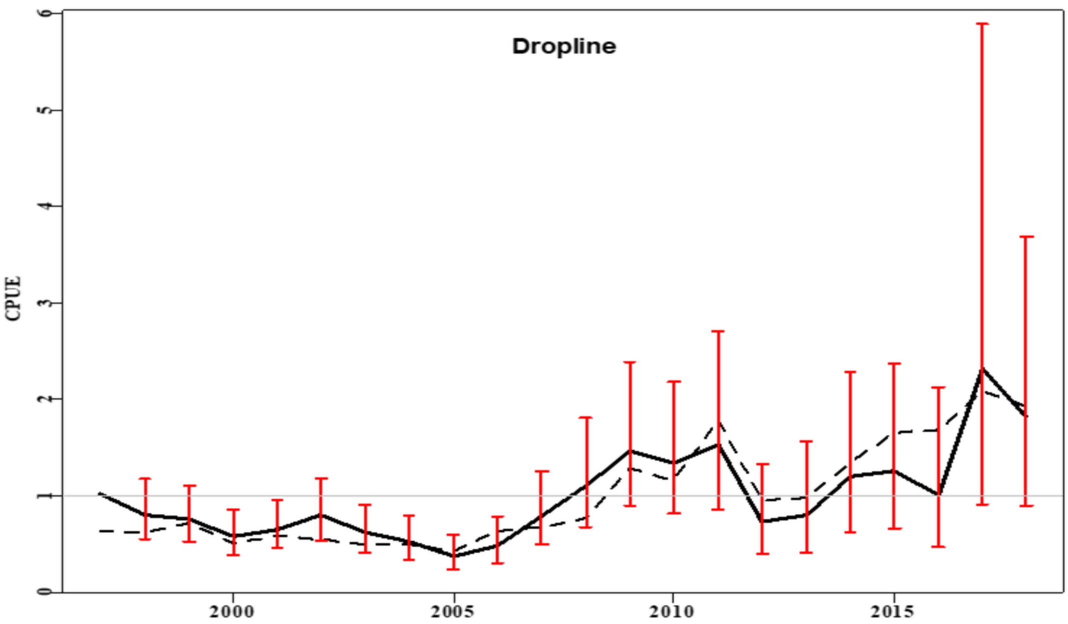


Figure 8. Standardised catch per unit effort in days (kg.day^{-1}) droplining for Yellowtail Kingfish for years 1997/98 to 2018/19 in NSW. The dashed line is the geometric mean CPUE while the solid line with 95% confidence intervals is the standardised CPUE. The horizontal line represents the average catch rate.

2009/10 – 2018/19

Standardised catch per unit effort (kg.day^{-1}) was also estimated using logbook data from the period 2009/10 – 2018/19 in which only days when Yellowtail Kingfish were landed were included. CPUE was standardized for variation across year, months, areas and vessels. CPUE was estimated for all line fishing methods combined (using the assumption that fishers generally only use a single method to target Yellowtail Kingfish on a day) as well as for the primary commercial method – handlining. Both sets of standardized CPUE series show differing patterns to the monthly-based CPUE estimate for handlining above that indicated recent declines between 2010/11 and 2018/19 (Fig. 5), instead showing slight declines between 2009/10 and 2013/14, but increases in recent years (2013/14 – 2018/19; Fig. 9).

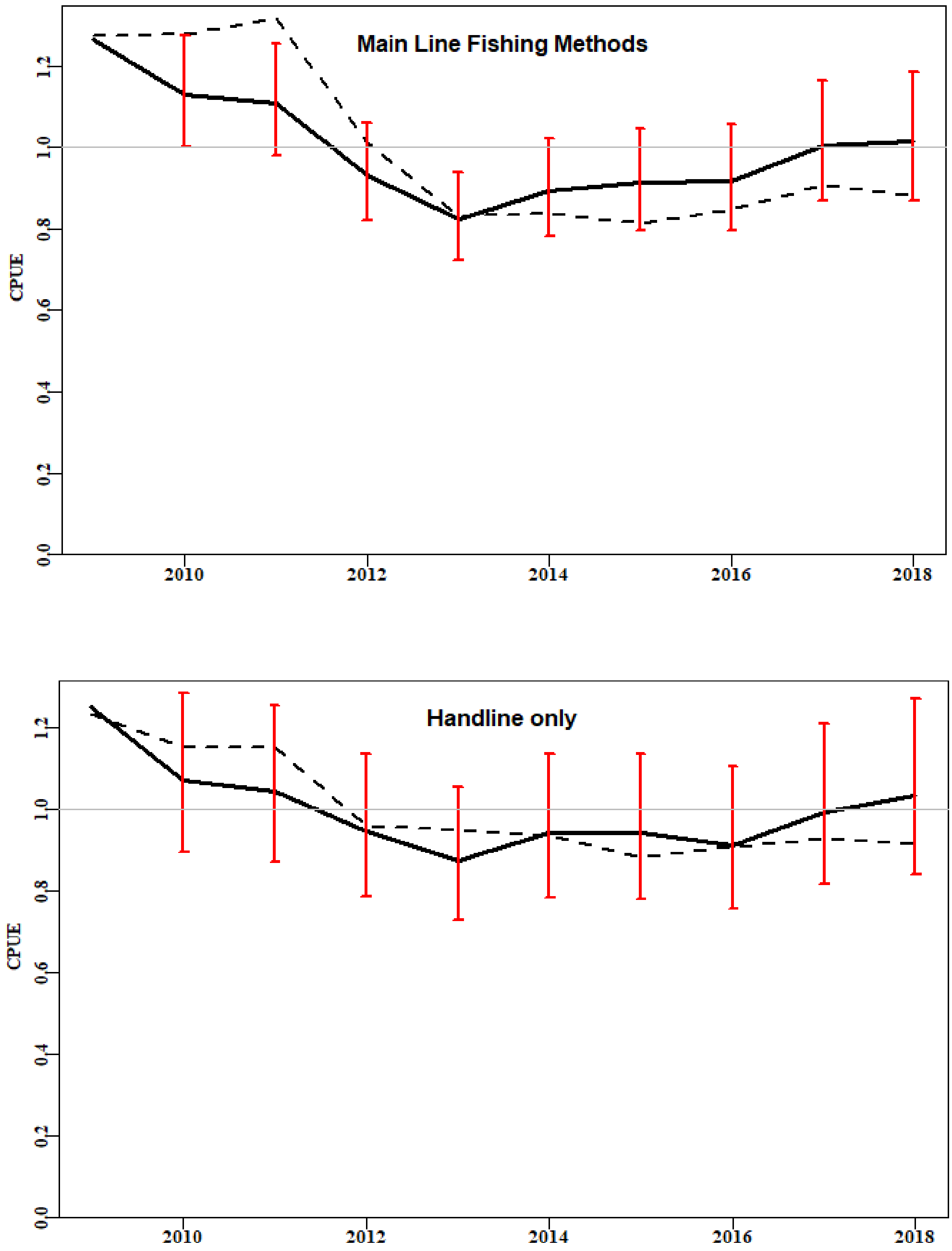


Figure 9. Standardised catch per unit effort (kg.day^{-1}) for all line fishing methods (upper panel) and handlining only (lower panel) for Yellowtail Kingfish for years 2009/10 to 2018/19 in NSW. The dashed line is the geometric mean CPUE while the solid line with 95% confidence intervals is the standardised CPUE. The horizontal line represents the average catch rate.

1997/98 – 2018/19 – adjusting for logbook change in 2009

The standardized catch rates from the monthly logbook data indicated a marked spike in the year following the implementation of the new daily logbook in 2009 (e.g. Fig. 5 - Handline CPUE). To investigate whether this spike was real (considering that landings in that year also increased by around 95%; Fig. 1), the distribution of days of effort reported using the method of Handline was assessed. The results indicated a substantial decline in the number of days reported following the implementation of the daily logbook in 2009 (Fig. 10).

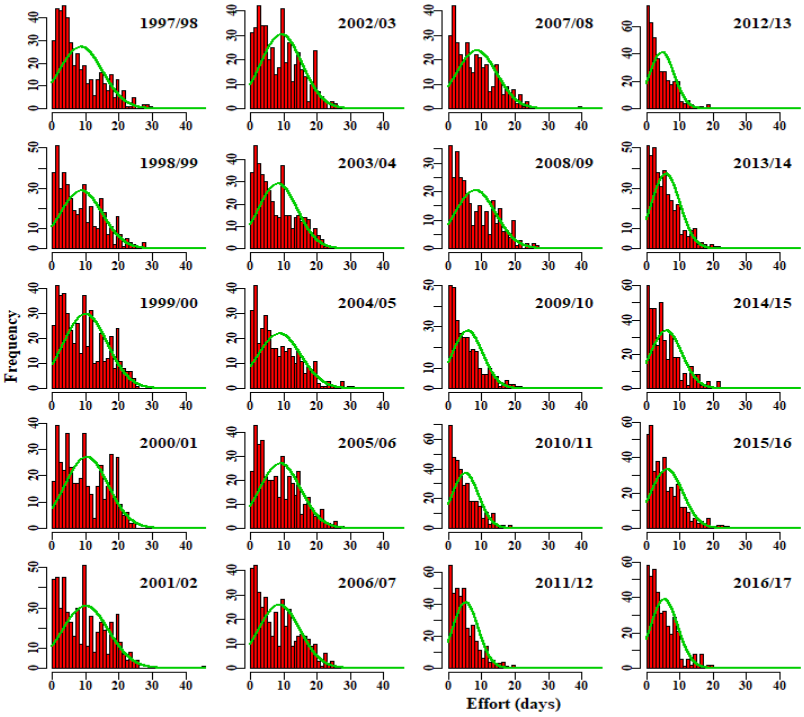


Figure 10. Distribution of reported days fished using the method of Handline for Yellowtail Kingfish

However, a comparison of the standardized catch rates using the monthly and daily records after the 2009 logbook reporting change indicated a very similar, parallel trend between the two series for eight years following the logbook change (Fig. 11).

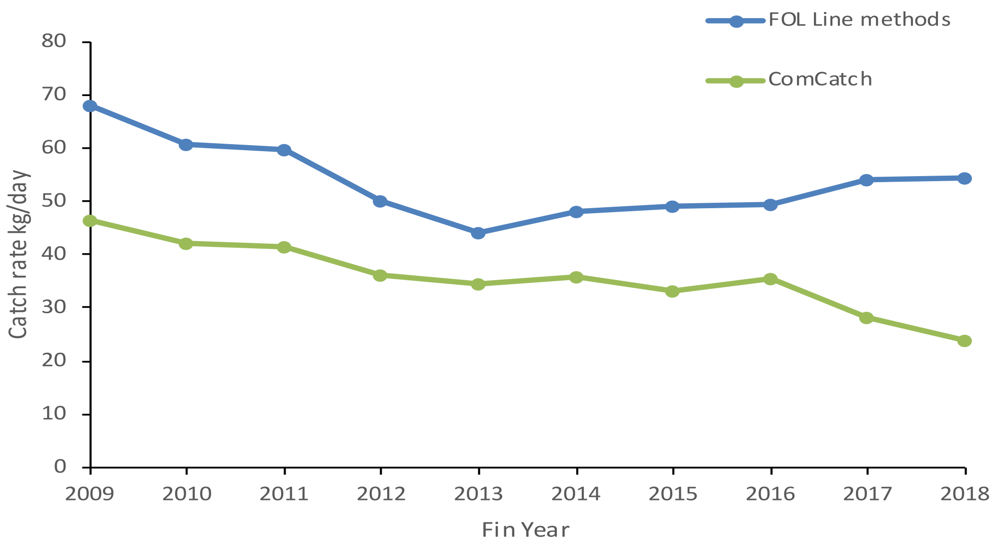


Figure 11. Standardized catch rates 2009/10 to 2018/19 from the monthly (green line – “ComCatch”) and daily (blue line – “FOL Line methods”) logbook data using the method of Handline for Yellowtail Kingfish.

Therefore, in order to correct for this potential bias, the monthly-based (ComCatch) catch rates were scaled by a factor of 1.46 (being the ratio of the 2 data series in 2009). The resulting time series of catch rates reduced the very large spike in CPUE between 2008 and 2009 and showed an overall increase from 1997/98 to 2001/02 followed by relative stability in the period since to 2018/19 (Fig. 12).

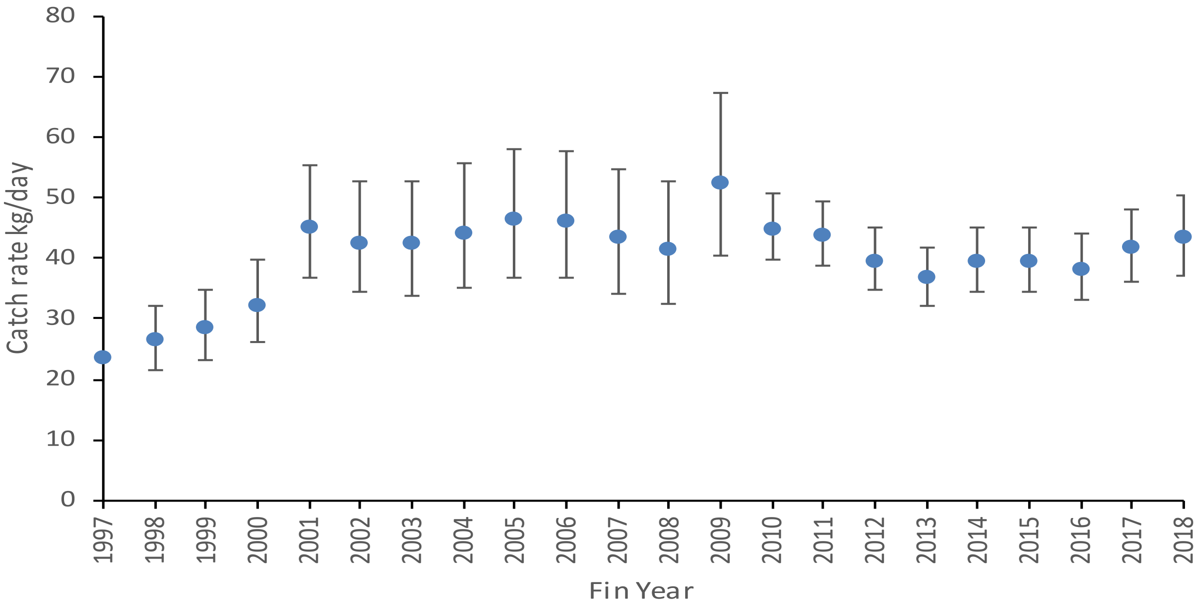


Figure 12. Standardized catch rates 1997/98 to 2018/19 using the method of Handline for Yellowtail Kingfish adjusted for predicted bias resulting from the logbook change from monthly to daily reporting which occurred in 2009

Stock Assessment Methodology

Year of most recent assessment	2020
Assessment method	Weight-of-evidence, including: 1. Standardised commercial CPUE, 2. Catch-MSY model-assisted catch-only assessment (CMSY) with Bayesian state-space implementation of the Schaefer surplus production model (BSM), 3. Total (Z) and fishing (F) mortality estimates, 4. Spawning potential ratio (SPR) analysis, 5. Tag-recapture rates.
Main data inputs	1. Reported commercial catch 1944/45 – 2018/19 2. Reconstructed recreational catch 1950/51 – 2018/19 3. Standardised commercial CPUE 1997/98 – 2018/19, 2009/10 – 2018/19 4. Length composition 1997/98 – 2000/01, 2004/05 – 2018/19

	5. Mortality estimates 6. Spawning potential ratio (SPR) analyses 2010/11 – 2018/19 7. Tag-recapture rates
Key model structure and assumptions	Standardised commercial CPUE Standardised catch per unit effort (kg.day^{-1}) for the four main commercial methods landing Yellowtail Kingfish – handlining, jigging, trolling and droplining was estimated using a general linear model (LM) constructed using the 'cede' package (Haddon *et al*., 2018) in 'R' statistical software. CPUE was standardised for variations across months, areas and vessels to a mean estimate of CPUE by year from 1997/98 to 2018/19 (Figs 5-8). CPUE was also standardised for 1997/98 to 2018/19 after comparison of daily and monthly logbook reporting post-2009 to assess potential bias resulting from a reporting change which occurred in 2009 (Figs 10-12). Finally, CPUE was also standardised for the period 2009/10 to 2018/19 (Fig. 9). *Assumptions*: Annual CPUE is an index of relative abundance and not unduly influenced by other factors that are not accounted for through standardisation. Catch-MSY (Maximum-Sustainable-Yield) model-assisted catch-only assessment (CMSY+; Martell & Froese, 2013) using the 'simpleSA' package in R (Haddon *et al*., 2018). This uses population productivity (*r*) and carrying capacity (*K*) parameters of an underlying Schaefer production model, applied to total annual catches, to estimate the ranges in biomass and harvest rate that could have resulted in the annual catches. *Assumptions*: Estimated ranges of the population growth rate parameter (r) and carrying capacity (*K*) of the stock are pre-determined through an assumed resilience; the underlying population biomass model is very generic and simplistic, with parameters that remain constant through time; the model outcomes are quite dependent on the lower bound of *r* selected (Martell & Froese 2013). 'Resilience' was set to low in the Catch MSY model specification, which allows for a possible range in population growth rate (*r*) of 0.1 – 0.6. Bayesian state-space implementation of the Schaefer surplus production model (BSM) using CMSY+ (Froese et al., 2019) The main advantage of BSM compared to other implementations of surplus production models is the focus on informative priors and the acceptance of short and incomplete (fragmented) CPUE data (Froese et al. 2017).

	Assumptions: Productivity models such as used by CMSY assume average recruitment across all stock sizes, including stock sizes below half of B_{msy}. However, if recruitment is indeed reduced at lower stock sizes, then production models and CMSY will overestimate production of new biomass and will underestimate exploitation rates. Priors for initial relative biomass in 1950/51 were 0.4 – 0.8, and for final relative biomass in 2018/19 at 0.1 – 0.5. <u>Length composition</u> The length composition of commercial catches is used in calculation of mortality rates (catch curve analysis) and subsequent SPR modelling. *Assumptions:* If the size composition of commercial landings is not representative of size composition of the Yellowtail Kingfish stock, then these mortality estimates and subsequent calculations of SPR may affect the assessment of biomass and fishing mortality levels derived from these models. <u>Length-converted catch curve analysis</u> Total mortality estimates (Z) were made using the length-converted catch curve method outlined in Caddy [1983] for approximate ages 2 to 9 (fork lengths (FLs) of 57.5 to 97.5 cm). An averaged length distribution incorporating annual distributions between 2010/11 and 2018/19 weighted by landings each year was used. Growth parameters were taken from the published Schnute growth model for Yellowtail Kingfish (Stewart et al., 2004). Ages 2 – 9 were selected in order to reflect the total mortality on age classes which comprised the vast majority of the fishery. Mortality estimates were made using a plausible range of values for natural mortality (M). *Assumptions:* Sampling is from a population not affected by immigration or emigration, mortality is constant across ages and years, and sampling is not biased regarding any age classes.
Sources of uncertainty evaluated	<u>Recreational catch reconstruction</u> A number of recreational catch histories were reconstructed based on the “Standard” reconstruction described above in “Recreational Catch Information” (Figs 2 & 3) together with reconstructions which reflected results from the “Stakeholder Survey” below. <u>Standardised commercial CPUE</u> A major reporting change for commercial fishers reporting yellowtail kingfish catches occurred in 2009 (Fig. 1).

Consequently, catch per unit effort in days ($kg.day^{-1}$) were standardised for variations across months, areas and vessels to a mean estimate of CPUE by year for:

- Two time series (1997/98 - 2018/19 and 2009/10 - 2018/19). The longer time series includes a major reporting change between 2008/09 and 2009/10 (Fig. 1).
- CPUE in 2008/09 set to equal that in 2009/10 to provide a worst-case correction for potential biases resulting from this major reporting change.
- CPUE from 2008/09 onwards rescaled by applying a 1.46 ratio in order to correct for the logbook reporting change.
- Different fishing methods ("handlining" or "all main line-fishing methods")

Bayesian state-space implementation of the Schaefer surplus production model (BSM) using CMSY+.

A number of scenarios using combinations of the above recreational catch histories and CPUE time series were therefore run through the CMSY+ BSM model (Table 1) to provide a range of plausible depletion trajectories. A 95% confidence interval around each depletion estimate for 2018/19 was derived from the uncertainty around the estimate for each scenario.

Table 1. Catch and CPUE series scenarios used in CMSY+ BSM modelling

Scenario	Catch reconstruction	Standardized CPUE series
1 (Base case)	Standard (Figs 2 & 3)	Handline kg/day 1997/98 – 2018/19 (Fig. 9)
2	0.5*recreational 1950 – 1970	Handline kg/day 1997/98 – 2018/19
3	0.5*recreational 1950 – 1970, 2*recreational 2000/01 – 2018/19	Handline kg/day 1997/98 – 2018/19
4	2*recreational 2000/01 – 2018/19	Handline kg/day 1997/98 – 2018/19

	5	Standard	Main line fishing methods combined 2009/10 – 2018/19
	6	Standard	Handline kg/day 1997/98 – 2018/19, 2008/09 = 2009/10
	7	1950/51 – 1996/97	None (catch-only)
	8	1997/98 – 2018/19 B/K 1997/98 = 0.2 (CI: 0.018 - 0.388) established from scenario 7	Handline kg/day 1997/98 – 2018/19 (2008/09 = 2009/10)
	9	1997/98 – 2018/19 B/K 1997/98 = 0.2 (CI: 0.018 - 0.388) established from scenario 7	Handline kg/day 1997/98 – 2018/19
	10	Standard	Handline kg/day 1997/98 – 2018/19, adjusted for logbook change
	11	0.5*recreational 1950 - 1970	Handline kg/day 1997/98 – 2018/19, adjusted for logbook change
	12	0.5*recreational 1950 -1970, 2*recreational 2000/01 - 2018/19	Handline kg/day 1997/98 – 2018/19, adjusted for logbook change
	13	2*recreational 2000/01 - 2018/19	Handline kg/day 1997/98 – 2018/19, adjusted for logbook change
	Length-converted catch curves. A 95% confidence interval around the estimate of Z was derived from the uncertainty around the slope of the catch curve. Natural mortality (M) estimates were made using various empirical methods [Hoenig 1983, Gillanders et al.		

	2001, Then et al. 2015], which provided a probable range for M of 0.2 – 0.3. <u>Length composition.</u> Seventeen commercial, recreational and charter fishers were engaged to complete a “Stakeholder Survey” of their historical experience and opinions concerning the Yellowtail Kingfish fishery in NSW. This survey provided insights into the perceived health, likely recreational catch and size composition of the stock through time. Key results included: • The biomass of the stock has declined. • The stock contains fewer large fish. • Small fish (<85 cm FL) have historically made up the majority of the landed catch, even when there were more large fish in the population. Consequently, size distributions, and the mortality estimates and SPR analysis models based on them, may not accurately reflect changes in biomass and fishing mortality levels derived from them. In addition, the recreational size composition of Yellowtail Kingfish from available current and historic monitoring was examined to compare with that of the commercial fishery.

Status Indicators and Limits Reference Levels

Biomass indicator or proxy	Current mean estimated biomass depletion (B, as a percentage of the estimated maximum biomass, K) from CMSY+ BSM modelling Current SPR Standardised commercial CPUE
Biomass Limit Reference Level	B_{lim}, expressed as 0.2 (20%) of *K* (B_0), the carrying capacity for the stock as estimated in this assessment 20% of estimated unfished SPR (indicator of low spawning stock biomass (SSB) and exploitable biomass [Goodyear 1993, Mace and Sissenwine 1993])
Fishing mortality indicator or proxy	Current mean estimated harvest rate as $F/F_{0.2}$ from CMSY+ BSM modelling Harvest relative to MSY Current mortality estimates (Z, F & M) Length composition (auxiliary indicator) Tag-recapture rates (auxiliary indicator)

Fishing mortality Limit Reference Level	$F < F_{B0.2}$ Total harvest < MSY F>>M (through time)

Stock Assessment Results

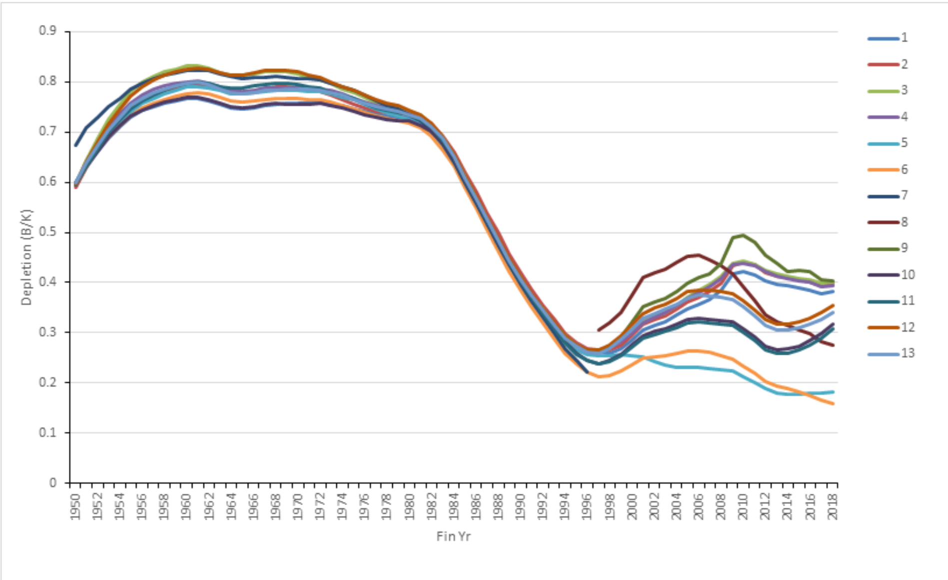
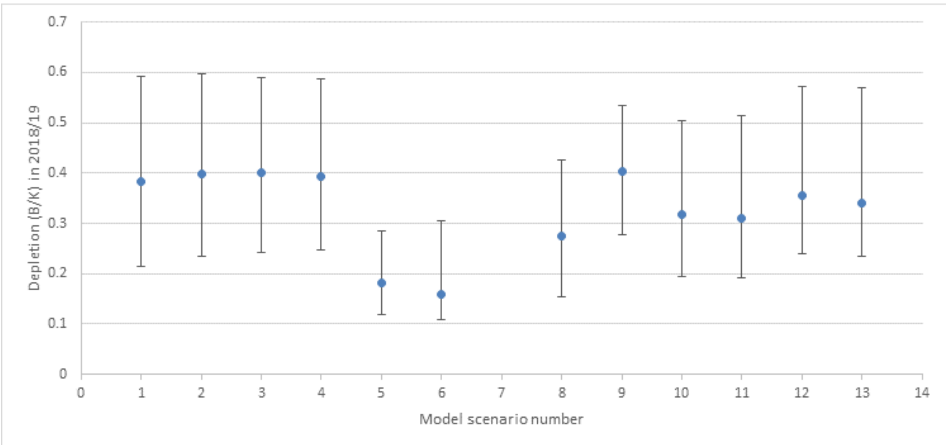
Standardised commercial CPUE	Refer Figures 5 – 12.
CMSY+ BSM modelling Figure 13. Depletion trajectories for the 13 scenarios using combinations of recreational catch histories and CPUE time series (Table 1) run through the CMSY+ BSM model for the period 1950-2018. Figure 14. Estimated depletion (B/K ± 95% CI) in 2018/19 for the 13 recreational catch histories and CPUE time series combination scenarios (Table 1) from the CMSY+ BSM model.	 

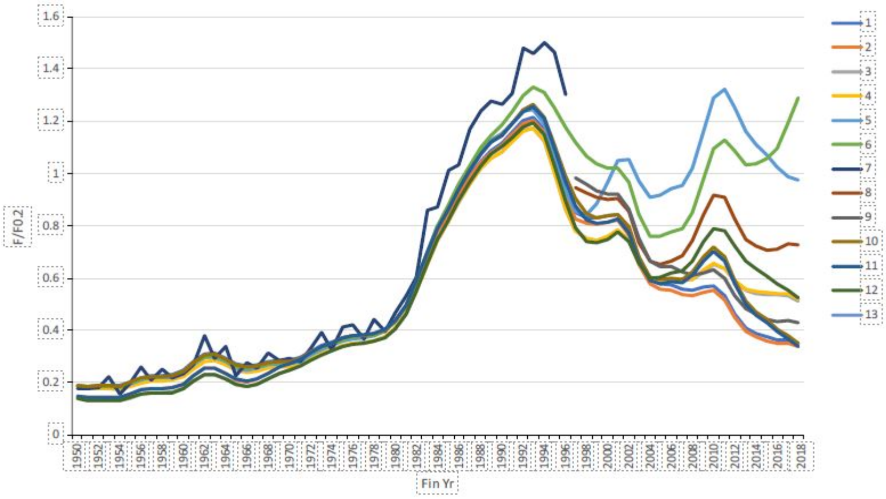
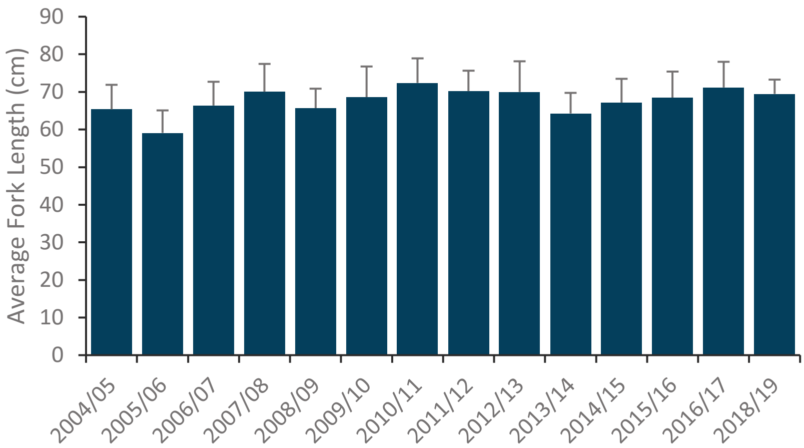
Figure 15. F/F0.2 trajectories for the 13 scenarios using combinations of recreational catch histories and CPUE time series (Table 1) run through the CMSY+ BSM model for the period 1950-2018.	
<u>Length composition</u> <u>Commercial</u> Figure 16. Average fork length (cm ± SE) of the NSW commercial catch of Yellowtail Kingfish from 2004/05 to 2018/19.	

Figure 17. Size composition of the NSW commercial catch of Yellowtail Kingfish from 2004/05 to 2018/19.

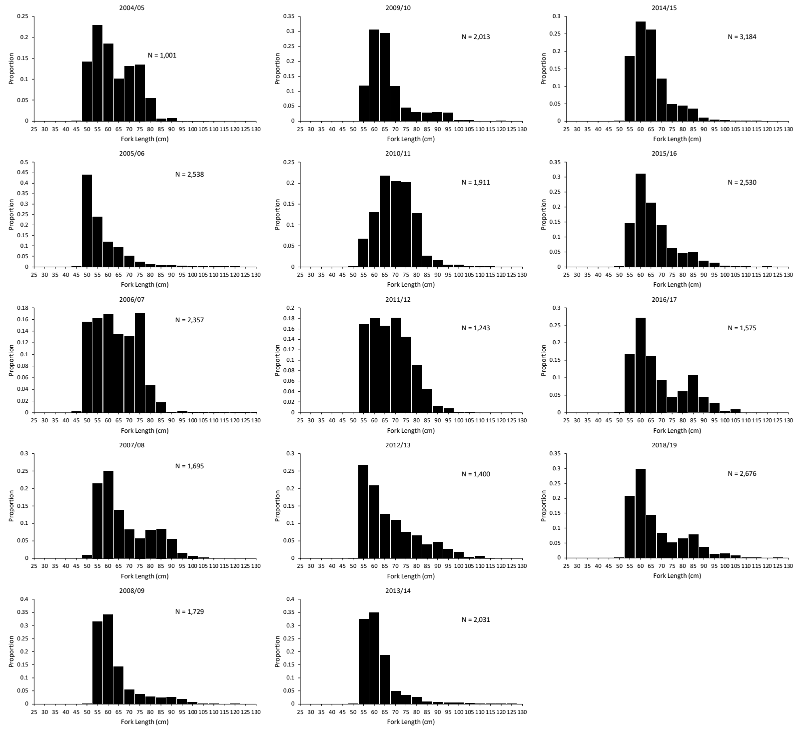
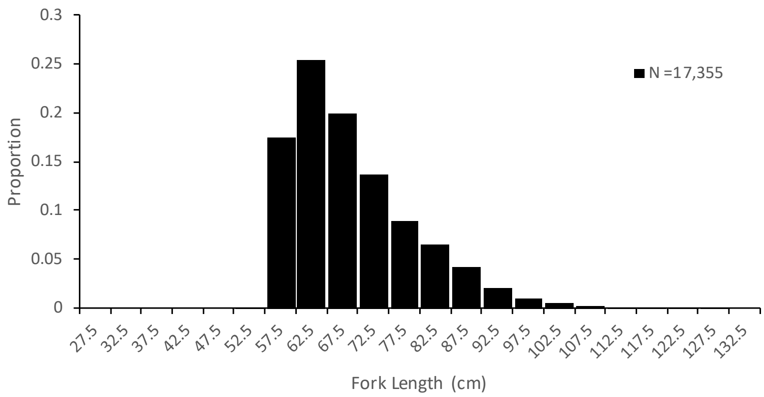


Figure 18. Size composition of the NSW commercial catch of Yellowtail Kingfish averaged from 2010/11 to 2018/19, weighted by reported landings for each year.



Recreational

Figure 19. Size composition of the recreational trailer boat catch of Yellowtail Kingfish in the Greater Sydney Region 2007-2009 (Steffe & Murphy 2011).

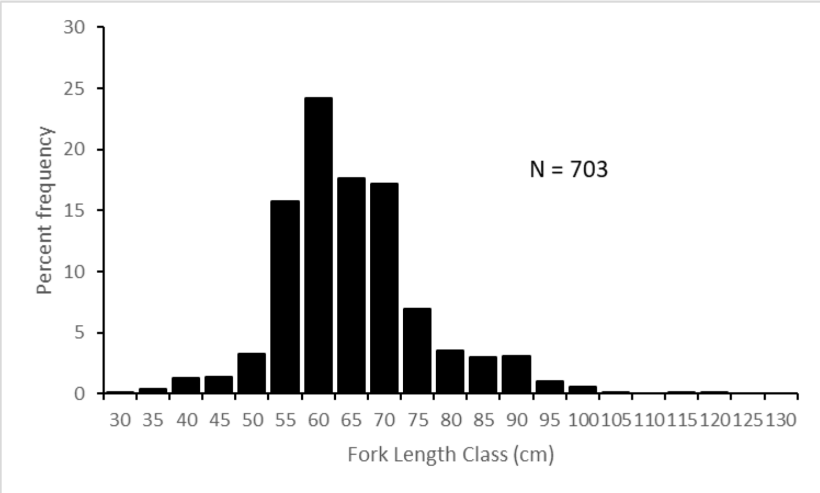


Figure 20. Size composition of the nearshore Charter Fishery catch of Yellowtail Kingfish in southern NSW 2017/18 (Hughes et al. 2020).

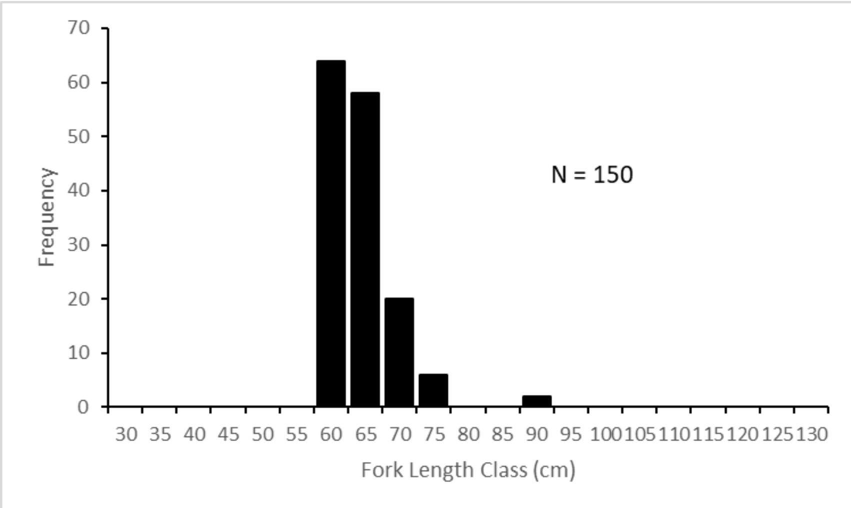
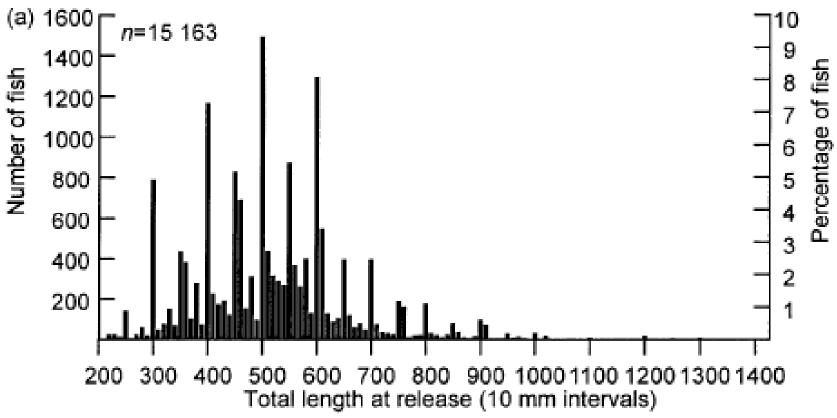


Figure 21. Size composition of Yellowtail Kingfish tagged and released between 1974 and 1995 as part of the NSW Fisheries Gamefish Tagging Programme. Figure is from Gillanders et al., 2001.



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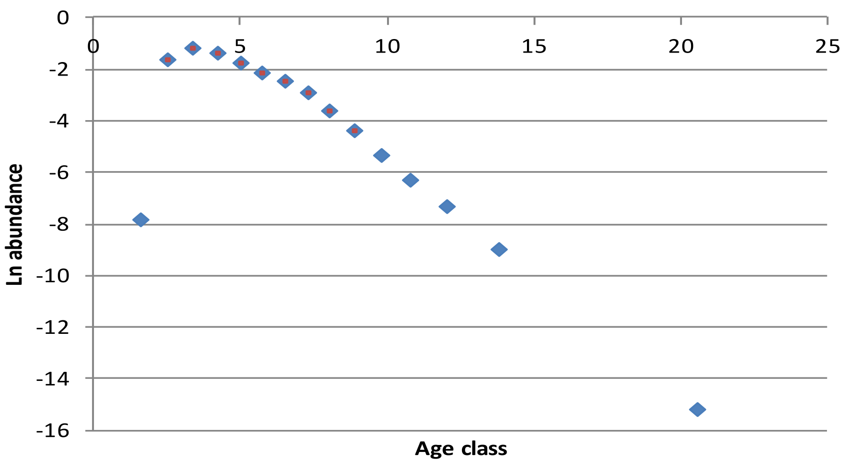
<u>Mortality and Spawning Potential Ratio (SPR) estimates</u>

Figure 22. Length-converted catch curve for Yellowtail Kingfish 2010/11 to 2018/19 indicative of a fishery where older fish are less vulnerable to exploitation. The slope between ages 2 to 9 is 0.47.

</td><td>



Ages 2 to 9.

Z (± 95% CI) = 0.47 (0.33 – 0.60)

M = 0.2 – 0.3

F = 0.17 – 0.27

<u>SPR modelling</u>

Using these mortality parameters, median SPR estimate is 20% with a range of 13% to 31%

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Biomass status in relation to Limit

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<u>Standardised commercial CPUE</u>

<u>1997/98 – 2018/19</u>

Standardised commercial CPUE for the main fishing method (handlining) increased by approximately 250% between 1997/98 and 2010/11 and in 2018/19 had declined to be at around 120% of the 1997/98 level (Fig. 5).

A more likely standardized catch rate series adjusted after 2009 due to a logbook change indicated that CPUE increased by around 85% between 1997/98 and 2018/19 (Fig. 12). Overall trends infer increased exploitable biomass.

<u>2009/10 – 2018/19</u>

Standardised commercial CPUE for the main fishing method (handlining) declined slightly and has since increased to be at roughly 2009/10 levels in 2018/19 suggesting no overall change in available biomass during this time (Fig. 9).

<u>CMSY+ BSM modelling</u>

Various reconstructions of historical recreational catch had little effect on the depletion trajectories when standardised CPUE data from 1997/98-2018/19 was used (scenarios 1 – 4; Fig. 13). These trajectories indicated that the stock underwent a decline in biomass from around 0.7 in the early 1980s through to around 0.25 in the mid-1990s. After this time biomass steadily increased to around 0.45 in 2010 and has remained reasonably stable at this level since. Current biomass depletion for all four scenarios

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	have large 95% confidence intervals (CIs; 0.3 – 0.6), but all put current biomass depletion above the limit reference point (B_{lim} = 0.2) with reasonable probability (Fig. 13). However, when standardised CPUE data from the shorter time series (2009/10 – 2018/19), or CPUE for 2009/10 was set to be equal to that in 2008/09 (to examine the logbook reporting change), were used (scenarios 5 & 6, respectively), biomass trajectories continued to decline from 0.25 in the mid-1990s to below B_{lim} by 2010/12 (Fig. 13). Current biomass depletion from these 2 scenarios is estimated to be below B_{lim} in 2018/19 but with ~50% probability (CIs 0.1 - 0.3; Fig. 13). Scenario 7 used catch-only (no CPUE data) to estimate a biomass depletion of 0.2 (CIs 0.018 – 0.388) in 1996/97. The two scenarios (8 & 9) which subsequently used this depletion as a starting point indicated biomass to have initially increased to above 0.4 between 1997/98 and 2005/06 (scenario 8) and to around 0.5 between 1997/98 and 2008/09 (scenario 9). Both scenarios indicate biomass to have declined since with current depletion estimates of 0.3 (CIs 0.15 – 0.42) for scenario 8 and 0.4 (CIs 0.29-0.54) for scenario 9 (Fig. 13). Using the same recreational catch reconstructions as used in scenarios 1 – 4; but adjusting the post-2009 CPUE to account for the logbook change (scenarios 10 – 13) showed the same historical trends in biomass trajectories seen for scenarios 1 – 4, but resulted in lower current estimates of biomass depletion (B/K = 0.31 – 0.35). Despite large CIs (0.2 – 0.6), all were estimated to be above B_{lim} with reasonable probability in 2018/19 (Fig. 13). Overall, several scenarios (5, 6, 8 & 9) estimated biomass to be depleting from 2009 onwards (Fig. 10). Conversely, several scenarios (10 – 13) estimated biomass to be increasing between 2013 and 2019. <u>SPR modelling</u> The SPR estimate for 2010/11 – 2018/19 straddles the limit reference level of 20% (range 13 to 31%) depending on which estimate of M was used.
Fishing mortality in relation to Limit	<u>CMSY+ BSM modelling</u> Estimated fishing mortality (F) remained below that predicted to drive biomass below $B_{0.2}$ until the early 1980s (Fig. 15). Overfishing ($F>F_{0.2}$) occurred between the early 1980s and the early 2000s under all scenarios; however has declined to sustainable levels in most scenarios since. Current harvest (all sectors) is in the vicinity of 200 to 330 t per annum (depending on which catch reconstruction is considered). The 13 model scenarios estimated MSY to be between 330 and 540 t (average 475 t). As such it is likely that overfishing was occurring during the 1980s and 1990s when harvest far exceeded these levels; but is currently constrained to sustainable levels.

	Mortality estimates Total mortality rate (Z) between 2010/11 and 2018/19 was estimated to be 0.47 (95% CIs 0.33 – 0.60). Fishing mortality rates (F = 0.17 – 0.27) have therefore been estimated to be similar to natural mortality (M = 0.2 – 0.3) over this period. Length composition The size composition of fish in commercial landings has remained relatively stable since the 1990s, except for the effect of increasing the minimum legal length in 2007 (Figs 16 & 17). The fishery is based largely on juveniles (as there are few fish >85 cm FL in the catch – the size at maturity for female Yellowtail Kingfish [Gillanders et al. 1999]). Around 90 per cent of catch is <85 cm FL with the number of individuals >100 cm FL in the commercial catch over the past decade being consistently low (<1% per year on average) (Figs 17 & 18). The available size composition of recreational catches of Yellowtail Kingfish shows similar patterns to that of the commercial catch. The most recent onsite recreational fishing survey carried out by NSW DPI found trailer boat catches of Yellowtail Kingfish in the Greater Sydney Region between 2007 and 2009 composed primarily (~88%) of individuals <85 cm FL (Steffe & Murphy 2011; Fig. 19). The size composition of nearshore Charter Fishery catches of Yellowtail Kingfish in 2017/18 in southern NSW was also similarly truncated with all fish measured between 65 and 90 cm FL size classes (Hughes et al. 2021; Fig. 20). Tagging data also indicates that the recreational fishery has been historically dominated by fish of immature (< 85 cm FL) sizes, with the vast majority of the > 15,000 Yellowtail Kingfish tagged and released as part of the NSW Fisheries Gamefish Tagging Programme being smaller than this size (Fig. 21). Tag-recapture rates High rates (~12-15%) of recaptures of tagged fish suggest ongoing high levels of localised exploitation [NSW DPI Gamefish Tagging Program].
Previous SAFS stock status	“Growth Overfished” in NSW assessments 2003/04 – 2013/14 “Uncertain” (Growth Overfished/Recruitment Overfished) in NSW assessment 2014/15 Eastern Australia stock “Undefined” SAFS 2014 Eastern Australia stock “Undefined” SAFS 2016 Eastern Australia stock “Undefined” SAFS 2018
Current SAFS stock status	There have been no attempts to assess the parts of the “Eastern Australia” Yellowtail Kingfish biological stock that occur in Commonwealth, Queensland, Victorian, Tasmanian and South Australian

	waters. The assessment presented here is therefore based on data collected from NSW only, but applies to the entire biological stock. <u>Weight-of-evidence in relation to biomass:</u> • CMSY+ BSM modelling indicates current biomass to be above B_{lim} with reasonable probability for the most likely reconstructed catch and CPUE scenarios. • Only two scenarios (using short or modified CPUE time series) estimated biomass to be below B_{lim}, but with lower probability (CIs 0.1 – 0.3). • Standardized commercial CPUE between 1997/98 and 2018/19 infers increased exploitable biomass. • Current Spawning Potential Ratio (SPR) is between 13 and 31% of virgin levels, which spans the limit reference level (20%). <u>Weight-of-evidence in relation to mortality:</u> • Current mean estimated fishing mortality (F) from CMSY+ - BSM modelling is below that which would result in biomass declining to below $B_{0.2}$ for most modelled scenarios. • Most modelled scenarios estimate that F has been declining relative to $F_{0.2}$ since around 2009. • Current total harvest (200 – 330 t per annum) is less than MSY (average 475 t). • Current mortality estimates from catch-curve analysis indicate that F has been roughly equivalent to M over the past 10 years. • Length composition of commercial and recreational catches indicate that the fisheries for Yellowtail Kingfish are based largely on juveniles, noting that the size composition of fish in commercial landings has remained relatively stable for more than 20 years which infers consistent recruitment. • Tag-recapture rates of ~12-15% indicate high levels of localised exploitation. <u>Interpretation of weight-of-evidence</u> Stock assessment modelling (using trends in reconstructed total historic harvest and standardised commercial CPUE) indicate that that the stock declined during the period of high catch and harvest rate from the early 1980s to the mid-1990s. Since then, the majority of model outputs indicate the stock biomass to have remained above B_{lim}. Most scenarios estimate biomass in 2018/19 to be above B_{lim}. Standardised commercial CPUE for the main fishing method (handlining) indicates that current stock abundance has increased since 1997/98, noting that these catch rates relate mainly to the availability of juveniles above the MLL. Since routine commercial length frequencies have been generated for Yellowtail Kingfish (1970s), the size composition of the exploited part of the stock has not changed markedly, being dominated by (immature) individuals <85 cm FL. This observation is also supported by data from

	the recreational fishery. The assumption that the size composition of landings is representative of the overall Yellowtail Kingfish stock is therefore likely to be violated. Such hyper-stable size frequency distributions, which are used to derive estimates of mortality (from catch-curve analyses) and subsequent spawning stock biomass estimates (from SPR modelling), are therefore likely to consistently indicate high mortality (F>>M) and low exploitable biomass. However, the stability of this long-term pattern also indicates stable recruitment into the fishery and provides no evidence of predicted recruitment failure suggested by long term trends in mortality rates and SPR modelling. It must also be noted that the NSW Yellowtail Kingfish fishery assessed here only targets a fraction of the geographical extent of the "Eastern Australia" stock which extends from southern Queensland through to SA. The long-term stability (since at least the 1970s) of the narrow size distributions seen in landings suggest that the stock is not fully mixed across its range [Green et al. 2020] and the ongoing source of recruits (mature spawning fish) are not available to the NSW fishery, thus providing continuing stable recruitment which aids the sustainability of the fishery. Examples of long-distance bi-directional movements of Yellowtail Kingfish in this region, both between Australia and New Zealand [Gillanders et al. 2001] and within Australia (between NSW and SA; NSW Gamefish Tagging Program unpublished data), have been recorded. It has also been suggested that the spawning stock occurs far offshore where it is not targeted by the fishery [Smith 1987, Gillanders et al. 1999]. However, reliable information on the population dynamics of the stock in this region is poorly known, particularly the distribution and migratory patterns of the spawning stock, as well as the source of juveniles. <u>Summary</u> The above evidence indicates that the biomass of this stock that occurs in NSW waters is not likely to be depleted and that recruitment is not likely to be impaired. This level of fishing mortality is unlikely to cause the biological stock to become recruitment impaired. On the basis of the evidence provided above, the "Eastern Australia" biological stock is classified as a **Sustainable** stock.

Qualifying Comments

The weight-of-evidence approach used here to assess stock status reveals considerable uncertainty due largely to the lack of data on size composition from historical landings, the recreational harvest, and the population dynamics of the stock (demographics, movements, connectivity, stock structure). Nevertheless, outputs from surplus production models using the most likely reconstructed historical harvests (from 1950/51) and catch rate series (from 1997/98), provides confidence that the current biomass of the stock is not below the limit reference point of 0.2 unfished biomass (B_{lim}) and fishing mortality (F) has been declining relative to $F_{0.2}$ since at least 2009.

Of the two model outputs which suggested that the stock biomass was below B_{lim}, not only did so with lower probability, but were also given reduced weighting due to the CPUE data series used. There is evidence that a change in logbook reporting in 2009 altered the CPUE levels; however we are confident that the adjustment we applied is reasonable and hence model scenarios derived from this CPUE time series (scenarios 10 – 13) are the ones in which we have the greatest confidence. Scenarios using either a modified CPUE time series (2009/10 = 2008/09) or a shortened times series (2009/10 – 2018/19) were therefore down-weighted in this assessment.

The current commercial and recreational fisheries for Yellowtail Kingfish in NSW are primarily based on juvenile individuals. All available evidence suggests that this has not changed historically (since at least the 1970s), mainly because of the temporally stable distribution and availability of these juveniles. As a result, the use of length- and age-based data collected from only the fished part of the NSW stock is of limited use for inferring abundance or mortality rates of the entire spawning stock, and these were consequently down-weighted in this assessment.

It must be noted however, that this assumption comes with a risk; that if incorrect then it is possible that the stock may be depleted to a level that may be below the limit reference level for recruitment overfishing as suggested by age- and length-based mortality rates and SPR modelling. Further work into examining the population dynamics of the stock in the region, and particularly investigating the distribution and movements of the spawning stock, as well as the source of juveniles, is suggested to address this uncertainty.

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