Total allowable commercial catch review for Queensland stout whiting (*Sillago robusta*), with data to December 2021

October 2022

Queensland Government

This publication has been compiled by L.I. Sumpter of Fisheries Queensland, Department of Agriculture and Fisheries.

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Summary

Stout whiting form a single biological stock on the east coast of Australia, in south-east Queensland and New South Wales. This report provides a recommended total allowable catch for the Queensland stout whiting fishery in 2022. Queensland commercial catch and effort data (1991-2021) were analysed to reconstruct stout whiting harvest and calculate standardised catch rates. Stout whiting catch rates have increased since 2016 and now exceed the 30 year average. Since 2017, the total allowable commercial catch (TACC) for Queensland remained at 1106 tonnes (t), before being increased to 1281 t in 2021.

Based on the trends in standardised catch rates, three recommended TACC options are presented for consideration by Fisheries Queensland managers and the fishery working group (Table 1). As detailed in 2.4, the recommended biological catch (RBC) at B_{targ} (1393 t) was instated as a maximum cap for the TACC, should the calculated TACCs exceed this value. In the case of this assessment, all three recommended TACC options exceeded 1393 t as a result of record high standardised catch rates. Hence, all TACC options presented in Table 1 have been capped at 1393 t.

Table 1: Recommended 2021 TACC (t) for the Queensland stout whiting fishery

Target reference point	TACC (t)		
	conservative estimate	estimate	least conservative estimate
Relative to fishing years 2019–2020	1393	1393	1393

1 Introduction

In Queensland, stout whiting (*Sillago robusta*) are caught between Sandy Cape and the Queensland–New South Wales border, using both Danish seine and finfish otter-trawl methods. The Queensland commercial fishing sector for stout whiting is identified by a T_4 symbol and is currently operated by two licensed vessels. In Queensland, no other sectors are licenced to retain stout whiting that are caught as by-catch. The stout whiting T_4 sector is managed by limiting vessel participants and total allowable commercial catch (TACC) between water depths of 20–50 fathoms (36–91 m). However, as part of a management trial, a permit was issued between 2017 and 2020 that allowed the T_4 operators to fish within 20 fathoms. The T_4 sector is managed and monitored separately to the trawl-whiting (stout and eastern school whiting) vessels operating in New South Wales. It is also managed separately to the much larger otter-trawl sectors that target eastern king prawns along Australia's east coast.

Since 2007, T_4 quota was adjusted annually in response to changes in standardised catch rates and catch-at-age frequencies (Table 1.1). Since the cessation of age sampling in 2015, the TACC was set based on information from the standardised catch rate analysis. The standardised catch rate analysis was used to set the TACC for 2016 (O'Neill et al. 2016), 2017 (Wortmann et al. 2016) and 2021 (Wortmann 2020). Since 2017, the TACC for Queensland was set at 1106 tonnes (t) until being adjusted to 1281 tonnes (t) in 2021.

Table 1.1: Recent history of annual quota changes

Calendar year	TACC (t)	Catch (t)
2007	1250	930
2008	1350	721
2009	1450	1158
2010	1500	1170
2011	1500	664
2012	1400	784
2013	1350	704
2014	1150	581
2015	1150	787
2016	1090	945
2017	1106	1026
2018	1106	1041
2019	1106	1105
2020	1106	1070
2021	1281	1193

Method 1 in O'Neill et al. (2016) and Wortmann et al. (2016) adjusted the following year's TACC based on the previous year's TACC. This method involved calculating the ratio between the previous year's catch rates and those of a target reference point. The resulting ratio was then applied to the previous year's TACC to give the following year's TACC. For the full methodology, see Section 2.4. In 2020, Fisheries Queensland undertook a retrospective analysis and supported Method 1 as being most appropriate for the T_4 fishery based on the following:

- Historically, Method 1 has been used for the quota setting process
- There is minimal risk as the TACC will be reset by a stock assessment every 3 years, and in the interim years the annual TACC would be adjusted using Method 1 outputs
- The commercial trawl fishery (fin fish) stout whiting harvest strategy (2021–2026), hereafter called 'the harvest strategy' (Fisheries Queensland 2021), will utilise the "hockey stick" rule taking a precautionary approach in setting the TACC until target biomass is achieved

The aim of this document is to present harvest and standardised catch rates for the Queensland commercial stout whiting fishery for the period January 1991–June 2021, and provide recommended Queensland T_4 TACC options for 2022 using Method 1.

2 Methods

2.1 Data sources

Data sources used in this analysis are detailed in Table 2.1.

Table 2.1: Data used in this analysis

Data	Years	Source
Commercial	January 1991–June 2021	CFISH—Logbook data collected by Fisheries Queensland
Wind	January 1991–June 2021	bom.gov.au—Bureau of Meteorology
Lunar	January 1991–June 2021	O'Neill et al. (2014)—continuous daily luminous scale of 0 (new moon) to 1 (full moon)
Seasonality	January 1991–June 2021	Mariott et al. (2014)—seasonal patterns of catch rates corresponding to autumn, winter, spring and summer periods

New data in this analysis since Wortmann (2020) include:

- Commercial harvest data up to June 2021
- Wind speed and direction for standardised catch rates up to June 2021
- Standardised catch rates up to June 2021

Fishing year was defined as the months from July to June. For example, the months starting from July 2020 to June 2021 were labelled as the 2021 fishing year, with July being the first fishing month and June being the twelfth fishing month.

2.2 Harvest estimates

Harvest data comprised all stout whiting caught and retained by the Queensland T_4 fishing sector from January 1991 to June 2021.

2.3 Standardised catch rates

For use in the standardised catch rates model, data from CFISH logbooks were filtered to obtain daily catch records of stout whiting for each fishing operation. A fishing operation was defined by the vessel, fishing method and owner to account for changes in vessel ownership or fishing methods. Prior to running the model, a number of filters were applied to the available data. Catch record data were included or excluded based on the following criteria:

- Excluded catch that was reported in 'bulk' - that is, where the reported catch spanned multiple fishing days and daily catch totals could not be derived (639 out of 66237 records, 0.9%, 882 out of 33694 t, 2.68%)
- Included catch occurring in logbook grids from w33 to w38 (30' by 30' grids) (Fig 2.1, 65335 out of 66237 records, 98.6%, 32664 t out of 33694 t, 96.9%)
- Excluded catch for fishing operations that exhibited poor sample sizes and/or fleeting catch history throughout the timeseries. These included fishing operations 3 (28 records in fishing year 2000, 7 (1 record in fishing year 1997 and 5 records in 1998), 14 (26 records in 1991) and 15 (46 records in 1991 and 9 records in 1992)

- Included records for net shots of zero stout whiting catch (115 out of 12571 records, 0.9%)

Further, some catch records had associated fields with missing data which were required as model terms for the standardised catch rates model. In these instances, the missing data comprised the minority of the available data, and the missing values were able to be modelled. Fields where missing data was modelled are listed below, along with the respective generalised linear models (GLMs) used:

- Hours - duration of each trawl shot (both finfish otter-trawl and Danish seine), in hours. This field is later aggregated to obtain daily totals for use in the standardised catch rates model. The records for which hours were modelled comprised missing values (733 out of 65335 records, 1.1%), and values of zero for hours where catch was not equal to zero (54 out of 65335 records, 0.08%). As decided by the project team, records with zero hours and non-zero catch likely represented misreporting. Hence, modelled hours were also used in these instances. Modelled records of hours are given by the model below:

$$hours \sim shots + vessel + year + \log(catch + 1) \tag{2.1}$$

  where:
  - *shots* = no. of shots per boat day
  - *vessel* = numeric vessel identifier
  - *year* = fishing year (see 2.1)
  - *catch* = catch in kilograms, per shot

- Depth - depth of each shot in meters, corrected for any records that were recorded in fathoms. The records for which depth was modelled comprised missing values (548 out of 65335 records, 0.8%) and values of zero for depth. As decided by the project team, values of zero for depth represented misreporting. Hence, modelled depth was also used in these instances.

$$depth \sim zone + vessel + year \tag{2.2}$$

  where:
  - *zone* = unique logbook grid (30' by 30'grids)
  - *vessel* = numeric vessel identifier
  - *year* = calendar year

The Queensland T_4 fishery operates in five logbook grids or 'zones' of water depths between 20–50 fathoms, labelled w33, w34, w35, w36 and w38 (Figure 2.1, Table 2.2). In this analysis, zones were grouped into two aggregated zones (or regions); 'North', and 'South'. Zones w33, w34 and w35 were grouped into 'North', and zones w36 and w38 comprised 'South' (Table 2.2). Catch rates of stout whiting were analysed by fishing year and region. An area weighted approach was used to calculate the overall Queensland commercial catch rate.

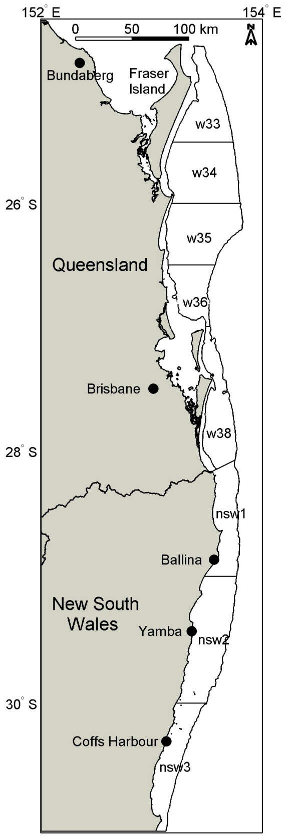

Figure 2.1: Map of Australian east coast stout whiting fishery analysis zones

Table 2.2: Zone definitions for standardised catch rates

30' by 30' logbook grid	Zone	Name	Region
w32, w33, x32, x33	w33	Fraser Island waters	North
w34, x34	w34	Fraser Island waters	North
w35, x35	w35	Sunshine Coast to Double Island Point waters	North
w36, x36	w36	Caloundra waters	South
w37, w38, w39, x37, x38, x39	w38	Stradbroke Islands and Gold Coast waters	South

The statistical model used for the standardised catch rates was a generalised linear model (GLM), with the response being a cube-root transform of the stout whiting catch. Catch rates were given in kilograms per boat day and scaled relative to the overall mean catch rate for 1991–2021. The analysis was carried out using the software R (version 4.0.5, R Core Team (2021)).

The form of the model was:

$$\sqrt[3]{Catch} \sim Year * Region + Seasonality + Vessel + \\ Vessel : \sqrt[3]{Hours} + Lunar + Region : \sqrt[3]{Hours} + Experience + Sonar + Wind \quad (2.3)$$

Model terms (daily data) in the catch rate standardisation were:

- Year (from logbooks, defined as 'fishing year', see 2.1)
- Region (aggregated 'zone' from logbooks, see 2.2)
- Seasonality (see Appendix A)
- Vessel (from logbooks, unique identifier containing vessel number and fishing method)
- Hours (from logbooks, hours fished)
- Lunar (Appendix A)
- Depth (from logbooks, water depth)
- Experience (see Appendix A, fishing experience)
- Wind (Appendix A, wind speed and direction)
- Sonar(Appendix A, binary variable identifying the use of sonar).

2.4 Total allowable commercial catch (TACC)

The TACC was given by:

$$TACC_{k+1} = min(TACC_k \times \theta_{k+1}, 1393) \tag{2.4}$$

$$\theta_{k+1} = \left(\frac{\bar{I}}{I_{target}}\right)^{\frac{1}{x}} \tag{2.5}$$

where

- $TACC_k$ is the total allowable commercial catch in year k
- 1393 is the recommended biological catch (RBC) to achieve B_{targ}, in tonnes. The harvest strategy advises that TACCs set between stock assessment years should not exceed the RBC to achieve B_{targ}. Therefore, this value is treated as the upper threshold for interim year TACC calculations.
- $\bar{I}$ is the indicator, from the average of the Queensland commercial catch rates in years k and $k-1$
- I_{target} is the target reference point. As defined in the harvest strategy, the target reference point is to be an average standardised catch rate of 1.0 from the fishing years 2019–2020.
- $x = 1, 2, 3$ adjusts the TACC according to the linear, square-root or cube-root transformation. The cube-root transformation ($x = 3$) is the strongest to mitigate variance and limit the magnitude of quota change (the conservative estimate) whereas the linear transformation ($x = 1$) is the least conservative method.

3 Results and discussion

3.1 Harvest estimates

Since 2013, two vessels have comprised the Queensland T_4 fishing fleet. In the 2021 fishing year, 1166 t were harvested Figure 3.1a. Annual landings averaged 1181 t for the fishing years 2018–2021, which is high relative to the last ten years. The history of harvest is also shown by calendar year, in Figure 3.1b.

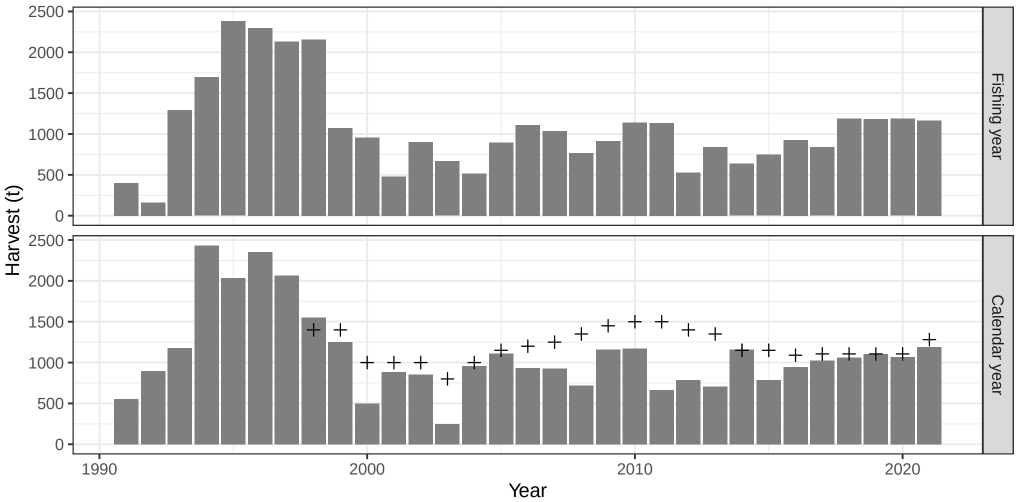

Figure 3.1: Reported commercial T_4 harvest in Queensland January 1991–June 2021—TACC settings are depicted by crosses in subplot b

3.2 Effort and fleet power

Prior to the year 2000, the bulk of the fishing effort was focused in Sunshine Coast to Double Island Point waters (zone ‘w35’) (Figure 3.2). This effort then shifted north to Fraser Island waters (zones ‘w33’ and ‘w34’) from 2001–2010. In terms of region, the bulk of T_4 fishing effort was concentrated in the northern region until 2011 (Figure 3.3). This was particularly evident between 2001 and 2009, while zone ‘w38’ in the southern region (Stradbroke Islands and Gold Coast waters) was closed to stout whiting fishing.

From 2011–2021, a significant spatial shift in effort occurred, with the majority of effort being expended in zone ‘w38’ (Stradbroke Islands and Gold Coast waters) once it reopened to fishing (Figure 3.2). In terms of region, this shift meant that from 2011 to present, the fishery expended a higher proportion of effort in the southern region than ever before in the timeseries (Figure 3.3). On average during the last ten years, the fleet expended 58% of the total effort in the southern region. Finally in 2021, fishing effort was split evenly between the two regions (50.5% and 49.5% in the northern and southern regions respectively).

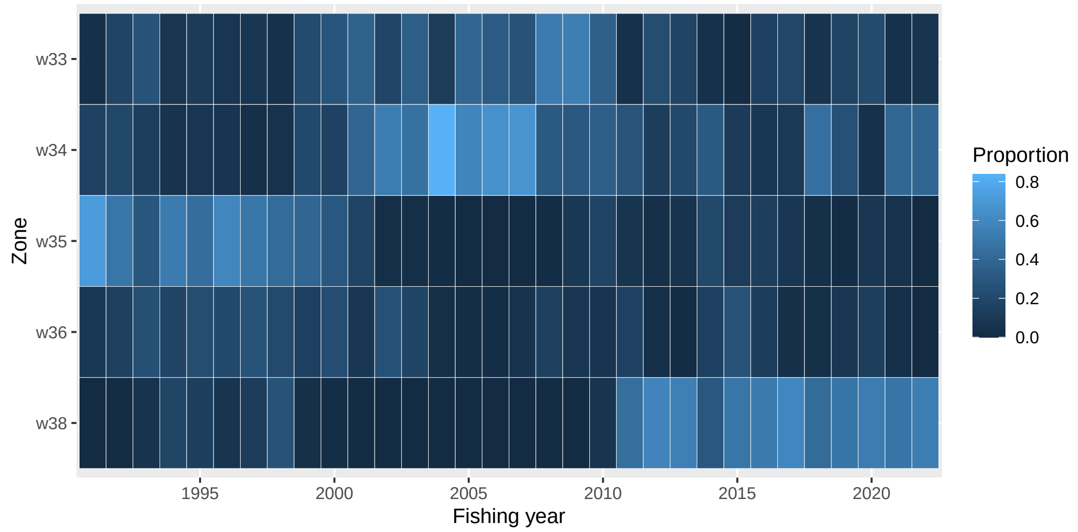

Figure 3.2: Proportion of boat-days for the Queensland T_4 fishery by zone, from January 1991–June 2021

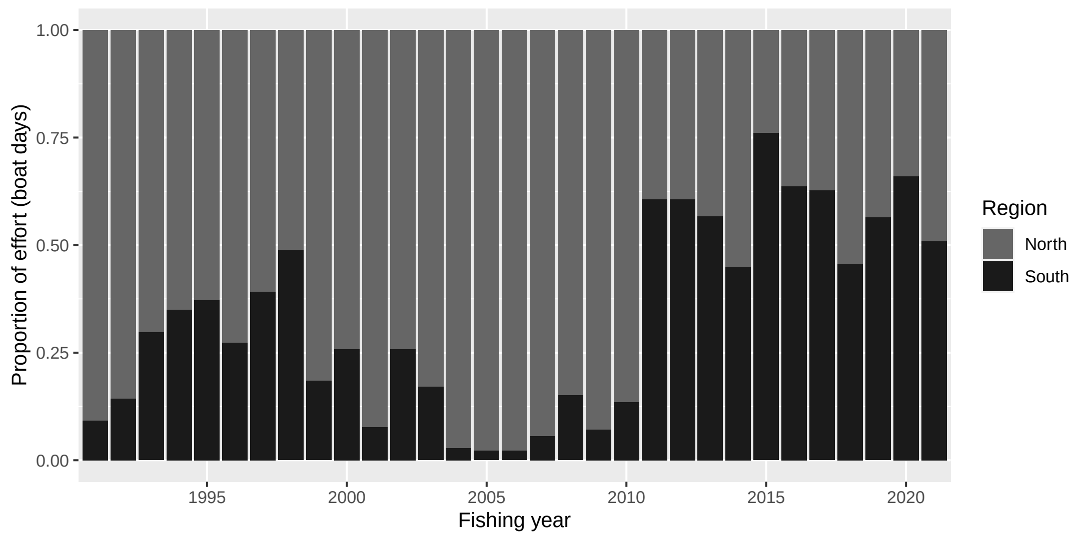

Figure 3.3: Proportion of boat-days for the Queensland T_4 fishery by region, from January 1991–June 2021

Fleet power remained relatively stable between 1991 and 2006 at a level below the historical average (Figure 3.4). A steady increase was seen from 2006 to 2015, by which time the T_4 fishing fleet had distilled to the two vessels that comprise the fleet today. From the peak in 2015 until 2021, fleet power plateaued and remained high relative to the historical average. The calculation of annual fleet power is given in Appendix A.8.

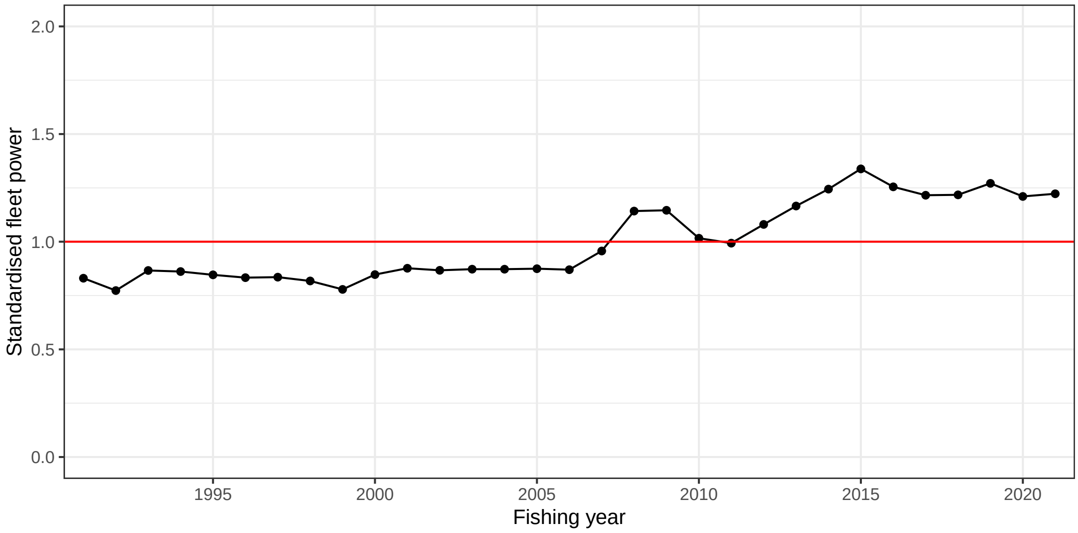

Figure 3.4: Fleet power (standardised) of the Queensland T_4 fishery from January 1991–June 2021 —- the calculation of annual fleet power is given in Appendix A

3.3 Standardised catch rates

The 2021 catch rate index for the whole T_4 fishery was above the long term mean, and the highest in the timeseries to date (Figure 3.5). Both northern and southern regions of the fishery exhibited high catch rates in recent years, also exceeding their respective historical maxima (Figure 3.6). However when considering the contrast in catch rates between 2020 and 2021 fishing years specifically, the northern region showed a significant increase while the southern region remained largely unchanged. Catch rate diagnostics are shown in Appendix A.

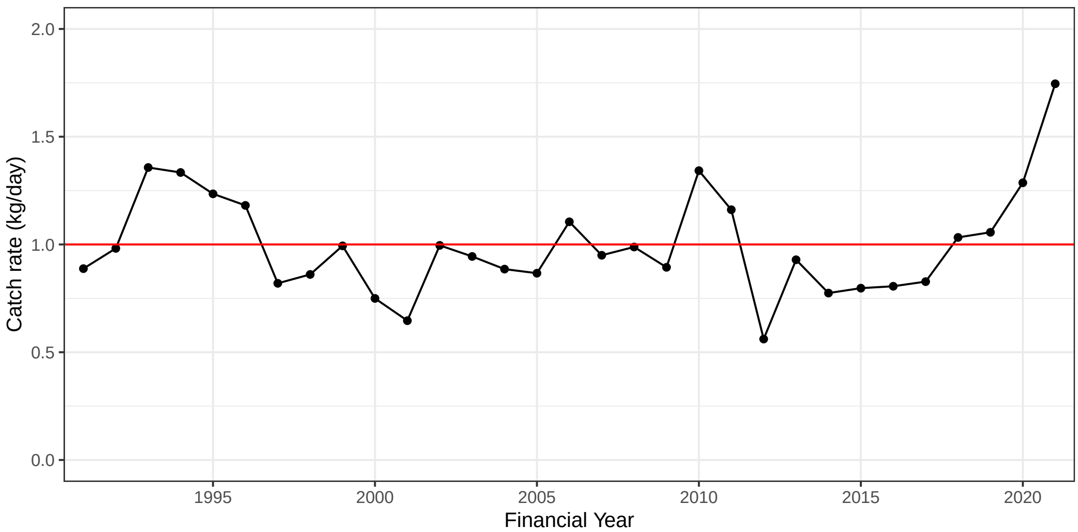

Figure 3.5: Annual relative standardised catch rates and 95% confidence intervals for the Queensland stout whiting fishery January 1991–January 2021

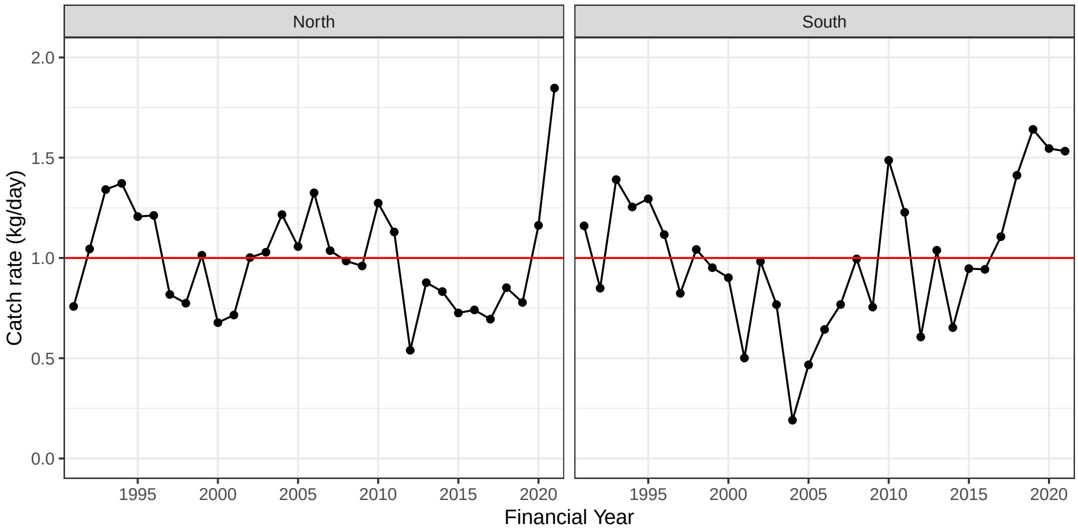

Figure 3.6: Annual relative standardised catch rates and 95% confidence intervals for the aggregated North and South zones of the Queensland stout whiting fishery January 1991–January 2021

Three model terms had particularly notable influences upon the standardised catch rates trends: Region, seasonality and fishing operation. These influences are discussed below, in order of their appearance in the model.

The inclusion of region and its interaction with fishing year had a particularly notable effect on two portions of the timeseries. From 2004 to 2010, it had a significant negative influence on catch rates. This corresponds to a period where almost all fishing effort was concentrated in the northern region (Figure 3.3). It also overlaps with the period in which 'w38' in the southern region was closed to stout whiting fishing (2001–2009). Here, the model is indicating that the average region fished in these years was more productive. Given almost all fishing effort was expended in the northern region during this period (Figure 3.3), this may indicate a genuine increased abundance in the northern region over this time. From 2018 to 2021, the model also adjusted catch rates downwards following the inclusion of region and its interaction with fishing year. This period corresponds closely to the duration of a trial closure by fisheries management from 2017–2020, whereby all waters south of Cape Moreton (southern region) were closed to the T_4 fleet between 20 September and 31 March annually. Despite this trial closure expiring in 2020, the T_4 fleet support the closure and continue to recognise it voluntarily to present. During the 2018–2021 period, the effort was split near evenly between the two regions, with vessels accessing the southern region during the 6 month period outside of the seasonal closure. With the inclusion of the region term and its interaction with fishing year, the model has indicated that the average region fished during this period was more productive by adjusting catch rates downwards. Hence, it is possible that abundance improved in the southern region as a result of the seasonal closure.

Further, inclusion of seasonality to the model plays an important role in the 2018–2021 period mentioned above. The key difference between the southern region closure in 2001–2009 and the trialled closure from 2017 to present, is that the latter is seasonal, lasting only 6 months per year. Hence, the inclusion of seasonality as a model term provided the model with more information in the 2018–2021 period. Namely, it provided the model with information that the change in catch rates in the southern region was seasonally dependant. As a result, the addition of seasonality adjusted catch rates back up in the final two years of the timeseries.

Finally, the inclusion of fishing operation had a considerable influence upon standardised catch rates. In the early portion of the timeseries, including fishing operation had a significant positive effect upon catch rates (Figure 3.7). This is likely attributable to reduced fleet power during this period (Figure 3.4), which means the catch rates were being attained with a reduced fleet power, implying a higher abundance index. Conversely, the inclusion of fishing operation had a negative influence upon catch rates from 2015 to 2021, which corresponds to the period of highest fleet power. In periods of high fleet power, the raw catch rates may be inflated by the increased ability of the fleet to find and catch fish and hence, the model adjusted catch rates downwards in this period accordingly.

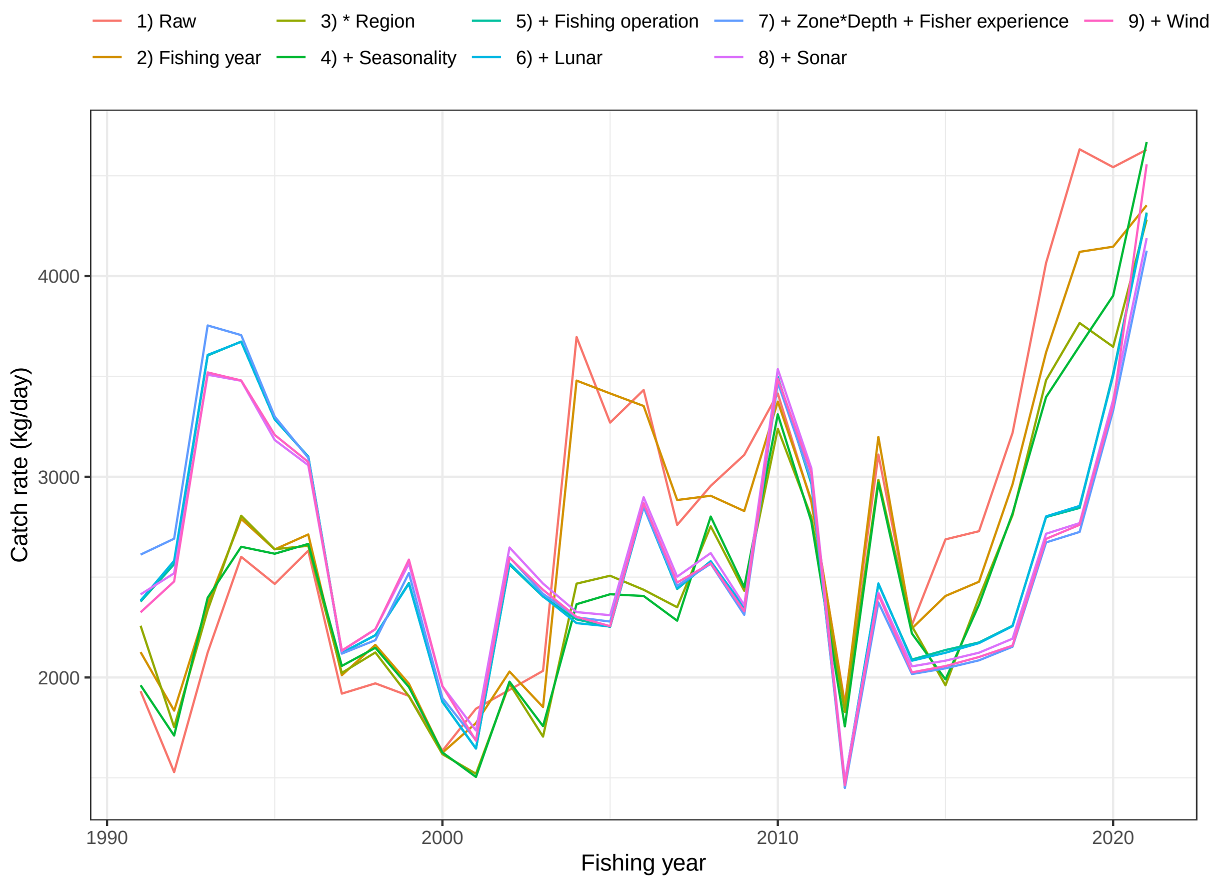

Figure 3.7: Influence of all model terms on standardised commercial catch rates for stout whiting in Queensland January 1991–June 2021—- 'Raw' refers to raw (unmodelled) annual mean catch rates

3.4 Conclusion

The calculations of the 2022 TACC covered three settings outlined in Table 1. The estimated 2022 TACC increased from the 2021 TACC of 1281 t by 112 t, giving an estimated TACC for 2022 of 1393 t. As detailed in Section 2.4, the harvest strategy stipulates that the recommended biological catch (RBC) at B_{targ} (1393 t) be instated as a maximum cap for the TACC, should the calculated TACCs exceed this value. In the case of this assessment, all three recommended TACC options exceeded 1393 t as a result of record high standardised catch rates. Uncertainty in the TACC estimates should be considered as they were sensitive to the data inputs and assumptions.

The harvest strategy for the Queensland stout whiting fishery requires a stock assessment (next due 2024) to be run every three years. The aim of the stock assessment is to inform the TACC setting such that the fishery achieves or maintains the target biomass of 48%. In the years between stock assessments, the quota calculations from this study will be used to guide the TACC setting.

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Appendix A Standardised catch rates

A.1 Wind data

Wind direction and strength data were sourced by Fisheries Queensland from the Bureau of Meteorology (bom.gov.au). The wind data were from representative coastal weather stations (Table A.1).

Table A.1: Weather stations used for zones

Station number	Station name	Zone
40068	Double Island Point Lighthouse	w33, w34
40043	Cape Moreton Lighthouse	w35, w36
40764	Gold Coast Sedgeway	w38

The recorded measures of wind speed (km hour^{-1}) and direction (in degrees, direction the wind blew from) in each latitude band were converted to an average daily reading based on recordings between 6 am and 6 pm. From this data the north-south (NS) and east-west (EW) wind components were calculated:

$$NS = wind\ speed \times \cos(wind\ direction) \tag{A.1}$$

$$EW = wind\ speed \times \sin(wind\ direction) \tag{A.2}$$

where wind speed was in km hour^{-1} and wind direction was converted to radians.

The wind components were used to test their effect on catch rates for different wind directions and strengths. The component functions considered the BOM defined wind directions as degrees measured clockwise from true north.

A.2 Lunar data

The influence of lunar phase on catch rates was tested by the addition of a sinusoidal luminance (lunar) pattern as described by using a continuous daily luminous scale of 0 (new moon) to 1 (full moon) throughout the lunar cycle. A lagged response of catch rates to lunar phase was assessed using a covariate (lunar advance) which advanced the luminance measure seven days (approximately $\frac{1}{4}$ lunar period). The two variables were modelled together to estimate the variation of catch according to the moon phase (i.e. contrasting waxing and waning patterns of the moon phase).

A.3 Seasonality data

Six trigonometric functions modelled an average monthly pattern of catch (Mariott et al. 2014):

$$s_1 = cos\left(\frac{2\pi d_y}{T_y}\right),\ s_2 = sin\left(\frac{2\pi d_y}{T_y}\right) \tag{A.3}$$

$$s_3 = cos\left(\frac{4\pi d_y}{T_y}\right),\ s_4 = sin\left(\frac{4\pi d_y}{T_y}\right) \tag{A.4}$$

$$s_5 = cos\left(\frac{6\pi d_y}{T_y}\right),\ s_6 = sin\left(\frac{6\pi d_y}{T_y}\right) \tag{A.5}$$

where

- d_y was the cumulative day of the year
- T_y was the total number of days in the year (365 or 366)

Using sine and cosine functions together identified the seasonal patterns of catch rates corresponding to autumn, winter, spring and summer periods.

A.4 Fishing experience

Fishing experience was calculated to follow an exponential learning curve:

$$log\left(\frac{v_y}{1+v_y}\right) \tag{A.6}$$

where v_y was the cumulative number of at-sea fishing days divided by 365.25.

The increase in experience was assumed sharpest in the initial fishing years, then levelling out to a limit.

A.5 Sonar

The use of sonar was filled in manually. The fishery had 2–5 vessels per year so the information was obtainable.

A.6 Fleet power

While not a part of the standardised catch rates model in itself, fleet power is a more intuitive way of visualising the effect of the model term 'fishing operation' through time. Fleet power is not to be confused with 'fishing power', which can refer to the fishing 'strength' of a particular vessel due to factors such as technological advances. Fleet power describes the strength of the fishing fleet that operated in a given fishing year. This is done by using model coefficients for fishing operation and applying these to the respective proportions of the annual fishing effort comprised by these fishing operations. The result is summed by year, to give a measure of relative 'strength' of the fleet in that year.

Annual fleet power (FP) was calculated as below:

$$FP = \sum_y \sum_v (P_{days} \times strength) \tag{A.7}$$

$$strength = intercept + b_{coeff} + hb_{coeff} \times \lambda \sqrt[3]{hours} \tag{A.8}$$

where:

- *y* = fishing year
- *v* = fishing operation
- P_{days} = days fished by a given fishing operation, as a proportion of total days fished by the T_4 fleet
- *strength* = weighting to indicate the 'strength' of a given fishing operation
- *intercept* = intercept estimated by the standardised catch rates model
- b_{coeff} = model coefficient for each fishing operation
- hb_{coeff} = model coefficient for the interaction of each fishing operation and hours fished
- *hours* = daily hours fished