Fisheries New Zealand

Tini a Tangaroa

Analysis of CPUE data from key hoki fisheries for the monitoring of recent recruitment

New Zealand Fisheries Assessment Report 2022/44

A.D. Langley

ISSN 1179-5352 (online)
ISBN 978-1-99-105227-8 (online)

September 2022

Te Kāwanatanga o Aotearoa
New Zealand Government

Disclaimer

Requests for further copies should be directed to:

Fisheries Science Editor
Fisheries New Zealand
Ministry for Primary Industries
PO Box 2526
Wellington 6140
NEW ZEALAND

Email: Fisheries-Science.Editor@mpi.govt.nz
Telephone: 0800 00 83 33

This publication is also available on the Ministry for Primary Industries websites at:
http://www.mpi.govt.nz/news-and-resources/publications
http://fs.fish.govt.nz go to Document library/Research reports

Please cite this report as:

Langley, A.D. (2022). Analysis of CPUE data from key hoki fisheries for the monitoring of recent recruitment. *New Zealand Fisheries Assessment Report 2022/44.* 41 p.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Langley, A.D.[1] (2022). Analysis of CPUE data from key hoki fisheries for the monitoring of recent recruitment.

***New Zealand Fisheries Assessment Report 2022/44.* 41 p.**

A Generalised Linear Modelling approach was applied to derive CPUE indices from catch and effort data from key hoki (*Macruronus novaezelandiae*) fisheries from 1999/2000 to 2020/21. The fisheries were selected on the basis that the catches were composed of a relatively high proportion of younger (2–6 yr) fish and, hence, the resulting indices may provide information regarding the strength of recent recruitment, particularly to the western hoki stock unit. The selected fisheries are: the west coast South Island (WCSI) North and South fisheries, the Snares Shelf fishery, and the Chatham Rise Southwestern, Northern and Shallow fisheries. The spatial and seasonal definitions of the fisheries are very similar to individual fisheries included in the recent (2021 and 2022) hoki stock assessments. The resultant CPUE indices were applied to derive age-specific CPUE indices by partitioning the annual CPUE indices by the corresponding annual fishery catch-at-age observations. The age-specific CPUE indices were applied to determine a time series of indices for individual year classes (at ages 2 yr, 3 yr, 4 yr, and 5 yr).

For most of the fisheries, there was considerable variability in the CPUE indices between years reflecting the high degree of variability in the recruiting year classes. In general, the trends in the CPUE indices from the mid 2000s are comparable with the trends in abundance from research surveys conducted in the corresponding fishery areas.

The CPUE indices were not included in the recent (2021 and 2022) hoki stock assessments. Nonetheless, the trends in the fishery CPUE indices from the mid 2000s are generally consistent with the corresponding trends in fishery specific vulnerable biomass derived from the stock assessment model. These observations provide a degree of corroboration of the stock assessment results. This is further supported by the correspondence between the model estimates of annual recruitment for the western hoki stock and the age-specific CPUE indices derived for the constituent fisheries.

For most fisheries, the trends in the CPUE indices from the initial period of the study (1999/2000–2002/03) did not reflect the extent of the decline in biomass indices from the Sub Antarctic and Chatham Rise trawl surveys. The fisheries selected for this study tend to operate over a relatively large area. However, an examination of the spatial distribution of trawls from the WCSI North fishery revealed a sharp contraction in the spatial extent of the fishery in the mid 2000s. Similar patterns were also apparent in the spatial scale of the other fisheries (WCSI South, Snares, Chatham Rise Southwestern Deep, Chatham Rise North). These trends in the operation of the fishery are likely to have contributed to the apparent increase in the efficiency in the fishing operation at around that time.

Since the mid 2000s, the operation of the individual fisheries has remained relatively stable and trends in the resultant CPUE indices have been consistent with other key sets of abundance indices. This indicates the potential utility of CPUE indices as additional indices of abundance. Within the current stock assessment framework, CPUE indices from the WCSI North and Snares fisheries have the potential to provide more immediate information regarding the relative strength of recent recruitment to the western hoki stock. This is in lieu of ongoing monitoring of hoki abundance (via acoustic survey or trawl survey) on the WCSI spawning grounds, while the Sub Antarctic trawl survey does not appear to fully monitor the abundance of younger hoki (age 3–6 yr fish). Increasing the precision of estimates of recent recruitments would improve estimates of current stock status and short-term (2–3 yr) stock projections for the western stock.

Seasonal trends in CPUE from the Chatham Rise and Snares fisheries did not reveal a strong reciprocal pattern that might indicate a strong, persistent seasonal movement of fish from the Chatham Rise to the

[1] Trophia Ltd, Kaikōura, New Zealand.

Snares (Sub Antarctic) area, as assumed in the current hoki stock assessment model. Instead, trends in the CPUE indices from the Snares fishery appear to precede the trends in abundance from the Sub Antarctic trawl survey (by about 2 years), indicating the younger fish in the Snares fishery are not broadly distributed throughout the Sub Antarctic area. Further, the younger hoki present in the Snares fishery do not appear to have fully recruited to the WCSI North spawning fishery. This may indicate that the Snares Shelf area represents an important habitat for hoki of the intermediate age classes transitioning from the juvenile nursery ground on the Chatham Rise. There is potential to utilise the CPUE indices from the Snares fishery to monitor this component of the stock, integrating the CPUE indices in the stock assessment model to inform the model regarding dispersal of hoki southwards from the Chatham Rise.

Age-specific CPUE indices from the Chatham Rise (Southwestern Deep) fishery were more comparable with model estimates of western recruitment than estimates of eastern recruitment. There is also some suggestion that the survey indices of 2+ yr hoki from the southern Chatham Rise were more consistent with the estimates of recruitment of western hoki from the stock assessment model, while trends in 2+ yr hoki from the northern Chatham Rise were more consistent with the estimates of recruitment of eastern hoki. These observations provide the basis for considering an alternative stock hypothesis that spatially partitions the western and eastern stock components of the Chatham Rise, at least for the younger age classes. This assumption would represent a contrast to the current assumption of a homogeneous population of juvenile hoki (eastern and western stocks) on the Chatham Rise.

1. INTRODUCTION

Stock assessments for hoki (*Macruronus novaezelandiae*) are normally conducted annually, with the most recent assessments conducted in 2021 (McGregor et al. 2022) and 2022 (McGregor et al. in press). The stock assessments have been conducted using an aged-structured population model, integrating the following primary datasets: hoki abundance indices and age compositions from the time series of *Tangaroa* trawl surveys of the Chatham Rise (Stevens et al. 2021) and Sub Antarctic (Stevens et al. 2022), acoustic survey abundance indices from the Cook Strait (O'Driscoll & Escobar-Flores 2020) and west coast South Island (O'Driscoll & Ballara 2019) spawning grounds, and annual commercial catches and age compositions stratified by fishery (Ballara & O'Driscoll 2020, Langley 2020).

The current stock assessment model is spatially structured to represent the generalised stock dynamics of hoki (McGregor et al. 2022). Hoki are considered to be composed of two stocks (eastern and western). The eastern and western stocks are assumed to share a common (primary) nursery ground on the Chatham Rise. At the onset of sexual maturity, western fish migrate from the nursery ground to the Sub Antarctic 'home ground'. Adult western hoki conduct annual migrations to and from the spawning grounds off the west coast of the South Island (WCSI). For the eastern stock, spawning predominantly occurs in Cook Strait with secondary spawning locations off the east coast of the South Island (Pegasus Canyon and Conway Trough) and during the non-spawning period adult fish reside on the Chatham Rise and off the east coast of the North Island (McGregor et al. 2022).

For the assessment model, the commercial hoki fisheries are structured spatially to reflect the main stock areas (Chatham Rise, Sub Antarctic, Cook Strait, and WCSI) (McGregor et al. 2022). The fisheries in each area are further subdivided to account for spatial differences in the length and age composition of the catch (Ballara & O'Driscoll 2020). In the Sub Antarctic region, the youngest fish (3–6 yr) are typically caught in the Snares fishery, while the youngest (3–8 yr) spawning fish are caught in the WCSI Northern fishery. The Chatham Rise fishery is partitioned by depth with the youngest (2–5 yr) fish dominating the catch from the Shallow (< 475m) fishery and slightly older (3–6 yr) fish dominating the catch from the Deep (> 475 m) fishery (Ballara & O'Driscoll 2020).

Annual Catch-Per-Unit-Effort (CPUE) indices are routinely derived for each of the main hoki fisheries (Ballara & O'Driscoll 2020). The CPUE indices are not included in the hoki stock assessment model because it is considered that the indices do not accurately index abundance over the long term (Ballara & O'Driscoll 2020). Nonetheless, the trends in the CPUE indices from the early 2000s are similar to the trends in the trawl survey abundance indices from the corresponding areas (Chatham Rise or Sub Antarctic) (Langley 2020).

The stock assessment model estimates annual recruitments for the eastern and western stocks. Juvenile hoki are monitored on the Chatham Rise (from age 2+ yr) by the *Tangaroa* trawl survey. However, it is only as the fish recruit to the Sub Antarctic area and respective spawning ground (WCSI or Cook Strait) that information is available regarding the relative proportion of western and eastern fish that compose an individual cohort. The precision of the estimates of annual recruitments for western and eastern stocks improves with successive years of observations of the age composition of the catch from the main spawning fisheries and associated home grounds (Chatham Rise and Sub Antarctic) and the corresponding abundance and age composition data from the *Tangaroa* trawl surveys.

Retrospective analyses conducted for the 2021 stock assessment revealed that recent estimates of annual recruitments for the western stock may be poorly determined and potentially over-estimated in some years (McGregor et al. 2022). While those retrospective patterns were not evident in the 2022 stock assessment, estimates of the most recent (2019–2020) recruitments remained imprecise (McGregor et al. in press). Over the last 20 years, hoki acoustic surveys (O'Driscoll & Ballara 2019) and trawl surveys (Devine et al. in press) of the WCSI spawning grounds have been conducted intermittently; however, currently there is no ongoing monitoring of the abundance of hoki in the WCSI fishery. Further, the stock assessment model indicates that recent recruits are not adequately monitored by the Sub Antarctic trawl survey; the model estimates that hoki are not fully available to the survey until about age 7–10 yr (McGregor et al. 2022).

There is potential for CPUE indices from selected fisheries to provide abundance indices for the younger fish recruiting to the western fisheries (Sub Antarctic and WCSI) and, thereby, provide more immediate information regarding the relative strength of recent recruitments, particularly for the western stock. This report investigates the utility of the CPUE data from a number of key fisheries, specifically the Northern WCSI spawning fishery, the Snares (Sub Antarctic) fishery, and the Chatham Rise fisheries. CPUE indices were derived for each fishery and partitioned by age class utilising the corresponding fishery age composition datasets. For corroboration, the CPUE indices were compared with the corresponding fishery independent abundance indices and outputs from the 2021 hoki stock assessment model. The study was funded by the Deepwater Group and presented to the Deepwater Fishery Stock Assessment Working Group in November 2021.

2. METHODS

Commercial catch and effort data from the hoki (HOK) fishery were sourced from the Fisheries New Zealand combined *warehou* and EDW databases. The data request encompassed all catch, effort, daily processing, and landings data from any fishing trip that targeted and landed hoki in HOK 1 during the period 1/10/1999 to 30/9/2021 (Fisheries New Zealand data extract 13901). Previous analyses (Ballara & O'Driscoll 2020) of CPUE data concluded that long-term CPUE trends were not consistent with the trends in hoki abundance and, hence, data from the preceding years were not included.

The study focused on the hoki factory trawl fleet. These vessels typically conduct fishing trips of 4–6 weeks duration. The vessels report estimated catches of hoki from individual trawls and provide a daily summary of the total catch of hoki processed. The total landed catch of hoki is also reported at each vessel unloading (discharge), although some of the catch may be retained on board and discharged at a subsequent unloading.

For each trip, the total hoki catch reported from the three formats was determined. Overall, there was a very strong correlation between the aggregated estimated and processed catches of hoki (corr. coef. 0.99) and between the aggregated estimated and landed catches (corr. coef. 0.97). Estimated catches typically represented 95–100% of the total processed catch reported for a trip. For each trip, individual estimated catches were rescaled to account for the trip ratio of estimated and processed catches (rescaled hoki catch).

The individual trawl records were allocated to the main hoki fisheries defined for the 2021 hoki stock assessment (McGregor et al. 2022) (**Table 1**). The analysis did not include the Cook Strait spawning hoki trawl fishery or the hoki spawning fishery operating inside the 25 nm exclusion zone in the Hokitika Canyon off the west coast South Island. These fisheries are predominantly conducted by smaller inshore vessels in areas where hoki are found in aggregations associated with undersea canyon features. It is generally accepted that catch and effort data from these fisheries are unlikely to provide indices of relative abundance of hoki. Data from several smaller hoki fisheries were also excluded rom the analysis. The Chatham Rise Deep fishery was partitioned into two separate fisheries: Southwestern and Northern Chatham Rise.

For each fishery, a core set of factory vessels was defined for the CPUE analysis. The core fleet selection criteria required vessels to have conducted at least 20 trawls in a minimum of 5 years during1999/2000 (2000) to 2020/21 (2021). For the qualifying fleets, comprehensive catch and effort datasets were available for the WCSI North and South fisheries and the Chatham Rise Southwestern and Northern fisheries (**Table 1**, Appendix 1). Limited data were available from the Snares fishery from the early to mid 2000s and from recent years 2018–2021) (Appendix 1, Table A3), and limited data were available from the Chatham Rise Shallow fishery from 2006/07 onwards (Appendix 1, Table A5).

Table 1: **A summary of the catch and effort datasets for 1999/2000 to 2020/21.**

Dataset	Season	Spatial definition	Number of vessels	Number of trawls	HOK catch (t)
WCSI North	Jun–Sep	North of 42°15’ S	29	28 564	420 162
WCSI South	Jun–Sep	South of 42°15’ S	21	26 889	315 453
Snares	Feb–Jun		7	6 098	47 417
Chatham Rise Shallow	Oct–Jun	< 475 m	11	6 855	40 477
Chatham Rise SW Deep	Oct–Jun	475–800 m West of 176°E South of 43°30’ S	15	29 579	208 958
Chatham Rise North	Oct–Jun	475–800 m West of 178° W North of 43°30’ S	17	25 379	160 193

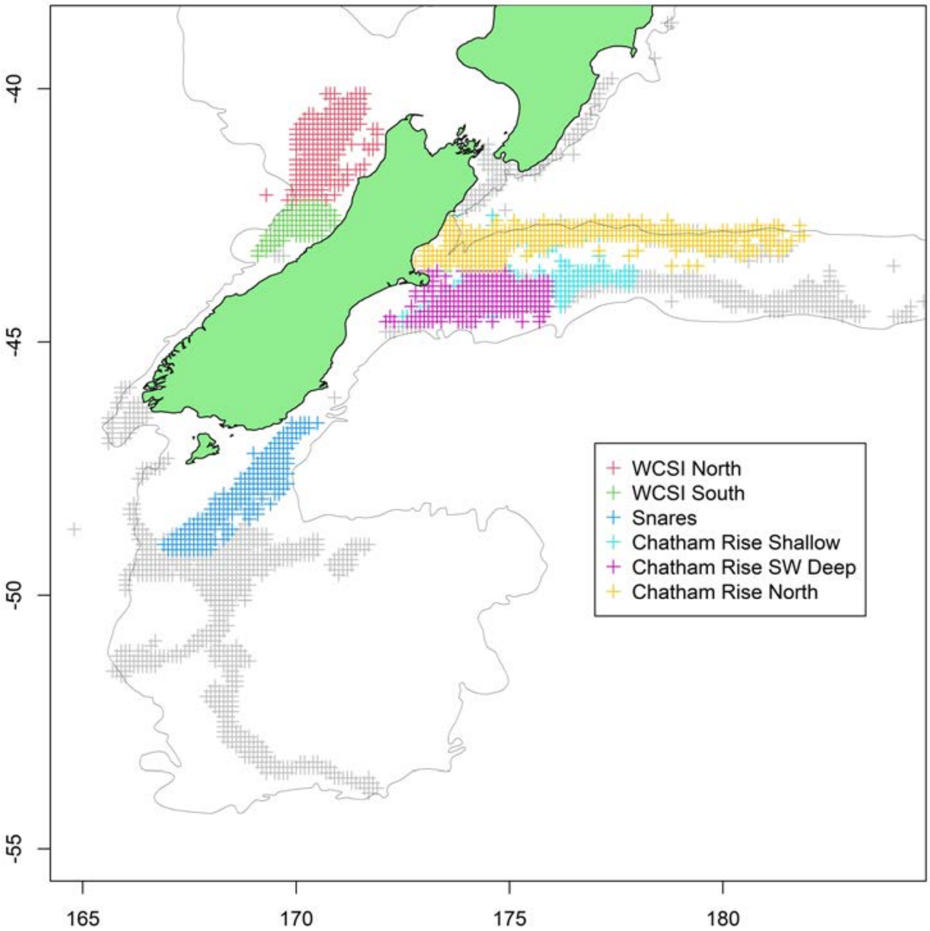


Figure 1: Distribution of hoki target trawls (grey) partitioned by individual fishery CPUE dataset (colour coded) from 1999/2000–2020/21.

2.1 CPUE analysis

For each defined fishery, the catch and effort data from qualifying fishing trips were restricted to declared HOK target trawls. A small proportion (< 1%) of the trawl records had no reported catch of HOK and those records were excluded from the datasets. The datasets included trawls conducted using single bottom trawl

(BT), twin rig bottom trawl (BT2), mid-water trawl (MW), Precision Harvesting bottom trawl (PRB), and Precision Harvesting mid-water trawl (PRM) (Table 2). The non-spawning fishery datasets were dominated by BT records with BT2 accounting for a significant proportion of records from the late 2000s. Mid-water trawls were the dominant fishing gear in the WCSI South fishery and, to a lesser extent, the WCSI North fishery. Mid-water trawl records were further categorised based on the height of the gear above the bottom (*TrawlHeight*) (Table 2). Precision Harvesting trawl gear was utilised by some vessels during 2017/18–2019/20.

The catch and effort datasets were analysed using a Generalised Linear Modelling (GLM) approach to model the magnitude of the hoki catch (*HOKcatch* predictor variable) from each trawl, assuming a lognormal error structure. The individual GLM models had a generic formulation incorporating the range of available explanatory variables (Table 2). Continuous variables were included as third-order polynomial functions. For each fishery, the trawl records are spatially distributed along a primary axis of latitude or longitude (Figure 1) and, typically, only the dominant spatial variable was included in the model.

For each GLM, the proportion of the total variance in *HOKcatch* explained by each variable was determined. The individual *Fyear* coefficients (and associated standard errors) were extracted from the model as annual CPUE indices for the respective fishery.

The resultant annual CPUE indices were compared with the available abundance indices included in the hoki stock assessment model and with the model (model 2021A) estimates of vulnerable biomass for the respective fisheries (McGregor et al. 2022).

Table 2: Key variables included in hoki CPUE models.

Variable	Description	Range
HOKcatch	Hoki catch (kg)	1–100 000
TargetSpecies	Declared target species of trawl	HOK
Fyear	Fishing year (categoric)	2000–2021
VesselFlag	Nationality of vessel (categoric)	
Vessel	Unique vessel identifier (categoric)	
FyearDay	Day of fishing year	
TrawlGear	Trawl gear code (categoric)	BT, BT2, MW, PRB, PRM
Speed	Trawl speed (knots)	2.5–5.5
Distance	Trawl distance (nautical mile)	0.5–60
TimeStart	Start time of trawl (24 hr)	
Latitude	Start latitude of trawl	
Longitude	Start longitude of trawl	
Bottom depth	Bottom depth at start of trawl (m)	< 1500
Duration	Trawl duration (hr)	0–11
TrawlHeight	Height of trawl above bottom Categories: 1, < 10 m; 2, 10–50 m; 3, > 50 m	< 300 m

2.2 Age-specific CPUE indices

Comprehensive age composition data were available for the individual hoki fisheries included in the 2021 stock assessment model (McGregor et al. 2022). The model catch-at-age data were compiled as proportional numbers-at-age stratified by sex and age classes 1–18 years, with the oldest age class accumulating fish 18 years and older.

The definitions of the fisheries included in the CPUE analyses generally corresponded to the assessment models (**Error! Reference source not found.**Table 3). Most (~ 70%) of the catch from the Chatham Rise Deep fishery has been taken from the southern Chatham Rise (Figure 2) and the fishery age composition data were associated with the Chatham Rise Southwestern (SW) Deep fishery, rather than the Chatham Rise North fishery. For the Snares fishery, age compositions were not available for the earlier years (2000–2005) (**Error! Reference source not found.**Table 3).

Table 3: A summary of the age composition data included in the derivation of age-specific CPUE indices, where fishing year 2000 is 1999/2000.

CPUE index	Model fishery	No. of observations	Fishing Years
WCSI North	WCSI North	21	2000–2020
WCSI South	WCSI South	21	2000–2020
Snares	Snares	14	2006, 2008–2020
Chatham Rise Shallow	Chatham Rise Shallow	19	2001–2019
Chatham Rise SW Deep	Chatham Rise Deep	20	2001–2020
Chatham Rise North	Not available	Not available	Not available

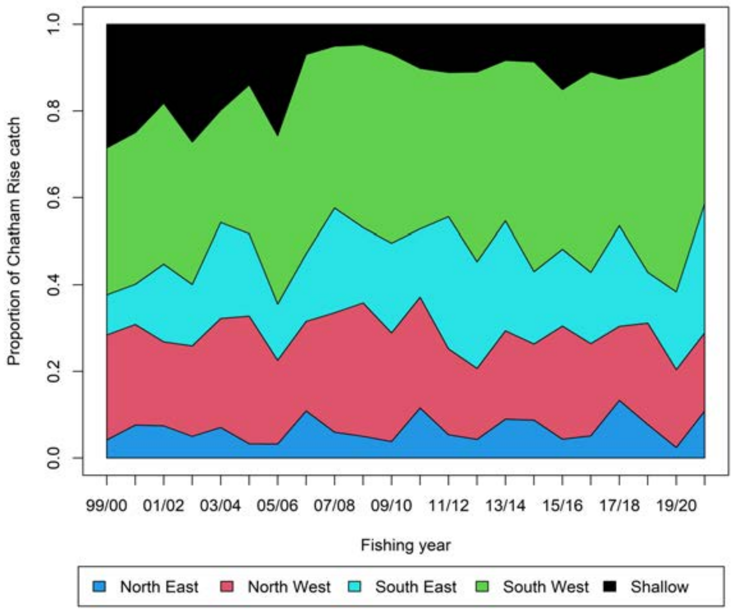


Figure 2: Distribution of Chatham Rise hoki catch by area.

The annual CPUE indices were apportioned by the corresponding annual age composition to derive CPUE indices for individual age classes. Initially, this required the individual age compositions to be converted from proportional numbers-at-age to proportional weight-at-age to be in equivalent units of mass to the CPUE indices.

For each fishery, the annual age-specific CPUE indices were calculated as the product of the annual CPUE index and the annual proportional weight-at-age (combined for males and females). The resulting age-specific CPUE indices enabled the relative abundance of each individual cohort (year class) to be monitored over the successive years of sampling from each fishery (at age 2 yr, 3 yr, 4 yr, 5 yr, etc). These age-based indices (normalised to the average of the series) were compared with the estimates of annual recruitments (western, eastern, and combined recruitment) from the hoki stock assessment model (McGregor et al. 2022).

3. RESULTS

3.1 CPUE indices

For most of the fisheries, there was considerable variability in the CPUE indices between years and the *Fyear* variable accounted for a significant proportion of the variation explained by the CPUE models (Appendix 1, Tables A7–12). The other main explanatory variables varied between fishery, but typically included *Vessel* (WCSI North, WCSI South, Chatham Rise North, Chatham Rise SW Deep, Chatham Rise Shallow), *TimeStart* (WCSI North, WCSI South, Snares, Chatham Rise North, Chatham Rise SW Deep, Chatham Rise Shallow), *Duration* (WCSI South, Snares, Chatham Rise North, Chatham Rise SW Deep, Chatham Rise Shallow), and *FyearDay* (WCSI North, WCSI South, Chatham Rise North) (Appendix 1, Tables A7–12).

For each fishery, the overall trends in the standardised CPUE indices do not differ appreciably from the annual unstandardised catch rate of hoki (median catch per trawl) (Figure 3).

For all fisheries, there was a decline in the CPUE indices in the early 2000s followed by an increase in CPUE during the mid–late 2000s (Figure 3). For the Chatham Rise fisheries, CPUE indices remained relatively stable during 2010–2021 (2009/10−2020/21). Conversely, the CPUE indices from the WCSI (North and South) and Snares fisheries declined during the 2010s although the trends in the indices varied between fisheries. The WCSI North fishery CPUE declined markedly during 2016–2018 and recovered in 2020 (Figure 3).

The general trends in the fishery CPUE indices were similar to the trends in the fishery-specific vulnerable biomass estimated from the 2021 hoki stock assessment (Figure 3). However, there were some notable differences; the CPUE indices tended to increase more rapidly and to a greater extent in the mid–late 2000s compared with the trends in vulnerable biomass. This was most pronounced in the Snares fishery and may indicate an overall increase in the efficiency of the trawl fleet during the period. Alternatively, differences in the trends vulnerable biomass may also be attributable to a mis-specification of the structure of the stock assessment model (for example, related to the estimated movement of hoki from the Chatham Rise to Sub Antarctic region).

For the most recent fishing years (2020 and 2021), the CPUE indices from the WCSI North fishery were considerably higher than predicted by the stock assessment model (Figure 3). The trends in the CPUE indices were compared with the hoki biomass indices from the *Tangaroa* Sub Antarctic trawl survey (Stevens et al. 2022), the primary abundance index for the western stock. The trawl survey biomass indices were partitioned by age groups (3 yr, 4–6 yr, and 7–10 yr old with the exception of the most recent (2021) trawl survey) for a more direct comparison with the age structure of the fishery catch (predominantly 3–10 yr fish) (Figure 4). Overall, there is a good correspondence between the trends in the CPUE indices and the total trawl survey biomass indices, although biomass indices in 2001–2003 were considerably higher than the corresponding CPUE indices (Figure 4). Trends in the CPUE indices were also consistent with the general trends in the 3 yr and 4–6 yr trawl survey indices (Figure 4).

A more direct comparison is available between the WCSI North CPUE indices and the hoki trawl survey biomass indices from the *Tangaroa* west coast South Island trawl survey (Devine et al. in press). The trawl surveys occurred during July–August and the survey area approximates the spatial definition of the WCSI North fishery. The hoki length compositions from the individual trawl surveys (Devine et al. in press) are very similar to the corresponding length compositions of the catch from the commercial fishery (Ballara & O'Driscoll 2020). Hoki is no longer considered to be a primary target species for this trawl survey and the precision of the biomass estimates is variable (CV 14–53%). There is also concern regarding the reliability of the large biomass estimate from the 2012 trawl survey (O'Driscoll et al. 2014), which may be biased by the northward progression of the survey coinciding with a northward movement of hoki through the survey area (O'Driscoll et al. 2014, Richard O'Driscoll, NIWA, pers. comm., see Appendix 2). On that basis, the 2012 biomass index was excluded from the comparison.

The limited number (5) of WCSI trawl survey biomass indices indicate that the hoki abundance varied considerably over the last decade, declining to a nadir in 2018 and recovering in 2021. The trends in the survey biomass indices are consistent with the corresponding WCSI North fishery CPUE indices, although the magnitude of the variation in the CPUE indices is lower than the variation in the trawl survey indices (Figure 5).

Hoki acoustic biomass indices from the northern WCSI survey strata were compiled for comparison with the WCSI North CPUE indices (data provided by Richard O'Driscoll, NIWA) (O'Driscoll & Ballara 2019). For each acoustic survey, there was considerable variation in the acoustic biomass estimates of hoki from the individual snapshots for the northern strata (Figure 6), indicating considerable within season variability in the abundance of hoki in the area. There are some broad similarities between the acoustic biomass estimates and the WCSI North CPUE indices, particularly the comparison between the higher indices from 2015 and lower indices from 2018 (Figure 6). However, there is considerably greater contrast between the annual sets of acoustic biomass indices, attributable, in part, to the extent of sampling variability during each season, including the timing of individual snapshots.

Trends in the Snares CPUE indices were compared with the Sub Antarctic trawl survey biomass indices; total biomass and biomass partitioned by age groups (to 2018) (Figure 7). The CPUE indices do not follow the decline in trawl survey biomass in the early 2000s. However, the large increase in the CPUE indices during the mid 2000s was followed by a comparable increase in total biomass two years later, primarily attributable to an increase in the biomass of 3 yr and 4–6 yr hoki (Figure 7). The decline in the trawl survey biomass indices (total and 4–6 yr) from the early 2010s is comparable with the decline in the CPUE indices over the same period (Figure 7). The two large 3 yr biomass indices from the 2014 and 2018 trawl surveys are not reflected in the corresponding annual Snares CPUE indices (Figure 7), although the individual age classes dominated the associated age compositions from the fishery.

The Chatham Rise trawl survey hoki 3++ biomass indices by strata (source: Sira Ballara, NIWA) were aggregated by strata groupings to approximate quadrants of the Chatham Rise: North West (strata 1, 7, 8, 18, 19, 20), North East (strata 2, 5, 9, 10, 11), South West (strata 6, 14, 15, 16, 17), and South East (strata 3, 4, 12, 13) (Stevens et al. 2021). The trends in the four sets of spatially stratified biomass indices are broadly comparable; the indices declined considerably during the late 1990s, reached the nadir in 2003–2005, and gradually increased during 2007–2014 and have remained relatively constant over the subsequent years (Figure 8 and Figure 9).

The extent of the initial decline was considerably higher for the North West and South West areas of the Chatham Rise, and the extent of the subsequent recovery in the South West quadrant was greater than for the North West quadrant. Recent (2016–2020) levels of biomass are approximately 40% (NW and SE) or 60% (NE and SW) of the average biomass level from the initial years of the survey (1992–1997) (Figure 8 and Figure 9).

The CPUE indices from the Chatham Rise North Deep fishery are composed of catch and effort records from the two northern quadrants of the Chatham Rise trawl survey area. The general trend in the CPUE indices is comparable with the trend in the trawl survey biomass indices from the two constituent areas with a similar magnitude of increase in the sets of indices during the late 2000s (Figure 10). However, the trawl survey biomass indices are more variable, particularly the high biomass indices from the 2002 trawl survey (following strong 2+ indices observed in the two preceding surveys).

The trend in the CPUE indices from the Chatham Rise Southwestern Deep fishery was also very similar to the general trend in the trawl survey biomass indices from the comparable area (Figure 10), although there is higher variability in the trawl survey series, particularly the high index from the 2013 trawl survey.

CPUE indices were not derived for the hoki fishery operating in the southeastern area of the Chatham Rise. Trawl survey biomass indices compiled for the southeastern quadrant fluctuated considerably during 2008–2014 (Figure 10) and stabilised at a lower level during 2016–2020. These trends differ from the CPUE indices derived from the adjacent area (Southwestern Deep fishery) (Figure 10).

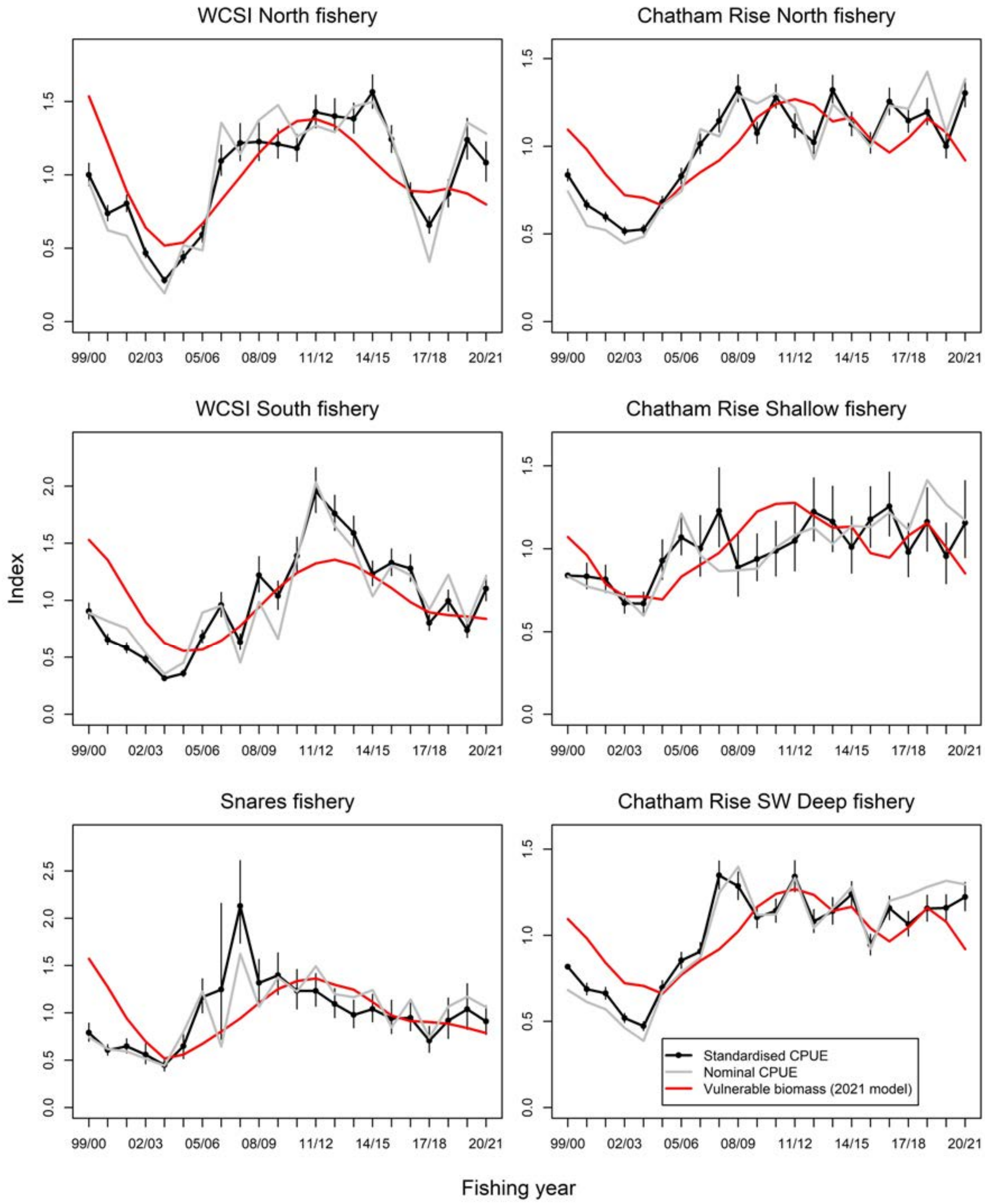


Figure 3: A comparison in trends in nominal hoki catch rates, standardised CPUE indices, and 2021 stock assessment model estimates (model 2021A) of fishery-specific vulnerable biomass.

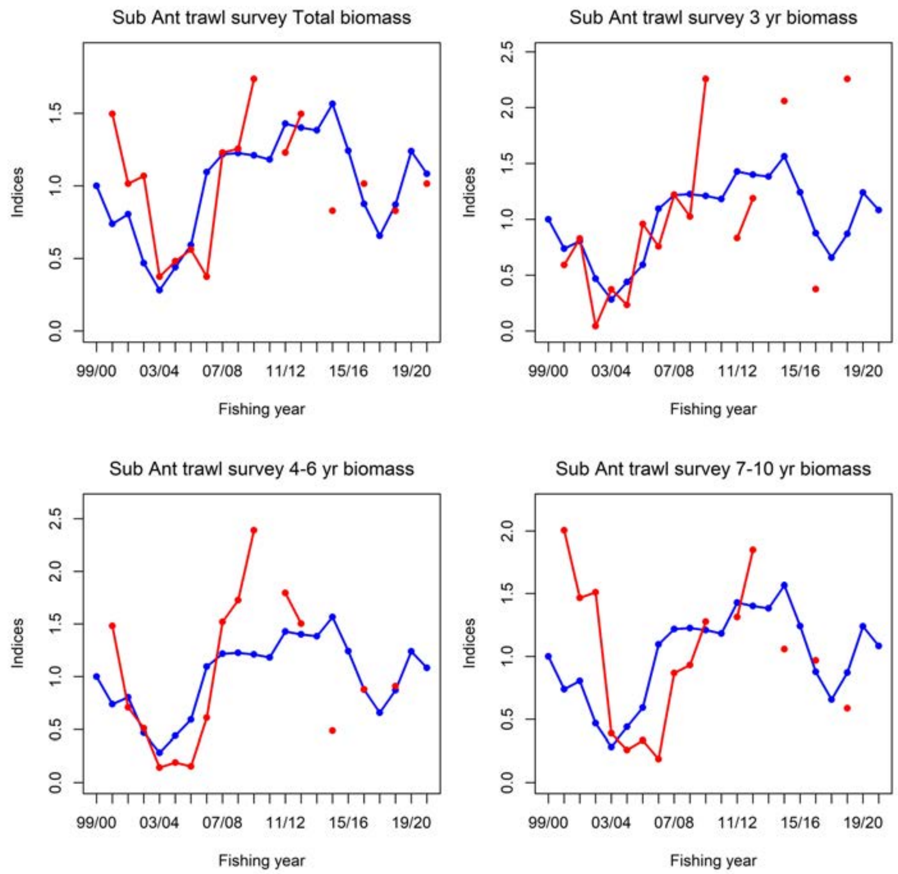


Figure 4: A comparison between the WCSI North CPUE indices (blue) and the hoki biomass indices (total and by specific age groups) from the *Tangaroa* Sub Antarctic trawl survey (red). The sets of indices are normalised to the average of the respective series.

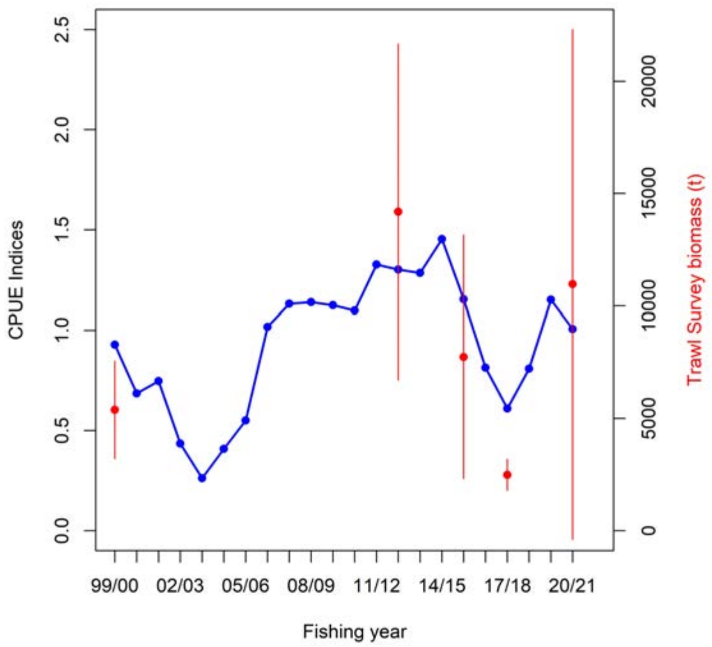


Figure 5: A comparison between the WCSI North CPUE indices (blue) and the hoki biomass indices (total) from the *Tangaroa* west coast South Island survey (red), excluding the 2012 survey index.

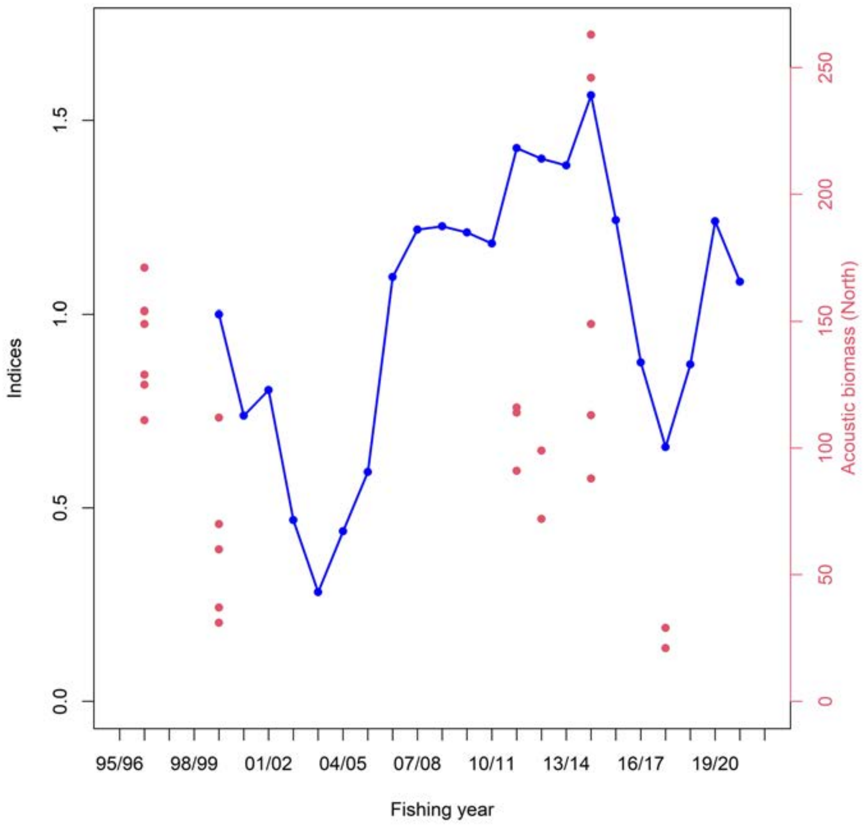


Figure 6: A comparison between the WCSI North CPUE indices (blue) and the hoki acoustic biomass estimates from individual survey snapshots from the northern strata of the west coast South Island (red points).

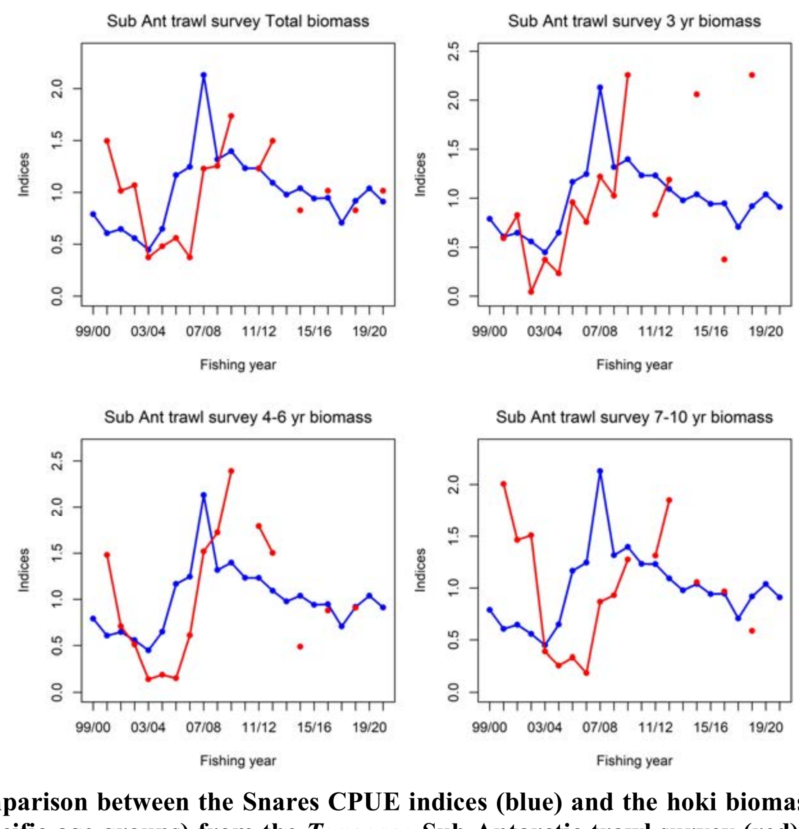


Figure 7: A comparison between the Snares CPUE indices (blue) and the hoki biomass indices (total and by specific age groups) from the *Tangaroa* Sub Antarctic trawl survey (red). The sets of indices are normalised to the average of the respective series.

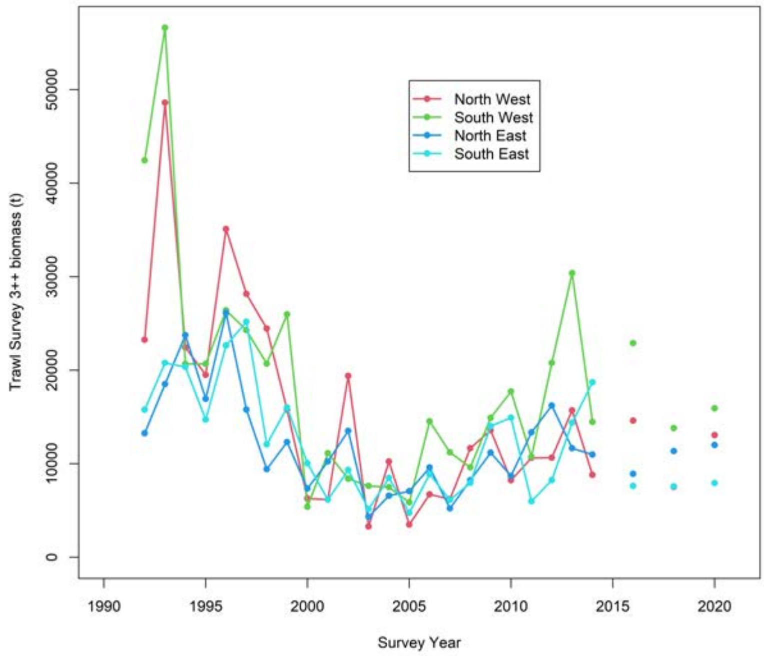


Figure 8: Biomass indices (t) of recruited (age 3 yr and older) hoki from the time series of *Tangaroa* Chatham Rise trawl surveys, partitioned by quadrants of the Chatham Rise (based on survey strata). The 2018 North West index is obscured by the South East index.

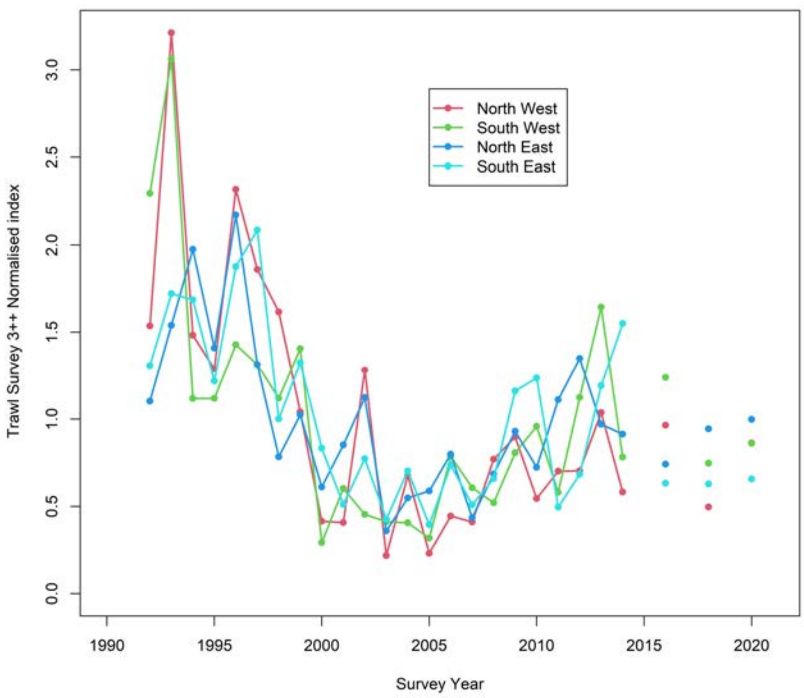


Figure 9: Normalised biomass indices of recruited (age 3 yr and older) hoki from the time series of *Tangaroa* Chatham Rise trawl surveys, partitioned by quadrants of the Chatham Rise (based on survey strata). The 2020 North West index is obscured by the South West index.

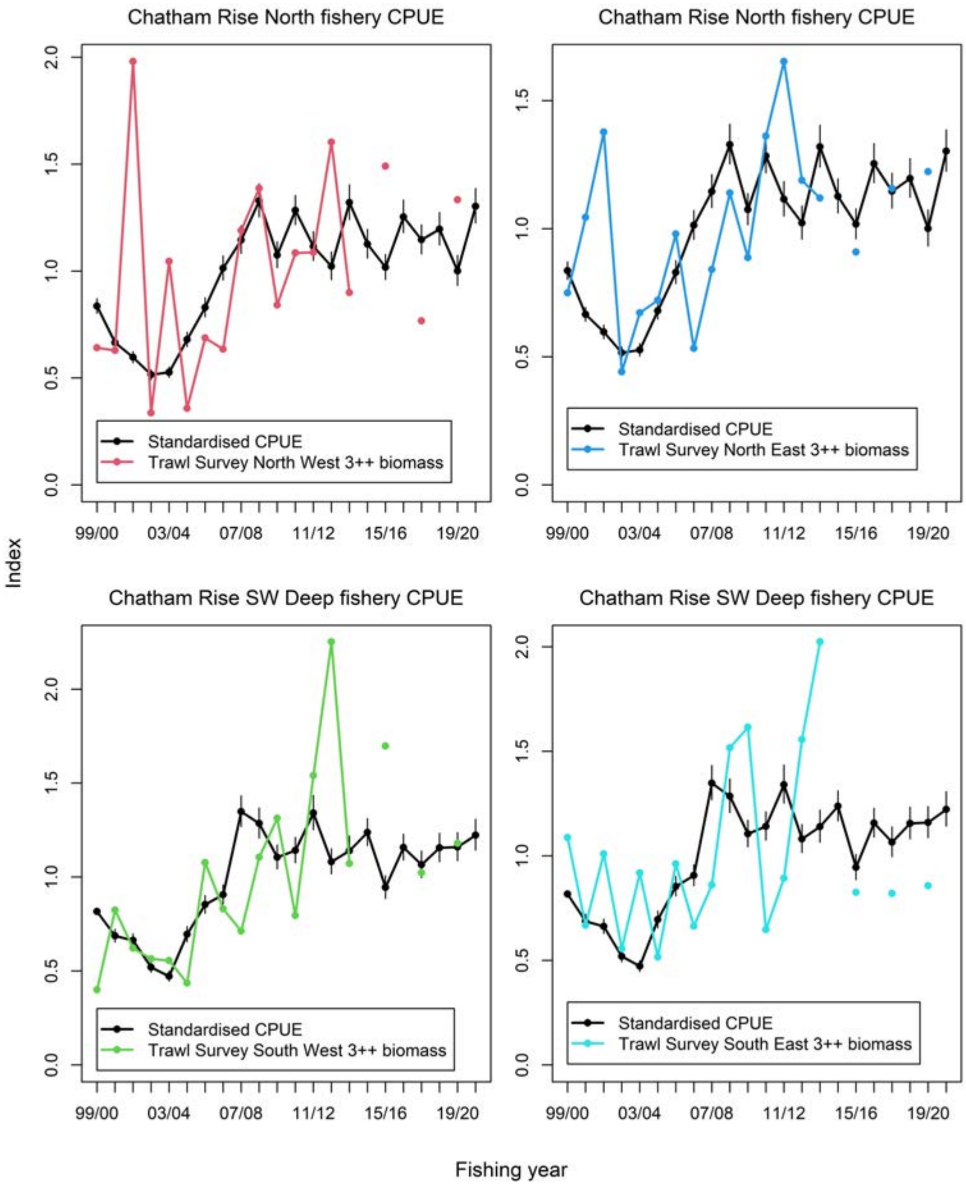


Figure 10: A comparison of Chatham Rise CPUE indices and normalised biomass indices of recruited (age 3 yr and older) hoki from the time series of *Tangaroa* Chatham Rise trawl surveys, partitioned by quadrants of the Chatham Rise (based on survey strata).

3.2 Seasonal CPUE trends

The current hoki stock hypothesis assumes western hoki migrate from the Chatham Rise to the Sub Antarctic region with the youngest immigrants present in the Snares fishery. Seasonal trends in the CPUE indices from the respective fisheries were compared to elucidate trends in abundance between the fishery areas. To increase the resolution of the analysis, the Snares fishery was partitioned into two latitudinal bands (north and south of latitude 48° S). For the Chatham Rise Shallow and Southwestern Deep fishery, hoki CPUE is predicted to increase during December–April, at least partly due to the somatic growth of fish in the younger cohorts that dominate the catch (Figure 11). The predicted CPUE from the Chatham Rise Southwestern Deep fishery declines during May and June.

For the northern area of the Snares fishery, there is a pronounced increase in CPUE during February–March that is followed by an increase in CPUE in the southern area of the Snares fishery (Figure 11). The CPUE in the northern Snares area declines considerably in May–June, while the CPUE in the southern Snares area is maintained. These trends are suggestive of a southern movement of fish along the Stewart-Snares shelf in advance of the main spawning period which occurs off the WCSI during July–August (Figure 11).

However, the CPUE trends do not provide evidence to indicate a strong seasonal movement of hoki from the Chatham Rise to the Snares area. Under that scenario, it would be expected that the increase in the CPUE in the Snares fishery would coincide with a seasonal decline in the CPUE from the Chatham Rise fishery. However, the increase in the CPUE in the Snares fishery during February–April was not reciprocated by a declining trend in CPUE from the Chatham Rise fisheries (Figure 11).

This may indicate that the transition of hoki from the Chatham Rise region to the Sub Antarctic region is not a strong seasonal process and/or the timing of the seasonal movement may vary between years. To further investigate this relationship, CPUE models for the Snares fishery and Chatham Rise Southwestern Deep fishery were configured to include a year-month variable. The observations from the Snares fishery are primarily from March, April, May, and June; the Snares CPUE indices tended to be higher in March and April although the seasonal pattern varied between years (Figure 12). There was no indication of a strong reciprocal trend in the monthly CPUE indices from the Chatham Rise Southwestern Deep fishery (Figure 12).

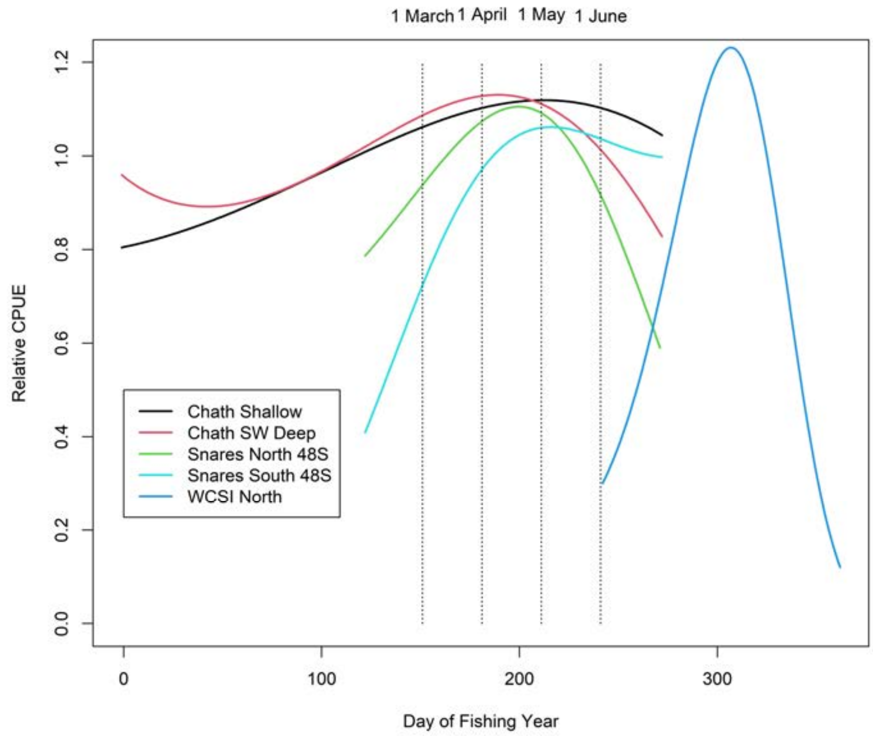


Figure 11: A comparison of the seasonal trends in hoki CPUE derived from the respective CPUE models.

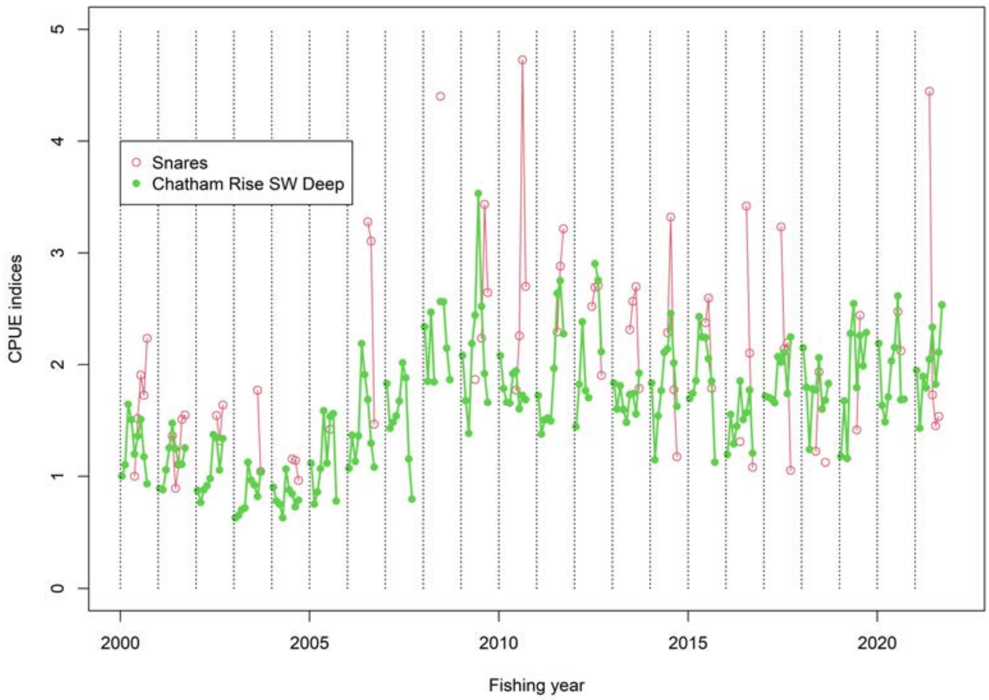


Figure 12: A comparison of the year-month CPUE indices derived from the Snares fishery and the Chatham Rise Southwestern Deep fishery.

Seasonal trends in the CPUE from the Chatham Rise Deep (> 475 m) fishery were further examined by comparing the seasonal predictions from separate CPUE models configured for the four quadrants of the Chatham Rise (partitioned by longitude 177° E and latitude 43°30’ S). The seasonal trends in CPUE were similar for the southwestern (SW), northeastern (NE), and southeastern (SE) quadrants with increasing CPUE during December–April and declining CPUE during May–June (Figure 13). For the northwestern (NW) quadrant, CPUE continued to increase during May–June and thus deviated from the trends in the other three quadrants (Figure 13). These trends may be indicative of a shift in the distribution of hoki on the Chatham Rise towards the NW area immediately prior to the spawning period. The NW area is in closer proximity to known spawning grounds off the east coast of the South Island and in Cook Strait compared to the other areas.

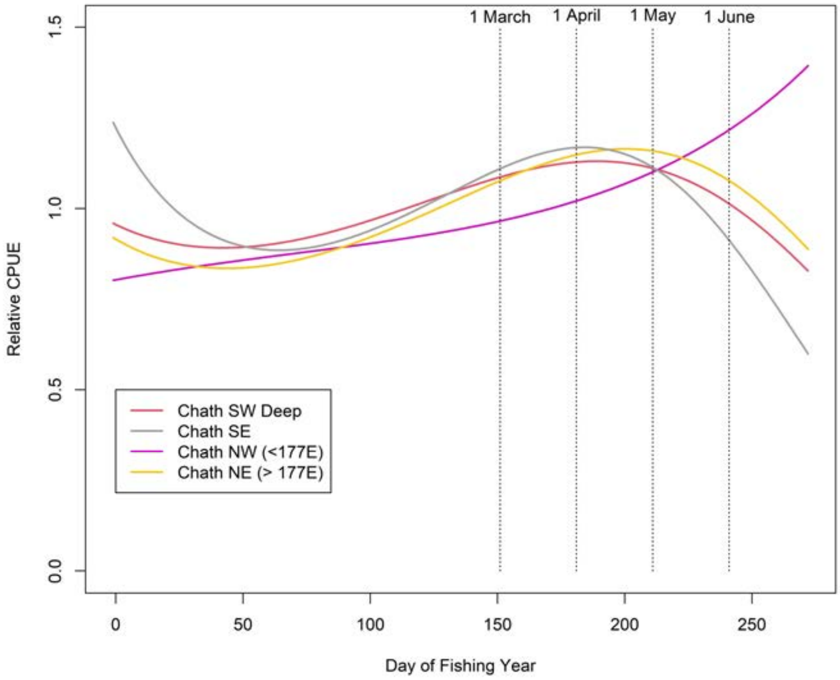


Figure 13: A comparison of the predicted seasonal hoki CPUE from the Chatham Rise deep (> 475 m) fishery partitioned by quadrant.

3.3 Age-specific CPUE indices

The fishery CPUE indices were decomposed by age from the available fishery age composition data, included in the 2021 stock assessment (Ballara & O'Driscoll 2020, McGregor et al. 2022). The fishery definitions of the CPUE and age data are comparable for most of the fisheries, with the exception of the Chatham Rise Southwestern Deep and Chatham Rise North fisheries. For the Chatham Rise fishery, the age composition data are compiled by depth strata (shallow and deep) and, hence, there is no explicit partitioning of the catch by area. Since 2005, the spatial distribution of the hoki catch from the deeper stratum has been relatively stable with approximately 40% of the catch from the southwestern area of the Chatham Rise, 30% from the northern Chatham Rise, and the remainder (~ 30%) from the southeastern Chatham Rise (Figure 2).

The amalgamated Chatham Rise Deep age composition data were linked to the CPUE indices from the Chatham Rise Southwestern Deep fishery as the southwestern area of the Chatham Rise accounted for a high proportion of the total catch (and effort) from the Chatham Rise Deep fishery.

For most of the fisheries, the age compositions were dominated by the 2–5 yr age classes (Figure 14). It was considered that these age classes have the most potential for the derivation of recruitment indices based on CPUE data; i.e., the age classes represent recent recruits to the fishery and were unlikely to have been heavily depleted by fishing. By contrast, younger fish (1 yr) represent a very minor proportion of the commercial catch in both the spawning and non-spawning fisheries.

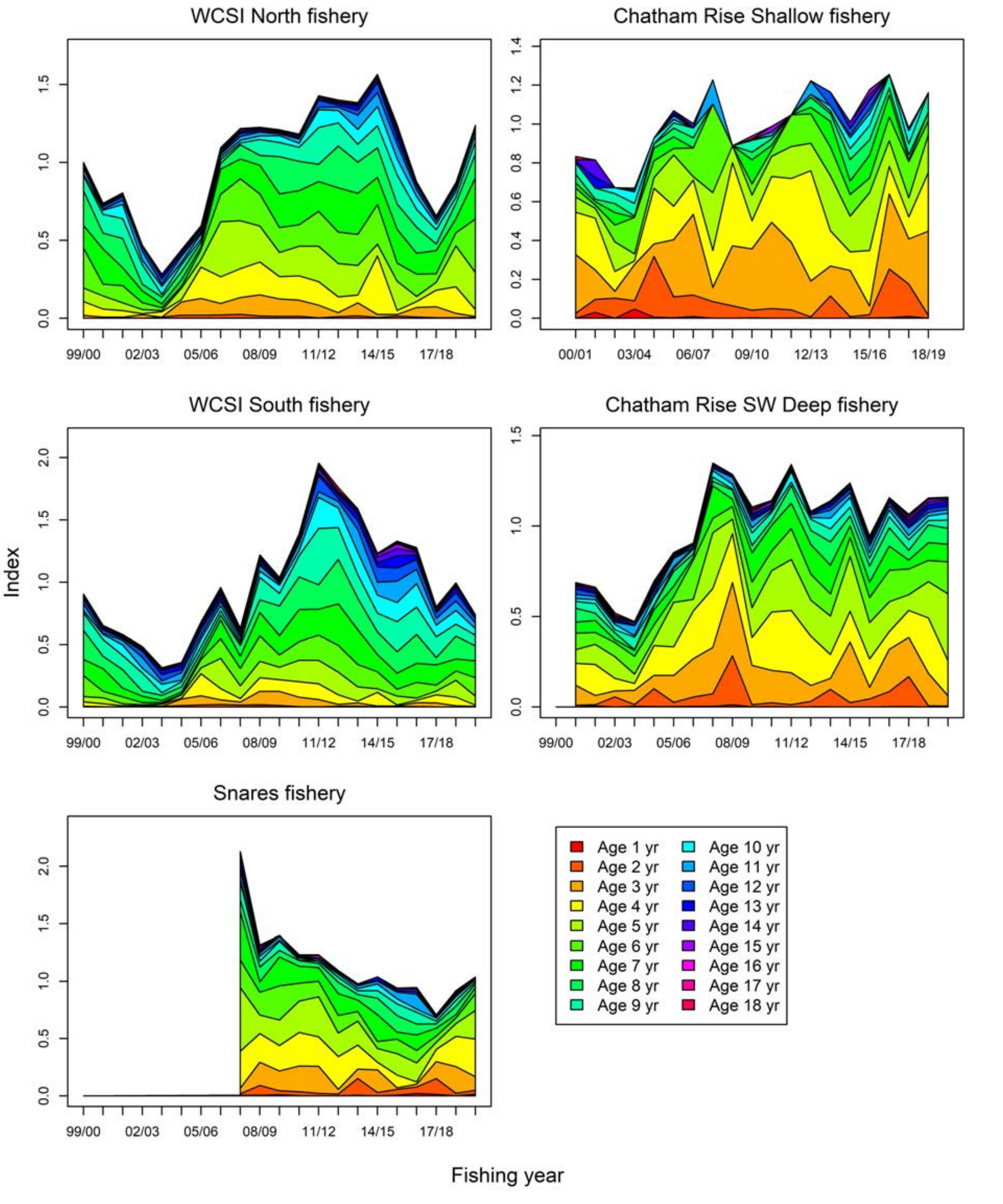


Figure 14: Annual CPUE indices from each fishery disaggregated by age class (male and female fish combined).

For each fishery, the age-specific CPUE indices derived for 2, 3, 4, and 5 yr old fish were compared with the corresponding estimates of annual recruitments (western, eastern, and combined) from the 2021 stock assessment model. There is a strong correlation between the western recruitments and the 3, 4, and 5 yr age-specific indices from the WCSI North fishery (Table 4, Figure 15) and the WCSI South fishery (Table 4, Figure 16), although the correlation was weaker for the 2007–2011 year classes.

There is also a good correlation between the western recruitments and the 3, 4, and 5 yr age-specific indices from the Snares fishery (Table 4, Figure 17), although there are fewer observations due to the lack of age composition data from the earlier years. The 2 yr age-specific CPUE indices differ from the older age indices, with higher indices for the 2013 and 2017 year classes which are more comparable with the corresponding estimates of recruitment for eastern hoki (Table 4, Figure 17).

Western recruitment estimates are also correlated with the 4 and 5 yr age-specific indices from the Chatham Rise Southwestern (Deep) fishery (Table 4, Figure 18). By comparison, there is a lower correlation between the age-specific CPUE indices from the Chatham Rise fisheries and the estimates of eastern recruitments (Table 4).

Table 4: Correlation coefficients between 2, 3, 4, or 5 yr age-based CPUE indices and the estimated number of recruits for the corresponding year class (western, eastern and combined) from the 2021 hoki stock assessment model.

	Age Class	Recruitment series		
Fishery	(yr)	Western	Eastern	Combined
WCSI North	2	0.640	0.425	0.598
	3	0.881	0.548	0.824
	4	0.787	0.569	0.782
	5	0.920	0.428	0.797
WCSI South	2	0.627	0.399	0.578
	3	0.740	0.387	0.659
	4	0.893	0.416	0.782
	5	0.855	0.290	0.691
Snares	2	0.485	0.746	0.629
	3	0.662	0.648	0.725
	4	0.766	0.621	0.731
	5	0.650	0.315	0.582
Chatham Rise Shallow	2	0.684	0.331	0.591
	3	0.615	0.552	0.658
	4	0.479	0.551	0.567
	5	0.392	0.295	0.393
Chatham Rise SW Deep	2	0.577	0.646	0.653
	3	0.650	0.448	0.635
	4	0.728	0.353	0.639
	5	0.696	0.458	0.672

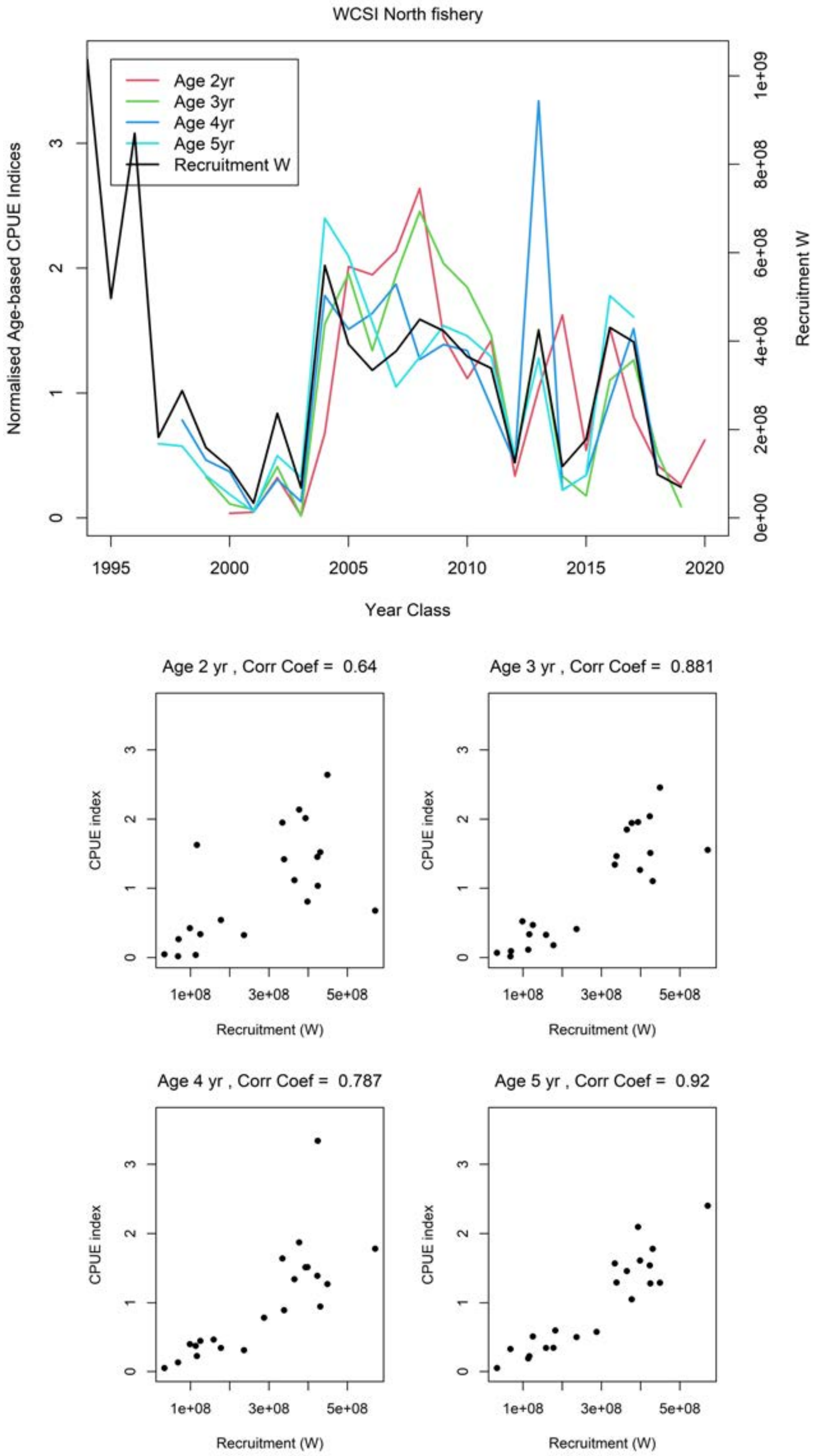


Figure 15: Age-specific CPUE indices of 2, 3, 4, 5 yr fish from the WCSI North fishery, by year class, compared with the estimates of annual recruitment for western hoki from the 2021 hoki stock assessment (top panel). The lower panels present correlations between the age-specific CPUE indices and the corresponding estimates of western hoki recruitment.

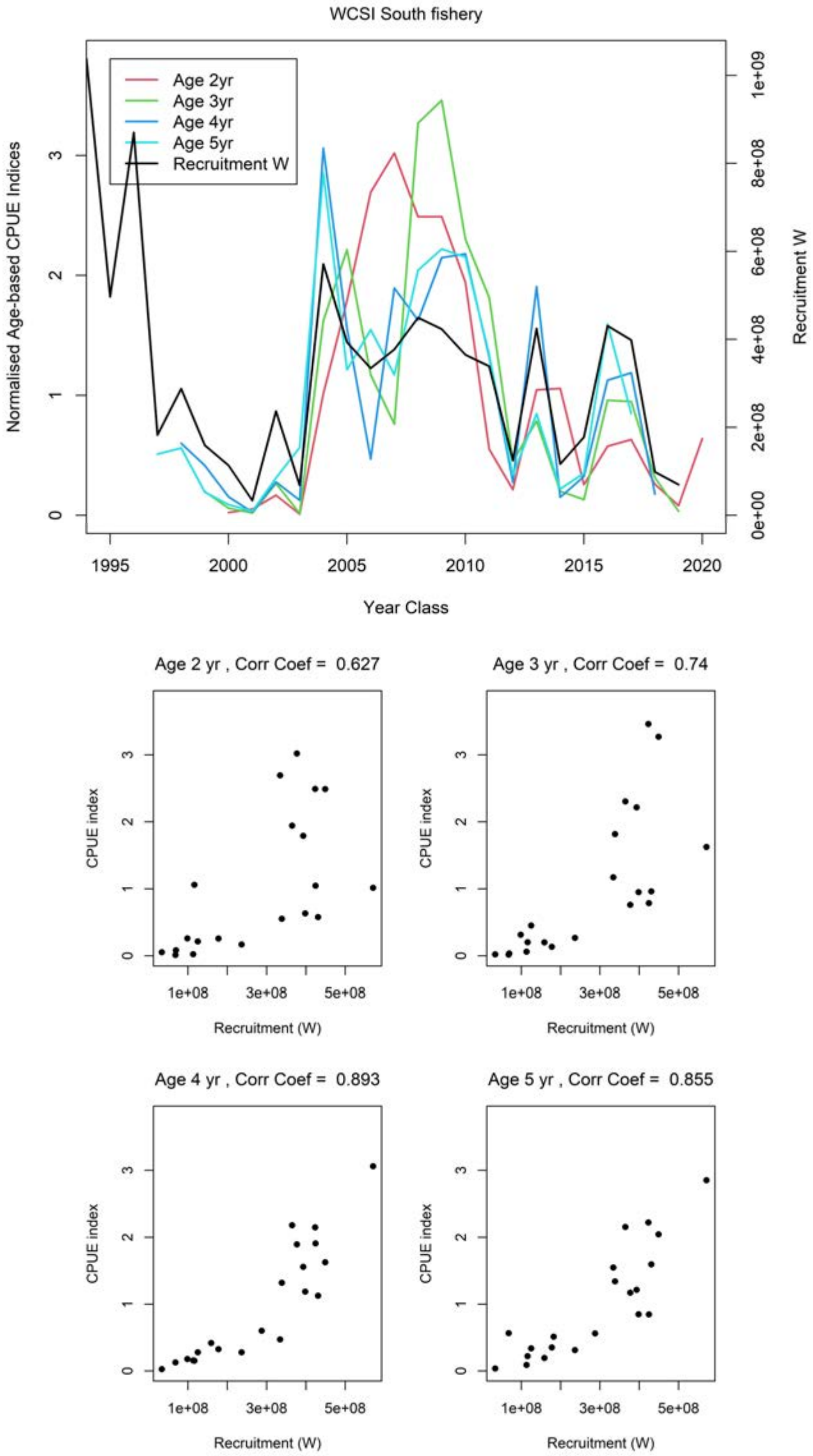
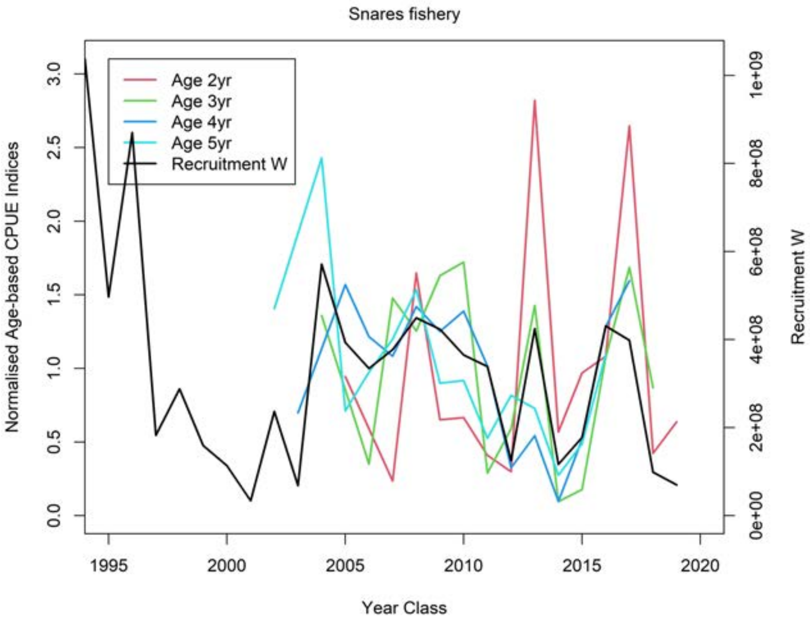


Figure 16: Age-specific CPUE indices of 2, 3, 4, 5 yr fish from the WCSI South fishery, by year class, compared with the estimates of annual recruitment for western hoki from the 2021 hoki stock assessment (top panel). The lower panels present correlations between the age-specific CPUE indices and the corresponding estimates of western hoki recruitment.



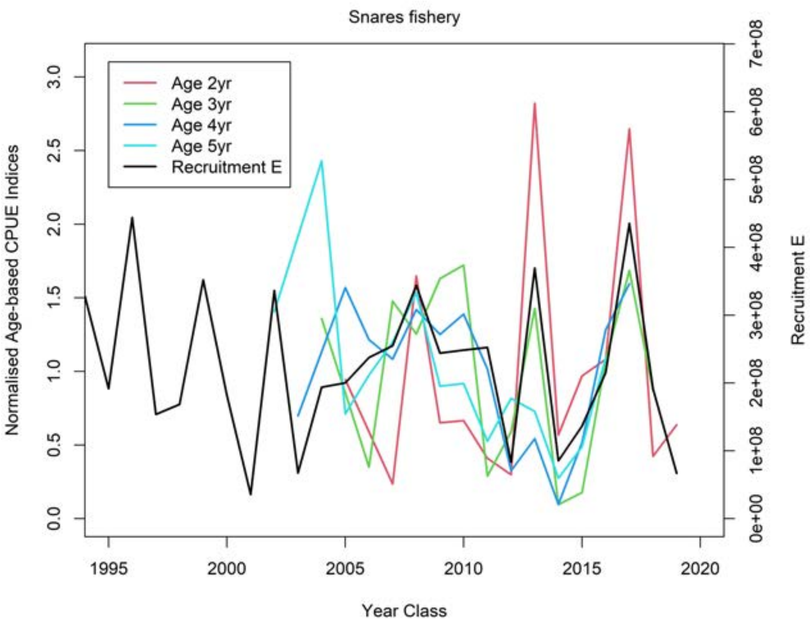


Figure 17: Age-specific CPUE indices of 2, 3, 4, 5 yr fish from the Snares fishery, by year class, compared with the estimates of annual recruitment for western hoki (top panel) and estimates of annual recruitment for eastern hoki (lower panel) from the 2021 hoki stock assessment.

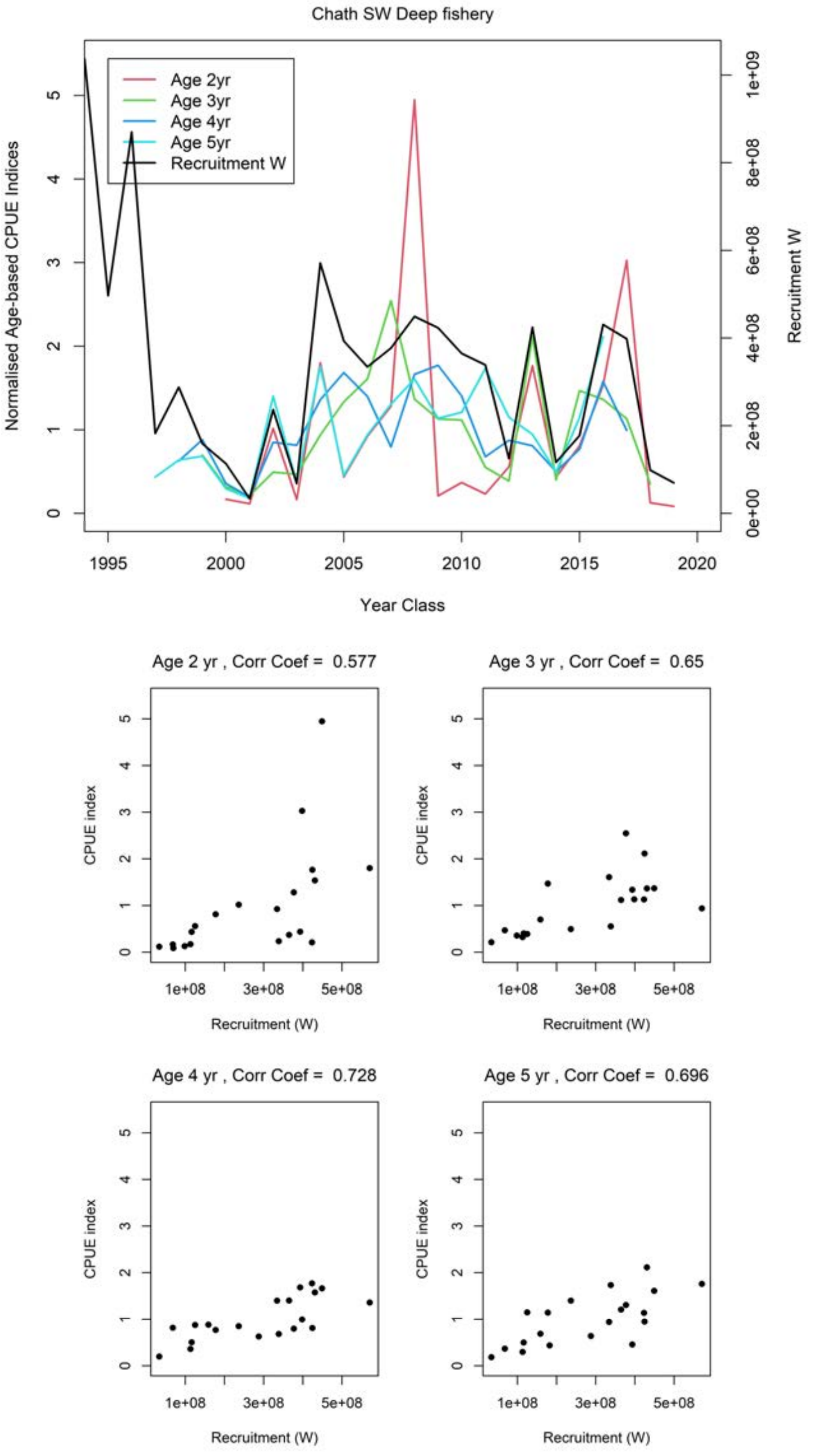


Figure 18: Age-specific CPUE indices of 2, 3, 4, 5 yr fish from the Chatham Rise Southwestern Deep fishery, by year class, compared with the estimates of annual recruitment for western hoki from the 2021 hoki stock assessment (top panel). The lower panels present correlations between the age-specific CPUE indices and the corresponding estimates of western hoki recruitment.

For individual year classes, the successive age-specific CPUE indices were compared between four fisheries: Chatham Rise Shallow, Chatham Rise Southwestern Deep, Snares, and WCSI North fisheries (Figure 19). These fisheries encompass the components of the hoki population recruiting to the western stock unit, under the stock hypothesis of the current hoki stock assessment (from the Chatham Rise nursery ground to the northern WCSI spawning ground via the Stewart-Snares shelf area).

The relative strength of individual year classes is broadly consistent between the four fisheries; for example, the age specific CPUE indices were low for all fishery/age observations of the 2000, 2001, 2003, and 2014 year classes indicating weak cohorts. Conversely, the higher age-specific CPUE indices for the 2004–2009 year classes indicate stronger cohorts (Figure 19).

In general, the indices for individual cohorts (year classes) were comparable from successive year (age) observations from each fishery, mediated by persistent age-based trends. For the Chatham Rise Shallow fishery, age-specific CPUE indices were generally highest for the 3–5 yr age classes and declined sharply for older age classes; age-specific CPUE indices were low for fish older than 7–8 yr (Figure 19). A similar trend is evident for the Chatham Rise Southwestern Deep fishery, although the peak in the age-specific CPUE indices of younger (3–4 yr) fish is generally less pronounced than the Chatham Rise Shallow fishery (Figure 19).

For the Snares fishery, the age-specific CPUE indices are relatively high for the 3–6 yr age classes and decline for older age classes (Figure 19). The trends in the age-specific CPUE indices for 3–6 yr fish are comparable with the Chatham Rise Southwestern Deep fishery for most year classes (Figure 19).

In general, the age-specific CPUE indices from the WCSI North fishery are relatively low for 2–3 yr fish (Figure 19). The indices increased for older fish, reaching a peak at about age 5–7 yr. The CPUE of the cohort declines for fish older than 8 yr and the indices are very low for fish older than 10 yr (Figure 19).

The differential in the age-specific patterns between the Snares and WCSI North fisheries suggests that a considerable proportion of the fish observed in the Snares fishery at ages 3–6 yr do not migrate to the WCSI North fishery to spawn. The age structure of the catches from the Snares fishery is more consistent with the Chatham Rise Southwestern Deep fishery, suggesting that the Snares area may represent an extension of the main nursery grounds for younger (3–5 yr) hoki.

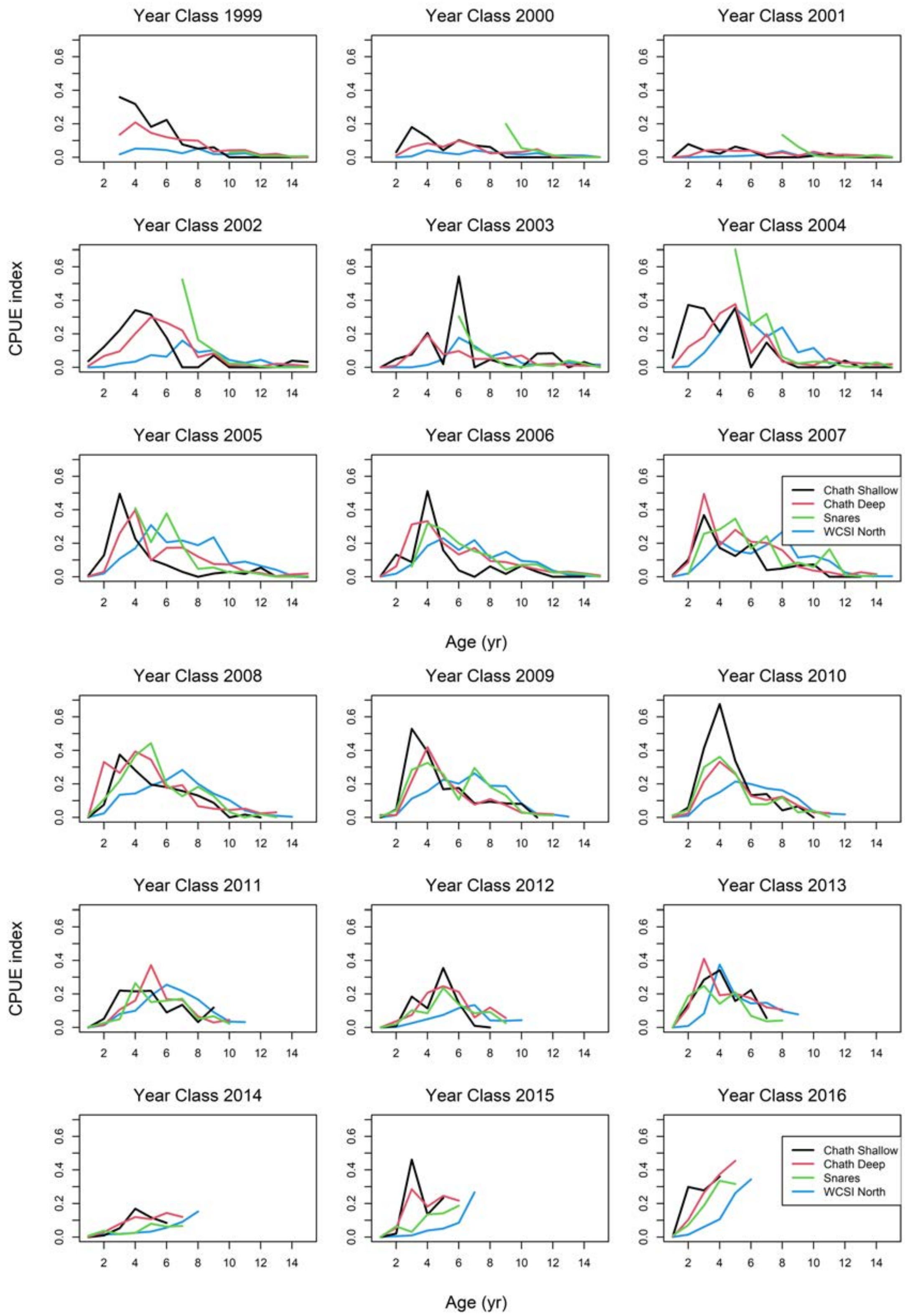


Figure 19: A comparison of age-specific CPUE indices for individual year classes (panels) by age from the Chatham Rise Shallow, Chatham Rise Southwestern Deep, Snares, and WCSI North fisheries.

3.4 Chatham Rise trawl survey

Estimates of abundance for age classes 2, 3, 4, and 5 yr from the Chatham Rise trawl surveys (to 2018) (Ballara & O'Driscoll 2020) were compared with the age-based CPUE indices from the Chatham Rise Shallow fishery (Figure 20). Overall, there was a good correspondence for 3 yr old fish, while the correspondence was poor for the other age classes. This probably reflects a good overlay between the depth distribution of 3 yr fish and the depth range of the Shallow fishery (< 475 m although there was limited fishing shallower than 400 m). A higher proportion of fish in the older age classes is likely to be in areas deeper than the maximum threshold (475 m) and not well 'sampled' by the fishery. Similarly, a high proportion of the 2 yr old fish is in shallower areas not available to the fishery (due to area closures under the hoki Code of Practice).

The survey estimates of abundance for age classes 2, 3, 4, and 5 yr were also compared with estimates of total recruitment (combined western and eastern) from the 2021 hoki stock assessment model. Overall, there is a good correspondence between the survey numbers at age 2–5 yr and the total recruitment for the corresponding year classes (Figure 21).

The Chatham Rise trawl survey hoki 2+ abundance indices were available by individual survey strata (source: Sira Ballara, NIWA). These data were aggregated to approximate two latitudinal strata groupings representing the northern Chatham Rise (strata 1, 7, 8, 18, 19, 20, 2, 5, 9, 10, 11) and southern Chatham Rise (strata 6, 14, 15, 16, 17, 3, 4, 12, 13) (see Stevens et al. 2021).

Overall, the northern Chatham Rise has accounted for the highest proportion (~ 60–80%) of the total 2+ hoki sampled throughout the survey time series (Figure 22). However, there is considerable variability in the latitudinal distribution of 2+ hoki between surveys, particularly for the 1993–2004 year classes. Differences in year class strength were also apparent between the stock assessment estimates of eastern and western recruitment during the same period. The trends in eastern recruitment were most closely aligned to the abundance of 2+ fish from the northern Chatham Rise, whereas the trends in western recruitment were most closely aligned with the southern Chatham Rise (Figure 22), although the respective trends deviated for the earlier year classes (1993–1995).

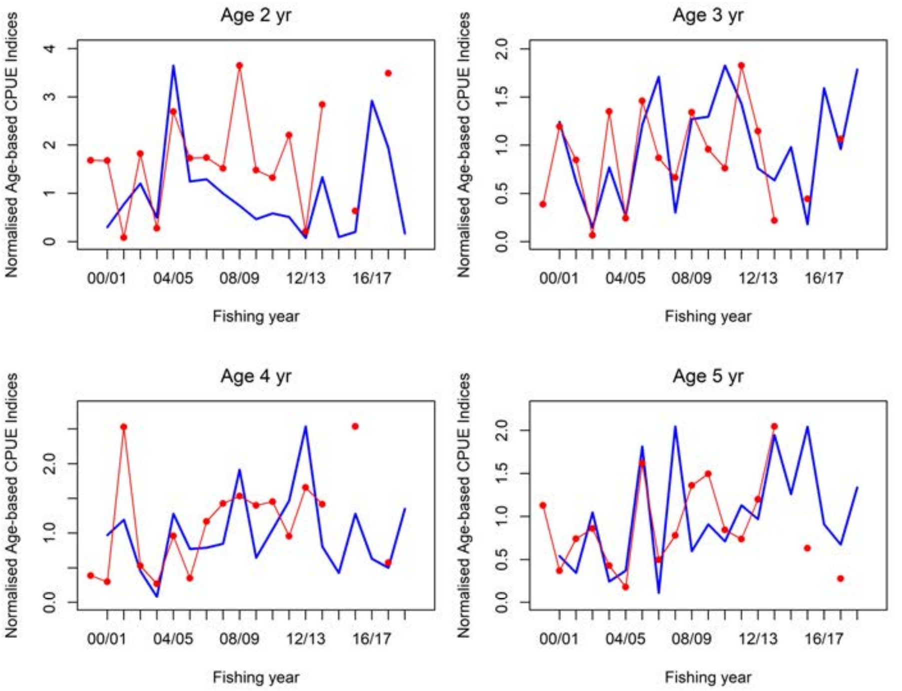


Figure 20: A comparison between the age-specific CPUE indices from the Chatham Rise Shallow fishery (blue lines) and indices of abundance from the *Tangaroa* Chatham Rise trawl survey (red points) for the corresponding age class (2–5 years). Fish assigned age 2 yr from the trawl survey were age 2+ at the time of the survey.

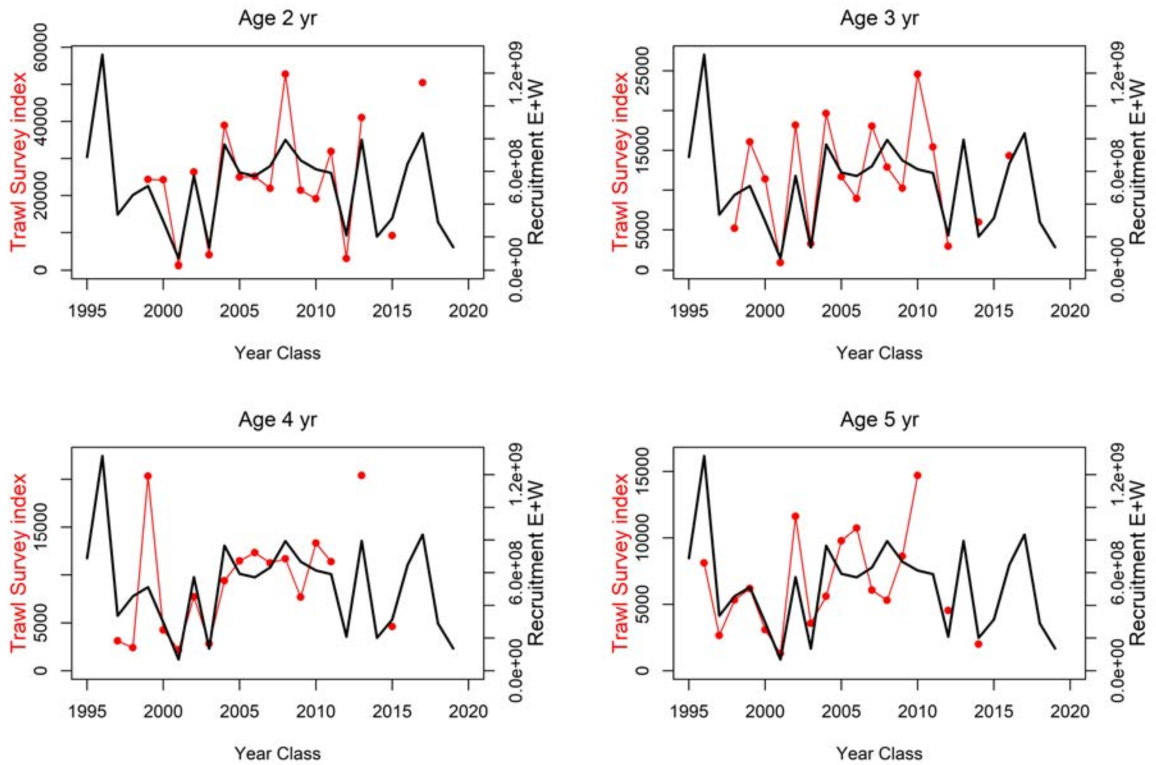


Figure 21: A comparison of indices of hoki abundance for ages 2, 3, 4, and 5 year old fish from the *Tangaroa* Chatham Rise trawl survey (red points) and estimates of total recruitments (eastern and western combined) from the 2021 hoki stock assessment model.

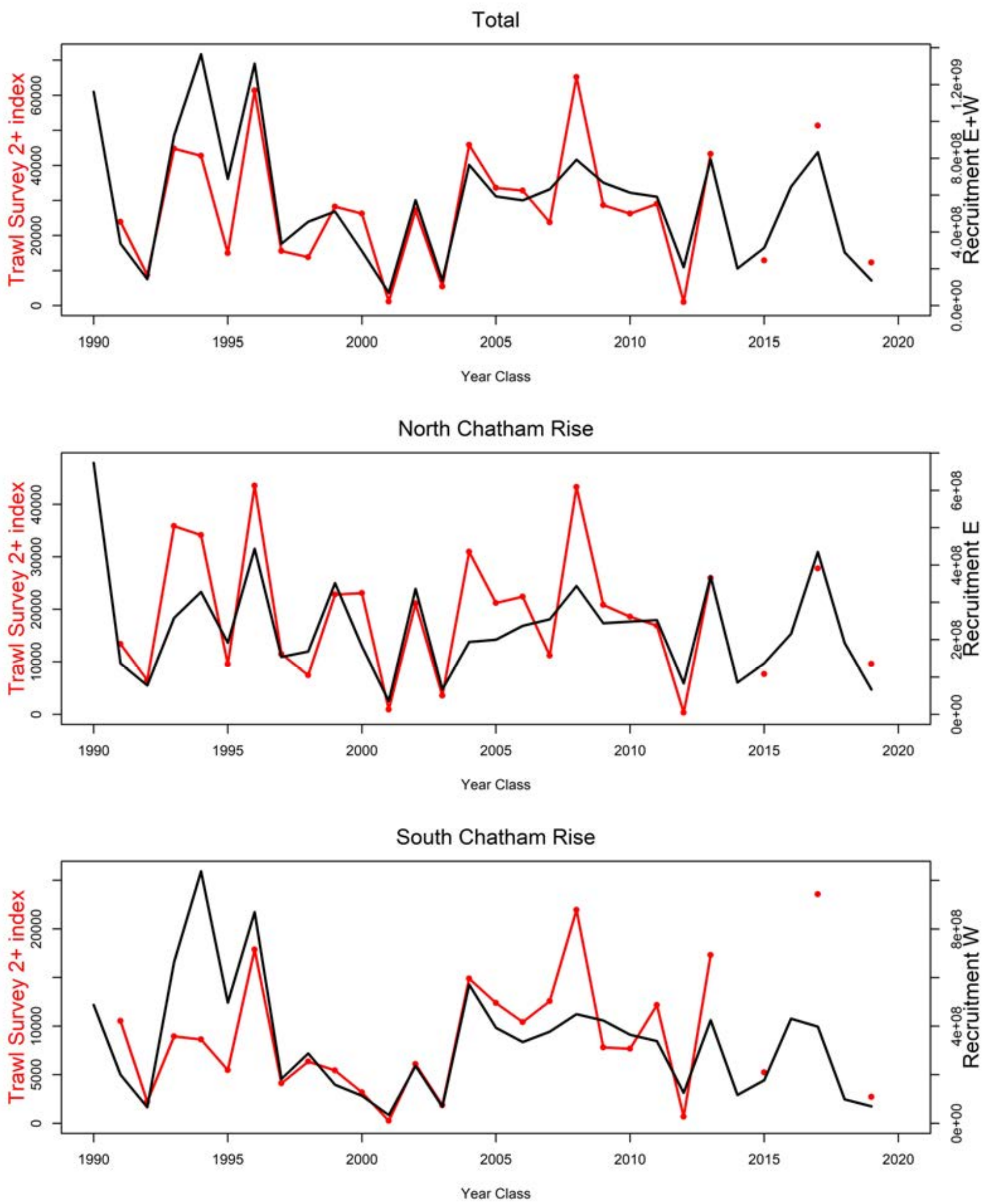


Figure 22: A comparison of indices of hoki abundance for age 2 (2+) yr fish (by year class) from the *Tangaroa* Chatham Rise trawl survey (red points) and estimates of total recruitment (eastern and western combined) from the 2021 hoki stock assessment (top panel). Indices of 2 yr abundance from the northern Chatham Rise and southern Chatham Rise are compared with estimates of eastern recruitment (middle panel) and western recruitment (lower panel), respectively.

4. DISCUSSION

The study derives CPUE indices for a number of key hoki fisheries. The resulting indices are very similar to CPUE indices derived for the equivalent fisheries by Ballara & O'Driscoll (2020). The CPUE datasets are dominated by the inter-annual variation in catch rates ('year effect') due to a high degree of variability in the recruiting year classes. In general, the trends in the CPUE indices from the mid 2000s are comparable with the trends in abundance from research surveys conducted in the corresponding fishery areas.

The CPUE indices were not included in the current (2021 and 2022) hoki stock assessment model. Nonetheless, the trends in the fishery CPUE indices from the last 15–20 years are generally consistent with the recent estimated trends in fishery-specific vulnerable biomass from the stock assessment model. These observations provide a degree of corroboration for the stock assessment results and indicate the utility of the CPUE indices for monitoring hoki abundance. This is further supported by the correspondence between the model estimates of annual recruitment for the western hoki stock and the age-specific CPUE indices derived for the constituent fisheries.

For most fisheries, the trends in the CPUE indices from the initial period of the study (1999/2000–2002/03) did not reflect the extent of the decline in biomass indices from the Sub Antarctic and Chatham Rise trawl surveys. This may indicate a change in the efficiency of the trawl fleet from the mid 2000s that is not adequately accounted for by the CPUE modelling approach. For some of the fisheries, there was an increased dominance of bottom trawling during the early 2000s and a retirement of a number of vessels from the fishery (See Appendix 1). This was followed by the introduction of twin-rig trawls to the fishery from the mid 2000s. By contrast, the operation of the individual fisheries was more stable during 2006/07–2020/21.

The CPUE indices tend to be less variable than the corresponding trawl survey abundance indices, particularly compared with the WCSI trawl survey indices and the spatially partitioned biomass indices from the Chatham Rise trawl survey. This may reflect the lower sampling intensity (precision) of the trawl surveys and/or variation in the spatiotemporal distribution of hoki available to the trawl surveys. Additionally, it may reflect a degree of hyper-stability of the CPUE indices, whereby, the fishery tends to concentrate in the areas of higher hoki abundance.

It has been well established that CPUE indices are not considered useful indicators of abundance for the spawning fisheries operating within submarine canyons, particularly Cook Strait Canyon and Hokitika Canyon, due to the aggregated nature of hoki. By contrast, the fisheries selected for this study tend to operate over a larger area and, for the non-spawning fisheries, are conducted when hoki are more widely dispersed. Nonetheless, an examination of the spatial distribution of trawls from the WCSI North fishery revealed a sharp contraction in the spatial extent of the fishery in the mid 2000s, whereas the spatial operation of the fishery remained relatively stable during the subsequent years (Appendix 2, Figure A2). Similar patterns were also apparent in the operation of the other fisheries (WCSI South, Snares, Chatham Rise Southwestern Deep, Chatham Rise North). These trends in the operation of the fishery are likely to have contributed to the apparent increase in the efficiency in the fishing operation at around that time (see above).

Since the mid 2000s, the operation of the individual fisheries has remained relatively stable and trends in the resultant CPUE indices have been consistent with other key sets of abundance indices. This indicates the potential utility of CPUE indices as additional indices of abundance. Within the current stock assessment framework, CPUE indices from the WCSI North and Snares fisheries have the potential to provide more immediate information regarding the relative strength of recent recruitment to the western hoki stock. This is in lieu of ongoing monitoring of hoki abundance (via acoustic survey or trawl survey) on the WCSI spawning grounds, while the Sub Antarctic trawl survey does not appear to fully monitor the abundance of younger hoki (age 3–6 yr fish).

Increasing the precision of estimates of recent recruitments would improve estimates of current stock status and short-term (2–3 yr) stock projections for the western stock. The CPUE indices could either be integrated into the assessment model as composite indices, linked to the appropriate fishery selectivity, or included as age-specific CPUE indices representing an index of year class strength (at the selected age). The latter approach may provide a more direct indicator of recent recruitment strength; however, it potentially violates some of the statistical properties of the model by duplicating the inclusion of the fishery catch-at-age data used to derive the age-specific indices.

The 4 yr and 5 yr age-specific CPUE indices derived for the Chatham Rise Southwestern Deep fishery are also strongly correlated with the estimates of annual recruitments for the western stock, indicating that these data might also be informative in the assessment modelling. The indices are also correlated with the corresponding age-specific indices from the Snares fishery (corr. coefs. 0.64 and 0.65), indicating similar recruitment patterns between the two fisheries. However, seasonal patterns in CPUE from the two fisheries did not reveal strong reciprocal trends that might indicate a strong, persistent seasonal movement of fish from the Chatham Rise to the Snares (Sub Antarctic) area, as assumed by the current hoki stock assessment model. Instead, trends in the CPUE indices from the Snares fishery appear to precede the trends in abundance from the Sub Antarctic trawl survey (by about 2 years), indicating the younger fish in the Snares fishery are not broadly distributed throughout the Sub Antarctic area. Further, the younger hoki present in the Snares fishery do not appear to have fully recruited to the WCSI North spawning fishery. This may indicate that the Stewart-Snares shelf area represents an important habitat for hoki of the intermediate age classes transitioning from the juvenile nursery ground on the Chatham Rise. These age classes appear to have a low availability to the Sub Antarctic trawl survey. There is potential to utilise the CPUE indices from the Snares fishery to monitor this component of the stock, integrating the CPUE indices into the stock assessment model to inform the model regarding dispersal of hoki southwards from the Chatham Rise.

The age-specific CPUE indices from the Chatham Rise Southwestern Deep fishery are more consistent with the model estimates of western recruitment than the estimates of eastern recruitment. The eastern recruitment estimates appear to be strongly informed by the abundance of 2+ yr hoki from the Chatham Rise trawl survey and from the Cook Strait age composition data. The current stock assessment model assumes the Chatham Rise represents a homogeneous region that supports a fully mixed population of juvenile hoki western and eastern stocks. Since 2008, there has been a higher proportion of the 2+ yr hoki sampled from the southern area of the Chatham Rise and differential trends in the abundance of recruited (3++) hoki between the northern and southern areas of the Chatham Rise.

There is some suggestion that the survey indices of 2+ yr hoki from the southern Chatham Rise were more consistent with the estimates of recruitment of western hoki from the stock assessment model, while trends in 2+ yr hoki from the northern Chatham Rise were more consistent with the estimates of recruitment of eastern hoki. Although speculative, these observations may provide the basis for developing an alternative stock hypothesis that partitions the western and eastern stock components on the Chatham Rise, at least for the younger age classes. This assumption would represent a contrast to the current assumption of a homogeneous population of juvenile hoki (eastern and western stock) on the Chatham Rise.

The 2021 hoki stock assessment model estimated that approximately 20–30% of the Chatham Rise catch (in weight) is composed of the western stock, although a higher proportion of the catch of the younger age classes is likely to be composed of the western stock. Since 2008, approximately 70% of the Chatham Rise catch has been taken from the southern area of the Chatham Rise. Attributing the southern and northern catches more explicitly to the western and eastern stock units (respectively) is likely to influence the resulting estimates of western and eastern recruitments, particularly following the development of the Chatham Rise fishery in the late 1990s. The stock assessment model provides a framework for the evaluation of alternative stock hypotheses, particularly in relation to key model datasets (abundance indices and age composition data from surveys and key fisheries).

5. ACKNOWLEDGEMENTS

The study was funded by the hoki quota owners of the Deepwater Group (DWG) and coordinated by George Clement and Arron Irving. Commercial catch and effort data were provided by Fisheries New Zealand. Outputs from the 2021 hoki stock assessment were provided by Vidette McGregor (NIWA) and other NIWA staff provided a range of datasets from various hoki surveys, specifically Richard O'Driscoll, Sira Ballara, Jennifer Devine. The report was reviewed by Geoff Tingley (for DWG).

6. REFERENCES

Ballara, S.L.; O'Driscoll, R.L. (2020). Catches and size and age structure of the 2018–19 hoki fishery. *New Zealand Fisheries Assessment Report 2020/22*. 205 p.

Devine, J.A.; Stevens, D.W.; Ballara, S.L. (in press). Trawl survey for middle depth fish species off the west coast South Island, July–August 2021 (TAN2107). Draft New Zealand Fisheries Assessment Report.

Langley, A.D. (2020). Review of the 2019 hoki stock assessment. *New Zealand Fisheries Assessment Report 2020/28*. 56 p.

McGregor, V.L.; Dunn, M.R.; Langley, A.D.; Dunn A. (2022). Assessment of hoki (*Macruronus novaezelandiae*) in 2021. *New Zealand Fisheries Assessment Report 2022/43.* 247 p.

McGregor, V.L.; Dunn, M.R.; Langley, A.D.; Dunn, A. (in press). Assessment of hoki (*Macruronus novaezelandiae*) in 2022. Draft New Zealand Fisheries Assessment Report.

O'Driscoll, R.L.; Bagley, N.W.; Ballara, S.L.; Oeffner, J. (2014). Trawl and acoustic survey of hoki and middle depth fish abundance on the west coast South Island, July–August 2012 (TAN1210). *New Zealand Fisheries Assessment Report 2014/09.* 102 p.

O'Driscoll, R.L.; Ballara, S.L. (2019). Trawl and acoustic survey of hoki and middle depth fish abundance on the west coast South Island, July–August 2018 (TAN1807). *New Zealand Fisheries Assessment Report 2019/19.* 120 p.

O'Driscoll, R.L; Escobar-Flores, P. (2020). Acoustic survey of spawning hoki in Cook Strait and off the east coast South Island during winter 2019. *New Zealand Fisheries Assessment Report 2020/21.* 50 p.

Stevens, D.W.; MacGibbon, D.J.; Ballara, S.L.; Escobar-Flores, P.C.; O'Driscoll, R.L. (2022). Trawl survey of hoki and middle depth species in the Southland and Sub-Antarctic, November–December 2020 (TAN2014). *New Zealand Fisheries Assessment Report 2022/08.* 107 p.

Stevens, D.W.; O'Driscoll, R.L.; Ballara, S.L.; Schimel, A.C.G. (2021). Trawl survey of hoki and middle depth species on the Chatham Rise, January 2020 (TAN2001). *New Zealand Fisheries Assessment Report 2021/33.* 122 p.

APPENDIX 1. CPUE MODELLING RESULTS

Table A1: Summary of catch and effort data included in the WCSI North CPUE analysis.

Fishing year	Number of vessels	Number of trawls	Total catch (t)	Total duration (hr)	Catch median (t)	Duration median (hr)	Bottom depth (m)	Proportion trawls BT
1999/00	23	2 260	31 248.4	9 534.1	11.67	3.67	450	0.32
2000/01	27	1 706	20 122.2	8 564.0	7.67	4.58	472	0.47
2001/02	25	1 937	22 527.4	9 679.0	7.20	4.92	460	0.68
2002/03	25	2 214	20 462.0	12 009.3	4.40	5.17	443	0.54
2003/04	24	1 451	8 343.0	9 314.4	2.37	6.00	440	0.61
2004/05	22	883	9 458.1	5 877.9	6.40	6.08	445	0.71
2005/06	22	927	9 876.3	6 288.2	5.98	7.08	446	0.82
2006/07	22	802	15 191.3	3 531.3	16.69	3.75	392	0.51
2007/08	17	595	10 712.6	2 378.0	14.10	3.67	425	0.59
2008/09	18	522	10 387.5	2 049.3	16.92	3.92	451	0.44
2009/10	23	1 195	24 546.0	4 271.6	18.17	3.13	440	0.42
2010/11	23	1 480	27 128.2	5 648.7	15.51	3.50	441	0.50
2011/12	24	1 507	27 847.6	5 491.4	16.44	3.17	447	0.63
2012/13	21	1 218	21 920.5	4 627.6	15.90	3.42	433	0.57
2013/14	21	1 673	33 976.7	6 951.6	18.05	3.82	436	0.47
2014/15	21	1 897	39 946.0	7 521.1	18.43	3.63	440	0.48
2015/16	18	1 900	30 901.2	6 535.6	15.51	3.17	429	0.66
2016/17	18	1 617	20 803.4	7 470.9	10.22	4.50	475	0.74
2017/18	17	1 226	10 965.2	7 384.8	5.03	5.66	498	0.95
2018/19	17	631	8 341.8	3 200.4	11.59	4.90	472	0.94
2019/20	14	529	8 854.5	2 230.8	16.72	3.82	492	0.81
2020/21	15	394	6 602.3	1 701.2	15.77	4.22	479	0.88

Table A2: Summary of catch and effort data included in the WCSI South CPUE analysis.

Fishing year	Number of vessels	Number of trawls	Total catch (t)	Total duration (hr)	Catch median (t)	Duration median (hr)	Bottom depth (m)	Proportion trawls BT
1999/00	16	1 535	18 032.8	4 404.2	7.81	2.50	505	0.22
2000/01	17	2 106	25 123.9	6 622.3	7.16	2.75	488	0.21
2001/02	17	1 811	18 876.1	5 623.3	6.61	2.75	500	0.21
2002/03	18	2 071	17 106.6	6 905.3	4.71	2.92	500	0.29
2003/04	18	2 307	11 928.5	7 365.5	3.10	2.50	500	0.19
2004/05	16	1 518	8 958.8	4 478.7	3.97	2.42	505	0.16
2005/06	16	1 470	16 276.2	5 036.8	7.82	3.00	498	0.21
2006/07	14	523	6 430.1	1 754.6	8.35	2.83	505	0.29
2007/08	12	570	4 029.8	1 159.8	3.97	1.58	492	0.12
2008/09	11	379	4 568.1	1 029.5	8.65	2.17	475	0.15
2009/10	12	450	4 894.6	1 036.7	5.79	1.83	483	0.12
2010/11	12	520	7 723.4	1 282.9	12.07	1.92	470	0.18
2011/12	13	719	14 719.7	2 088.2	17.80	2.50	485	0.14
2012/13	13	1 182	21 273.9	3 222.6	14.45	2.42	480	0.15
2013/14	14	1 068	17 505.2	3 526.2	12.74	2.83	482	0.14
2014/15	14	1 192	16 836.2	4 138.4	9.07	3.08	500	0.19
2015/16	13	1 204	17 913.6	3 911.1	11.43	2.75	498	0.16
2016/17	13	1 200	19 663.3	4 939.7	10.69	3.92	505	0.35
2017/18	13	1 803	20 029.1	7 285.2	8.07	3.77	510	0.37
2018/19	13	1 193	16 594.7	5 416.0	10.72	4.20	506	0.22
2019/20	11	1 211	13 776.8	4 058.2	7.03	2.70	483	0.20
2020/21	11	857	13 191.8	3 644.2	10.58	3.92	507	0.18

Table A3: Summary of catch and effort data included in the Snares CPUE analysis.

Fishing year	Number of vessels	Number of trawls	Total catch (t)	Total duration (hr)	Catch median (t)	Duration median (hr)	Bottom depth (m)	Proportion trawls BT
1999/00	6	1 031	6 655.1	4 559.1	4.64	4.42	679	1.00
2000/01	7	691	3 392.7	3 136.9	3.85	4.58	671	1.00
2001/02	6	399	2 112.6	1 833.7	3.70	4.83	680	1.00
2002/03	5	117	512.2	584.9	3.22	4.92	688	1.00
2003/04	6	218	876.8	1 073.3	2.76	4.85	644	1.00
2004/05	4	73	541.9	354.7	4.99	4.83	568	1.00
2005/06	4	202	1 800.5	950.7	7.64	4.67	530	1.00
2006/07	1	12	70.7	56.0	4.02	4.81	531	1.00
2007/08	2	111	1 268.6	513.0	10.12	4.75	585	1.00
2008/09	3	186	1 653.9	775.2	6.64	4.18	552	1.00
2009/10	4	287	3 006.1	1 142.1	8.57	3.98	579	1.00
2010/11	3	215	2 069.9	904.8	7.63	4.13	580	1.00
2011/12	3	452	4 790.3	2 000.1	9.31	4.33	569	1.00
2012/13	3	447	4 426.0	2 203.3	7.47	4.75	579	1.00
2013/14	5	337	3 094.0	1 663.3	7.26	4.72	558	1.00
2014/15	4	401	3 628.0	2 005.8	7.74	4.90	585	1.00
2015/16	3	143	1 064.5	680.0	5.28	4.65	594	1.00
2016/17	4	270	2 402.4	1 271.3	7.12	4.72	568	1.00
2017/18	5	131	873.2	591.5	4.60	4.52	545	1.00
2018/19	4	97	861.6	435.6	6.64	4.05	536	1.00
2019/20	4	77	627.6	332.1	7.29	4.35	537	1.00
2020/21	5	201	1 689.4	966.0	6.61	5.05	547	1.00

Table A4: Summary of catch and effort data included in the Chatham Rise North CPUE analysis.

Fishing year	Number of vessels	Number of trawls	Total catch (t)	Total duration (hr)	Catch median (t)	Duration median (hr)	Bottom depth (m)	Proportion trawls BT
1999/00	23	2 260	31 248.4	9 534.1	11.67	3.67	450	0.32
2000/01	27	1 706	20 122.2	8 564.0	7.67	4.58	472	0.47
2001/02	25	1 937	22 527.4	9 679.0	7.20	4.92	460	0.68
2002/03	25	2 214	20 462.0	12 009.3	4.40	5.17	443	0.54
2003/04	24	1 451	8 343.0	9 314.4	2.37	6.00	440	0.61
2004/05	22	883	9 458.1	5 877.9	6.40	6.08	445	0.71
2005/06	22	927	9 876.3	6 288.2	5.98	7.08	446	0.82
2006/07	22	802	15 191.3	3 531.3	16.69	3.75	392	0.51
2007/08	17	595	10 712.6	2 378.0	14.10	3.67	425	0.59
2008/09	18	522	10 387.5	2 049.3	16.92	3.92	451	0.44
2009/10	23	1 195	24 546.0	4 271.6	18.17	3.13	440	0.42
2010/11	23	1 480	27 128.2	5 648.7	15.51	3.50	441	0.50
2011/12	24	1 507	27 847.6	5 491.4	16.44	3.17	447	0.63
2012/13	21	1 218	21 920.5	4 627.6	15.90	3.42	433	0.57
2013/14	21	1 673	33 976.7	6 951.6	18.05	3.82	436	0.47
2014/15	21	1 897	39 946.0	7 521.1	18.43	3.63	440	0.48
2015/16	18	1 900	30 901.2	6 535.6	15.51	3.17	429	0.66
2016/17	18	1 617	20 803.4	7 470.9	10.22	4.50	475	0.74
2017/18	17	1 226	10 965.2	7 384.8	5.03	5.66	498	0.95
2018/19	17	631	8 341.8	3 200.4	11.59	4.90	472	0.94
2019/20	14	529	8 854.5	2 230.8	16.72	3.82	492	0.81
2020/21	15	394	6 602.3	1 701.2	15.77	4.22	479	0.88

Table A5: Summary of catch and effort data included in the Chatham Rise Shallow CPUE analysis.

Fishing year	Number of vessels	Number of trawls	Total catch (t)	Total duration (hr)	Catch median (t)	Duration median (hr)	Bottom depth (m)	Proportion trawls BT
1999/00	10	1 077	5 978.4	3 996.6	4.24	4.00	440	0.93
2000/01	11	685	3 701.2	2 739.7	3.93	4.08	461	0.92
2001/02	10	585	2 842.1	2 341.7	3.78	4.17	462	0.90
2002/03	10	817	4 012.6	3 502.7	3.60	4.42	460	0.91
2003/04	9	605	2 878.1	2 423.9	3.04	4.08	460	0.87
2004/05	7	301	1 834.5	1 134.8	4.28	3.92	460	0.83
2005/06	9	747	5 643.8	3 062.4	6.16	4.33	457	0.93
2006/07	7	121	694.3	437.2	4.88	3.33	458	0.83
2007/08	8	81	514.7	262.7	4.40	2.83	458	0.86
2008/09	8	69	374.7	236.0	4.43	3.08	454	0.99
2009/10	7	178	951.5	580.7	4.47	3.08	440	0.74
2010/11	7	144	929.1	516.0	5.12	3.50	450	0.86
2011/12	8	101	707.9	397.5	5.51	4.00	455	0.90
2012/13	7	167	1 163.6	614.0	5.73	3.88	450	0.88
2013/14	8	118	723.7	399.8	5.23	3.08	444	0.97
2014/15	8	141	1 028.9	541.9	5.78	4.17	453	0.95
2015/16	7	177	1 258.0	648.3	5.75	3.63	443	0.97
2016/17	8	192	1 401.5	696.0	6.19	3.24	448	0.93
2017/18	7	158	976.3	524.7	5.66	3.14	440	0.98
2018/19	7	191	1 435.0	662.7	7.18	3.22	445	0.96
2019/20	7	106	762.7	402.1	6.43	3.89	444	0.94
2020/21	6	94	664.9	286.4	5.96	2.73	420	0.97

Table A6: Summary of catch and effort data included in the Chatham Rise South-West Deep CPUE analysis.

Fishing year	Number of vessels	Number of trawls	Total catch (t)	Total duration (hr)	Catch median (t)	Duration median (hr)	Bottom depth (m)	Proportion trawls BT
1999/00	11	1 647	8 276.1	7 306.2	4.16	4.42	525	0.73
2000/01	13	1 985	9 049.0	9 196.2	3.74	4.73	528	0.90
2001/02	13	1 725	7 630.2	8 145.5	3.48	4.75	540	0.87
2002/03	14	1 832	6 857.8	9 472.1	2.82	5.00	520	0.92
2003/04	13	1 334	4 929.6	6 301.5	2.36	4.50	535	0.98
2004/05	12	1 256	7 281.5	6 455.5	4.11	5.00	520	0.93
2005/06	11	1 535	9 541.5	7 268.4	4.79	4.75	517	0.99
2006/07	9	1 701	11 929.1	7 228.7	5.32	4.17	522	1.00
2007/08	8	1 076	9 749.8	4 791.6	7.60	4.67	521	1.00
2008/09	6	1 131	10 934.9	4 480.0	8.53	4.17	524	1.00
2009/10	7	1 486	12 093.1	6 973.8	6.82	4.83	530	1.00
2010/11	7	1 324	11 029.4	5 905.9	6.85	4.67	525	1.00
2011/12	8	876	8 433.6	4 032.0	8.14	4.83	520	1.00
2012/13	7	1 285	10 012.7	6 000.5	6.37	4.92	520	1.00
2013/14	7	867	7 588.1	4 199.1	7.07	5.00	516	1.00
2014/15	8	1 611	14 554.3	7 619.2	7.81	5.00	521	1.00
2015/16	8	1 056	7 305.3	5 053.3	5.63	5.00	521	1.00
2016/17	9	1 482	12 523.6	6 999.1	7.32	4.98	524	1.00
2017/18	9	995	8 412.5	4 600.2	7.53	4.70	517	1.00
2018/19	9	1 251	11 257.2	6 070.3	7.82	4.85	520	1.00
2019/20	9	1 218	11 045.8	5 981.3	8.04	4.92	520	1.00
2020/21	9	906	8 522.7	4 362.0	7.91	4.86	525	1.00

Table A7: Analysis of variance for variables included in the WCSI North fishery hoki CPUE model.

Term	Degrees of freedom	Deviance	Residual deviance	R^2	Improvement
Null model	28 563	53 570			
Fyear	21	7 022	46 548	0.131	
VesselFlag	2	214	46 335	0.135	0.4%
Vessel	26	2 129	44 206	0.175	4.0%
FyearDay	3	2 958	41 248	0.230	5.5%
TrawlGear	4	110	41 138	0.232	0.2%
Speed	3	102	41 037	0.234	0.2%
TimeStart	3	5 261	35 775	0.332	9.8%
Latitude	3	59	35 716	0.333	0.1%
Bottom depth	3	371	35 345	0.340	0.7%
Duration	1	10	35 335	0.340	0.0%
TrawlHeight	2	46	35 289	0.341	0.1%

Table A8: Analysis of variance for variables included in the WCSI South fishery hoki CPUE model.

Term	Degrees of freedom	Deviance	Residual deviance	R^2	Improvement
Null model	26 888	43 187			
Fyear	21	3 871	39 316	0.090	
VesselFlag	2	52	39 264	0.091	0.1%
Vessel	18	621	38 643	0.105	1.4%
FyearDay	3	4 887	33 756	0.218	11.3%
TrawlGear	4	100	33 655	0.221	0.2%
Speed	3	42	33 614	0.222	0.1%
TimeStart	3	575	33 039	0.235	1.3%
Latitude	3	123	32 916	0.238	0.3%
Bottom depth	3	298	32 619	0.245	0.7%
Duration	1	885	31 734	0.265	2.0%
TrawlHeight	2	113	31 621	0.268	0.3%

Table A9: Analysis of variance for variables included in the Snares fishery hoki CPUE model.

Term	Degrees of freedom	Deviance	Residual deviance	R^2	Improvement
Null model		6 990			
Fyear	21	618	6 372	0.088	
VesselFlag	1	65	6 307	0.098	0.9%
Vessel	5	6	6 301	0.099	0.1%
FyearDay	3	56	6 245	0.107	0.8%
TrawlGear	2	61	6 184	0.115	0.9%
Speed	3	5	6 178	0.116	0.1%
TimeStart	3	641	5 537	0.208	9.2%
Latitude	3	132	5 405	0.227	1.9%
Bottom depth	3	52	5 353	0.234	0.7%
Duration	1	79	5 273	0.246	1.1%
TrawlHeight	2	1	5 272	0.246	0.0%

Table A10: Analysis of variance for variables included in the Chatham Rise North fishery hoki CPUE model.

Term	Degrees of freedom	Deviance	Residual deviance	R^2	Improvement
Null model	33 224	27 026			
Fyear	21	3 912	23 114	0.145	
VesselFlag	2	10	23 104	0.145	0.0%
Vessel	19	1 163	21 941	0.188	4.3%
FyearDay	3	490	21 451	0.206	1.8%
TrawlGear	4	46	21 405	0.208	0.2%
Speed	3	5	21 400	0.208	0.0%
TimeStart	3	289	21 111	0.219	1.1%
Longitude	3	114	20 997	0.223	0.4%
Bottom depth	3	113	20 885	0.227	0.4%
Duration	1	932	19 953	0.262	3.4%
TrawlHeight	2	21	19 932	0.262	0.1%

Table A11: Analysis of variance for variables included in the Chatham Rise Shallow fishery hoki CPUE model.

Term	Degrees of freedom	Deviance	Residual deviance	R^2	Improvement
Null model	7264	7 210			
Fyear	21	232	6 978	0.032	
VesselFlag	1	24	6 953	0.036	0.3%
Vessel	9	585	6 369	0.117	8.1%
FyearDay	3	72	6 296	0.127	1.0%
TrawlGear	4	21	6 275	0.130	0.3%
Speed	3	1	6 274	0.130	0.0%
TimeStart	3	179	6 095	0.155	2.5%
Latitude	3	38	6 057	0.160	0.5%
Bottom depth	3	6	6 052	0.161	0.1%
Duration	1	174	5 877	0.185	2.4%
TrawlHeight	2	3	5 875	0.185	0.0%

Table A12: Analysis of variance for variables included in the Chatham Rise South-West Deep fishery hoki CPUE model.

Term	Degrees of freedom	Deviance	Residual deviance	R^2	Improvement
Null model		22 589			
Fyear	21	3 637	18 952	0.161	
VesselFlag	1	34	18 918	0.163	0.2%
Vessel	13	381	18 537	0.179	1.7%
FyearDay	3	144	18 393	0.186	0.6%
TrawlGear	4	88	18 305	0.190	0.4%
Speed	3	2	18 303	0.190	0.0%
TimeStart	3	1 456	16 847	0.254	6.4%
Latitude	3	57	16 790	0.257	0.3%
Longitude	3	23	16 767	0.258	0.4%
Bottom depth	3	96	16 670	0.262	0.4%
Duration	1	631	16 040	0.290	2.8%
TrawlHeight	2	8	16 032	0.290	0.0%

Table A13: Annual CPUE indices for the WCSI North fishery and the associated lower (LCI) and upper (UCI) values of the 95% confidence interval.

Fishing year	Index	LCI	UCI
1999/00	1.000	0.926	1.079
2000/01	0.738	0.687	0.793
2001/02	0.804	0.749	0.863
2002/03	0.468	0.437	0.501
2003/04	0.282	0.261	0.305
2004/05	0.440	0.401	0.482
2005/06	0.593	0.541	0.650
2006/07	1.095	0.997	1.203
2007/08	1.218	1.097	1.351
2008/09	1.226	1.098	1.369
2009/10	1.210	1.114	1.314
2010/11	1.182	1.093	1.277
2011/12	1.428	1.321	1.544
2012/13	1.401	1.290	1.520
2013/14	1.383	1.284	1.491
2014/15	1.565	1.455	1.683
2015/16	1.242	1.153	1.337
2016/17	0.876	0.810	0.947
2017/18	0.657	0.602	0.717
2018/19	0.871	0.782	0.969
2019/20	1.239	1.108	1.386
2020/21	1.083	0.957	1.226

Table A14: Annual CPUE indices for the WCSI South fishery and the associated lower (LCI) and upper (UCI) values of the 95% confidence interval.

Fishing year	Index	LCI	UCI
1999/00	0.905	0.839	0.977
2000/01	0.654	0.608	0.703
2001/02	0.581	0.539	0.627
2002/03	0.484	0.449	0.520
2003/04	0.315	0.293	0.338
2004/05	0.358	0.331	0.388
2005/06	0.682	0.629	0.739
2006/07	0.958	0.858	1.071
2007/08	0.633	0.567	0.706
2008/09	1.220	1.075	1.384
2009/10	1.039	0.922	1.170
2010/11	1.389	1.241	1.554
2011/12	1.955	1.769	2.161
2012/13	1.759	1.611	1.921
2013/14	1.589	1.452	1.738
2014/15	1.232	1.128	1.345
2015/16	1.329	1.217	1.452
2016/17	1.279	1.166	1.402
2017/18	0.802	0.737	0.874
2018/19	0.995	0.907	1.092
2019/20	0.739	0.675	0.809
2020/21	1.102	0.998	1.218

Table A15: Annual CPUE indices for the Snares fishery and the associated lower (LCI) and upper (UCI) values of the 95% confidence interval.

Fishing year	Index	LCI	UCI
1999/00	0.790	0.699	0.892
2000/01	0.607	0.554	0.665
2001/02	0.647	0.577	0.726
2002/03	0.559	0.462	0.675
2003/04	0.449	0.386	0.521
2004/05	0.649	0.516	0.816
2005/06	1.167	1.001	1.361
2006/07	1.246	0.720	2.159
2007/08	2.130	1.738	2.611
2008/09	1.318	1.109	1.566
2009/10	1.397	1.194	1.635
2010/11	1.233	1.043	1.459
2011/12	1.232	1.071	1.416
2012/13	1.093	0.951	1.257
2013/14	0.978	0.843	1.135
2014/15	1.040	0.905	1.195
2015/16	0.942	0.782	1.135
2016/17	0.947	0.812	1.104
2017/18	0.707	0.584	0.857
2018/19	0.919	0.730	1.157
2019/20	1.039	0.825	1.308
2020/21	0.911	0.772	1.075

Table A16: Annual CPUE indices for the Chatham Rise North fishery and the associated lower (LCI) and upper (UCI) values of the 95% confidence interval.

Fishing year	Index	LCI	UCI
1999/00	0.836	0.803	0.871
2000/01	0.666	0.639	0.693
2001/02	0.597	0.571	0.624
2002/03	0.516	0.493	0.539
2003/04	0.527	0.502	0.552
2004/05	0.680	0.647	0.715
2005/06	0.830	0.786	0.876
2006/07	1.013	0.958	1.072
2007/08	1.145	1.083	1.212
2008/09	1.329	1.254	1.408
2009/10	1.075	1.016	1.137
2010/11	1.284	1.218	1.354
2011/12	1.115	1.050	1.185
2012/13	1.023	0.960	1.090
2013/14	1.320	1.241	1.404
2014/15	1.126	1.061	1.195
2015/16	1.018	0.961	1.079
2016/17	1.254	1.180	1.333
2017/18	1.146	1.080	1.217
2018/19	1.196	1.123	1.275
2019/20	1.001	0.933	1.074
2020/21	1.303	1.225	1.386

Table A17: Annual CPUE indices for the Chatham Rise Shallow fishery and the associated lower (LCI) and upper (UCI) values of the 95% confidence interval.

Fishing year	Index	LCI	UCI
1999/00	0.839	0.765	0.920
2000/01	0.833	0.759	0.914
2001/02	0.815	0.737	0.902
2002/03	0.672	0.612	0.738
2003/04	0.670	0.606	0.740
2004/05	0.928	0.816	1.056
2005/06	1.069	0.964	1.185
2006/07	1.002	0.836	1.201
2007/08	1.228	1.013	1.489
2008/09	0.888	0.715	1.103
2009/10	0.938	0.807	1.091
2010/11	0.988	0.837	1.166
2011/12	1.047	0.867	1.265
2012/13	1.223	1.046	1.428
2013/14	1.164	0.983	1.377
2014/15	1.010	0.853	1.196
2015/16	1.178	1.008	1.375
2016/17	1.256	1.077	1.464
2017/18	0.980	0.832	1.155
2018/19	1.162	0.986	1.368
2019/20	0.955	0.789	1.156
2020/21	1.156	0.947	1.411

Table A18: Annual CPUE indices for the Chatham Rise South-West Deep fishery and the associated lower (LCI) and upper (UCI) values of the 95% confidence interval.

Fishing year	Index	LCI	UCI
1999/00	0.817	0.778	0.859
2000/01	0.687	0.654	0.722
2001/02	0.663	0.630	0.698
2002/03	0.520	0.493	0.547
2003/04	0.472	0.447	0.500
2004/05	0.695	0.656	0.737
2005/06	0.854	0.808	0.902
2006/07	0.906	0.857	0.958
2007/08	1.348	1.269	1.433
2008/09	1.286	1.208	1.368
2009/10	1.105	1.044	1.171
2010/11	1.142	1.076	1.211
2011/12	1.341	1.253	1.435
2012/13	1.081	1.017	1.150
2013/14	1.140	1.065	1.219
2014/15	1.238	1.168	1.312
2015/16	0.945	0.886	1.008
2016/17	1.157	1.090	1.228
2017/18	1.065	0.997	1.139
2018/19	1.155	1.082	1.234
2019/20	1.160	1.087	1.237
2020/21	1.223	1.143	1.307

APPENDIX 2. WEST COAST SOUTH ISLAND NORTH FISHERY

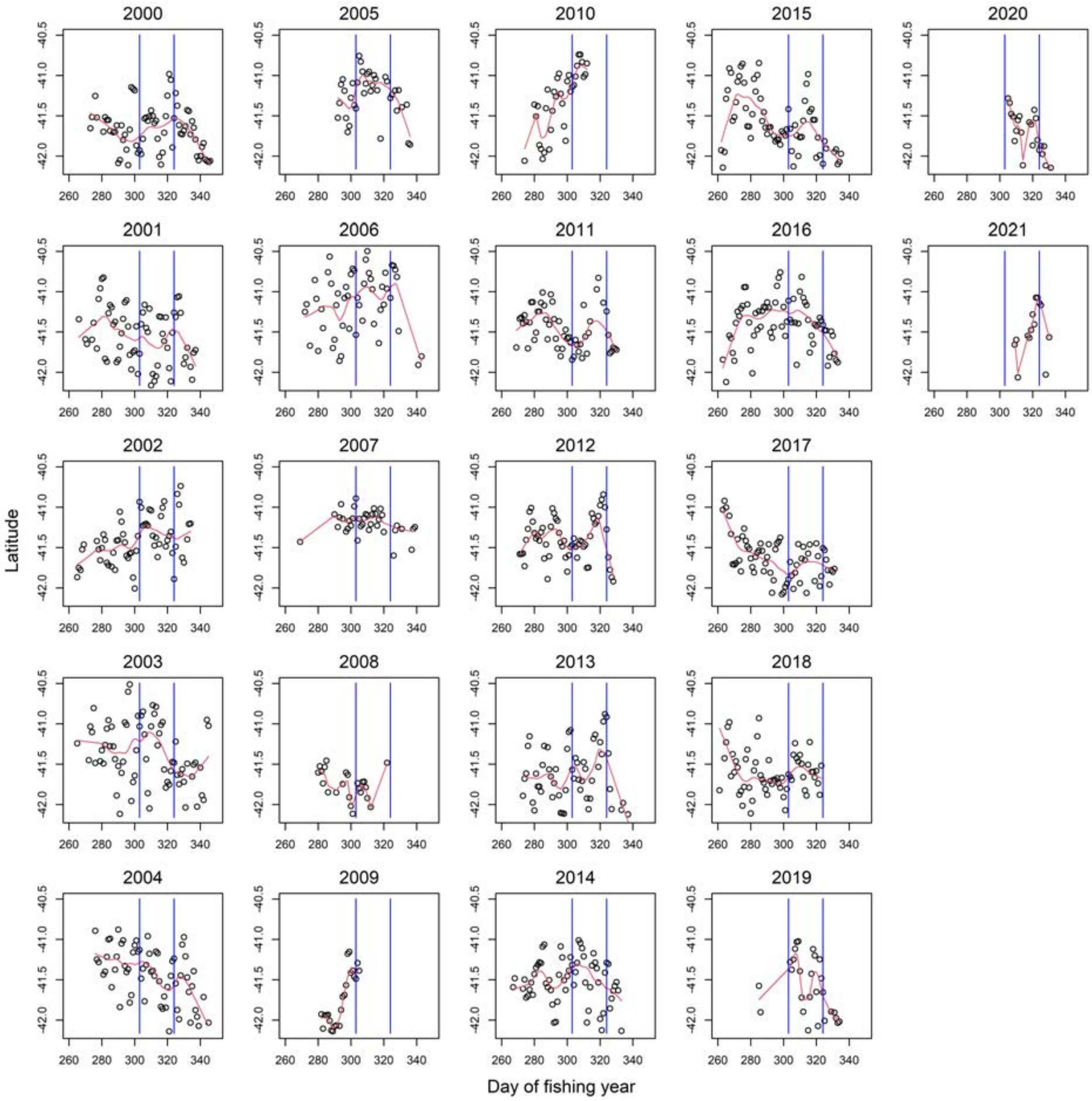


Figure A1: Average daily latitude of fishing location, weighted by the magnitude of the hoki catch, of the commercial fishery in the northern WCSI area by year (points). The red line represents a lowess smoother applied to the data. The blue vertical lines correspond to 1 August and 21 August representing the main period of the *Tangaroa* WCSI trawl surveys.

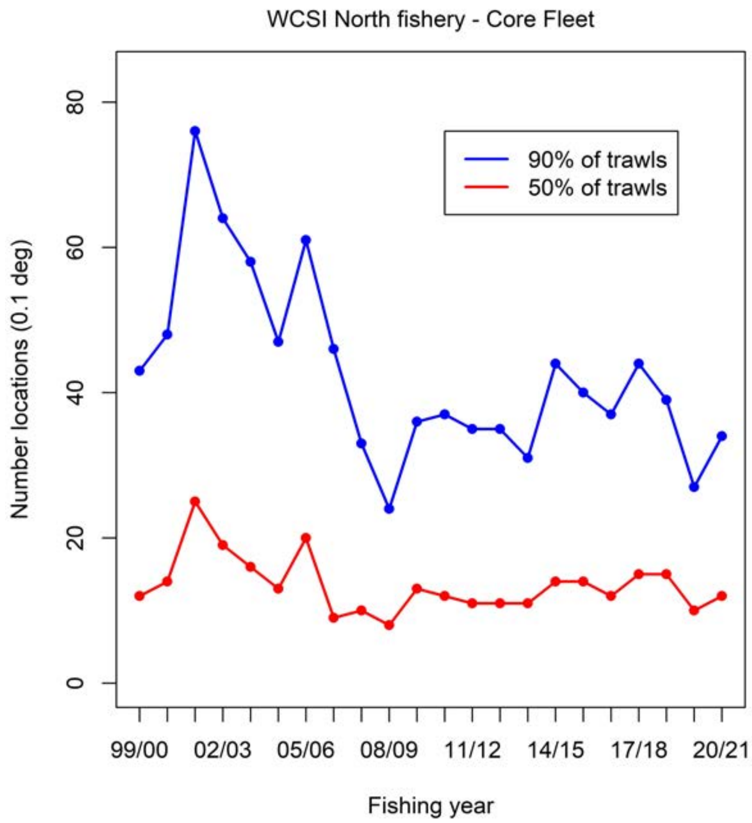


Figure A2: The number of 0.1° latitude/longitude cells accounting for 50% and 90% of the total number of trawls conducted annually by the core fleet within the WCSI North fishery.